ECE 442/542: Digital Control Systems
Spring Semester 2022

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Office Hours:
Wednesdays 3:00pm-4:00pm
Fridays 11:00am-12:00pm
Location: Henry Koffler Bldg, Rm 218 (and Zoom)
Lectures: MW 5:30pm-6:45pm
Course Web-Site: http://d2l.arizona.edu

Course 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. *Prerequisite: ECE 320A*.

Textbook:
- "*Digital Control Engineering: Analysis and Design*," by M. Fadali and A. Visioli, Second Edition, Academic Press, Waltham, MA, 2013. ISBN: 978-0-12-394391-0. Available as an e-Book or Download through the University of Arizona Library [link].

Equipment and Software Requirements:
For this class you will need access to the following hardware: web-enabled device with webcam (phone with camera) and microphone; regular access to reliable internet signal; ability to download and run the following software: web browser, Adobe Acrobat, and Matlab. The webcam will be used mainly for exam purposes.

You will be required to use Matlab to work on assignments throughout the course. *We will NOT cover ``how to program in Matlab," rather, you are expected to know it or pick it up*. You can download Matlab at the Student Software website through the University of Arizona (link).

Class Recordings:
- The class sessions will be recorded to allow those students unable to attend the Live Online sessions an opportunity to view the recorded session. For that reason, these recorded sessions will be available only through D2L. If you would prefer personally identifiable information not be included in these recorded sessions, then please modify your Zoom settings to provide an alias and share your alias with the instructor via e-mail.
- Students may not modify content or re-use content for any purpose other than personal educational reasons. All recordings are subject to government and university regulations. Therefore, students accessing unauthorized recordings or using them in a manner

inconsistent with UArizona values and educational policies are subject to suspension or civil action.

Class Attendance:

- If you feel sick, or may have been in contact with someone who is infectious, stay home. Except for seeking medical care, avoid contact with others and do not travel.
- Notify your instructors if you will be missing an in person or online course.
- Campus Health is testing for COVID-19. Please call (520) 621-9202 before you visit in person.
- Visit the UArizona COVID-19 page for regular updates. [http://covid19.arizona.edu]

Absence and Attendance Policy:

UArizona's policy concerning Class Attendance, Participation, and Administrative Drops is available at this link. The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable (see this link).

Absences pre-approved by the UArizona Dean of Students (or Dean Designee) will be honored. See this link. Participating in courses 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.

Withdrawal Policies:

It is the responsibility of the student to know and understand the withdrawal policy at the University of Arizona. There are different withdrawal dates for undergraduate students and graduate students. The second drop deadline for both undergraduate students and graduate students is the end of the 10th week of class. Any student who intends to drop or withdraw from a course must do so following the drop and withdrawal instructions

- https://catalog.arizona.edu/policy/undergraduate-change-schedule-dropadd

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.

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 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 \emph{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).

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.

Academic Advising:
If you have questions about your academic progress this semester, or your chosen degree program, please note that advisors at the Advising Resource Center can guide you toward university resources to help you succeed.

Life Challenges:
If you are experiencing unexpected barriers to your success in your courses, please note the Dean of Students Office is a central support resource for all students and may be helpful. The Dean of Students Office can be reached by phone 520-621-7057 or by emailing them directly at DOS-deanofstudents@email.arizona.edu.

Physical and mental-health challenges:

If you are facing physical or mental health challenges this semester, please note that Campus Health provides quality medical and mental health care. For medical appointments, call (520-621-9202. For After Hours care, call (520) 570-7898. For the Counseling & Psych Services (CAPS) 24/7 hotline, call (520) 621-3334.

