ECE380 **Analog Control Systems** **Winter 2021**

Calendar Description: Introduction to control systems. Advantages of closed-loop feedback systems. The role of system mathematical model. Block diagrams and system flow graphs. The basic control system design problem, stability in control systems. Frequency response analysis techniques. Root-locus analysis. Elementary lead-lag compensation.

Instructor: Prof. Stephen L. Smith (stephen.smith@uwaterloo.ca)

- Office hours: Friday 3:00pm-4:00pm via Zoom link
- Please put "ECE380" at the front of your subject line for all course related email.

Lab Instructor: Carmen Caradima (carmen.caradima@uwaterloo.ca)

Teaching Assistants:

- Jean-Luc Bastarache (jbastarache@uwaterloo.ca) – Lab TA
- Craig Joseph Lalumiere (cjlalumiere@uwaterloo.ca) – Tutorial TA

Website: http://learn.uwaterloo.ca/

Lectures:

- Asynchronous lectures will be posted each week.
- Friday 3-4pm will be used as a live Q&A to review the weeks material via Zoom link.

Tutorials: Mondays 4:30-5:20pm. The tutorial will be held live.

Course Objectives: At the end of the course, it is hoped that you have learned:

- What feedback is and why it is important.
- How to model a system using differential equations.
- What it means for a system to be linear.
- Why we use transfer functions and the frequency domain.
- What stability means.
- How to determine if a feedback system is stable.
- The relation between a systems transfer function and its tracking performance.
- The Nyquist stability criterion and the meaning of stability margin.
- How to design a simple feedback controller using frequency-domain methods

Reference Material:

1. Mandatory Course Notes: Posted on LEARN and can be downloaded as a single PDF.
2. Optional Supplementary Text: Norman S. Nise, *Control Systems Engineering*, 7th edition, Wiley, 2014.

Course Grading:

The grading scheme is as follows:

Labs:	25%	(lab1, lab2, lab3, lab4, lab5) $= (3\%, 5\%, 5\%, 6\%, 6\%)$
Term Tests:	35%	(best two of three, 17.5% each)
Final Exam:	40%	

- Labs are mandatory. You must obtain 50% or higher on the lab component to pass the course.

Term tests: There will be three term tests on the following days:

1. Test 1: Wednesday Feb 03, 2021
2. Test 2: Wednesday Mar 03, 2021
3. Test 3: Wednesday Mar 31, 2021

The lowest term test score is dropped, and your term test grade (worth 35%) is the average of the remaining two.

Test and exam rules:

- Tests and final exams will be administered via crowdmark.
- For each test and the exam, you will be given a 24 hour time window in which to complete it. The test/exam will be timed, so once you start you will have a fixed amount of time.
- Tests and exam are open book in the sense that you may consult your course notes and material posted in the course LEARN site and lecture videos. Use of any other resource (including file-sharing services such as chegg.com, coursehero.com, stack-exchange.com, ...) is prohibited. You may not communicate directly or indirectly with any person except the course instructor. You may not use MATLAB or any other computing tool, unless it has been explicitly allowed.
- Missed Tests:
  - If you miss a test for any reason, then the missed test scores a grade of zero.
  - If you miss two tests, both for valid reasons, then the written test will be given a weight of 17.5% and the final exam mark will be given a weight of 57.5%.
  - If you miss three tests, all for valid reasons, then the test mark will be a given a weight of 17.5%, the final exam mark will be given a weight of 57.5%, and you will receive an INC until a makeup test (which will be the source of the test mark) can be arranged.
  - The instructor makes the ultimate determination about the validity of a reason for missing a test.

Course Outline:

1. Motivation
   Introduction to control engineering, the basic unity feedback structure, feedforward control, feedback control, typical design specifications.

2. Basic Signal and Systems Concepts
   Complex variables, Laplace transforms, transfer functions, frequency response (Bode plots).

3. System Modeling
   Differential equation models of physical systems, electromechanical examples, block diagram manipulation.

4. Step Responses of Linear Systems
   First order systems, second order systems, standard forms, performance measures, effects of poles and zeros on step response, reduced order models.

5. Stability of Linear Time-Invariant Systems
   BIBO stability, characterization of stability in terms of poles, pole-zero cancellations, stability of unity-feedback loop, tests