ECE 442/542 Course Outcomes:

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

1. Design a pure, two-pole system that satisfies specified performance specifications like percent overshoot, peak time, settling time, and DC gain.
2. Calculate the z-plane location of a pair of dominant poles given time-domain performance information like percent overshoot, settling time, and peak time.
3. Create discrete equivalents from given continuous-time systems, e.g.,
    a. create a zero-order hold equivalent discrete-time state space representation from a continuous-time, state space representation,
    b. create a discrete-time transfer function from a continuous-time transfer function using a numerical integration strategy (Numerical Integration Strategies: Forward Rectangular, Backward Rectangular, and Tustin/Trapezoidal) or using a pole-zero mapping technique,
    c. create a zero-order hold equivalent discrete-time transfer function of a system given a continuous-time transfer function preceded by a zero-order hold.
4. Construct a discrete-time difference equation containing input variables and output variables at particular time instances from a system's discrete-time transfer function.
5. Produce a closed-form expression for the output of a system given a system description and an applied input waveform. The system description could be in the form of a block diagram, transfer function, difference equation, or state space representation.
6. Numerically compute the value of any system variable (e.g., state variable or output variable) at any discrete, time instant given initial conditions and input waveforms.
7. Compute the settling time, peak time, and percent overshoot for a discrete-time system. The discrete-time system could be represented in the form of a difference equation, a state-space representation, a block diagram, or a transfer function.
8. Compute the z-Transform of a given discrete-time waveform.
9. Compute the transfer function of a given system given a system representation in difference equation form, state-space form, or block diagram form.
10. Compute the Inverse z-Transform given a rational expression in the frequency domain and the Region of Convergence (ROC).
11. Correlate the different Region of Convergence (ROC) shapes with when the time domain waveform is defined, e.g., as a right-sided time sequence (one-sided), a left-sided time sequence (one-sided), or when the sequence is defined for all time indices (two-sided).
12. Find the steady-state error in a given system.
13. Determine if a discrete-time system is Bounded-Input, Bounded-Output (BIBO) stable. The system could be described in the form of a difference equation, a block diagram, a transfer function, or a state-space representation.

14. Create a state-space representation of a system from a given system description. The system description could be in the form of a difference equation, a block diagram, or a transfer function.
15. Apply the Final Value Theorem for discrete-time systems to find the limiting values of given system variables, i.e., errors, state variables, or output variables.
16. Design stabilizing controllers for unstable systems using classical control design strategies, i.e., design strategies based on root locus design techniques.
17. Sketch (by hand) a root locus diagram corresponding to a given system model that is interconnected in a negative, unity output-feedback configuration. The root locus diagram provides the possible closed-loop pole locations associated with the given system as a function of an adjustable parameter. The actual closed-loop pole locations will depend on the particular gain value that is chosen.
18. Perform each step in the root locus diagram construction process, i.e., locate the open-loop poles and the open-loop zeros on the complex plane, identify the real-axis segments belonging to the root locus diagram, construct the asymptotes (angles and location) that guide the behavior of the root locus branches that approach the zeros at infinity, determine the breakaway and re-entry points on the real-axis if they exist, and determine the angle of arrival of the root locus for complex zeros or the angle of departure of the root locus from complex poles if either of these complex factors exist.
19. Design controllers based on the Ragazzini controller design approach. The Ragazzini design approach provides insight into different constraints that must be observed during a controller design process. In particular, some of the constraints are imposed to avoid canceling unstable poles or unstable zeros with controller zeros or controller poles, respectively.
20. Identify a range of gain values that would provide a stable, closed-loop system if such a range of gain values exists.
21. Design full-state feedback controllers to locate closed-loop poles at particular locations in the complex z-plane.
22. Utilize the phase-angle condition in the root locus design approach to locate pole and zero locations in 1st-order or 2nd-order controllers.
23. Design full-state feedback controllers with non-zero reference inputs to produce desired closed-loop pole locations and the desired DC gain in the closed-loop system

Final Grades

Your final numerical grade will be computed as follows.

ECE442

Homework	40%
In-Class Exams (2)	40%
Final Exam	20%

ECE452

Homework	25%
In-Class Exams (2)	40%
Final Project	15%
Final Exam	20%

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

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

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. It is impossible for me to answer the question “what grade will I get” at the week of the withdrawal deadline, please do not ask me this. *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*.

Subject To Changes:
The contents of this syllabus are subject to change at the instructor's discretion.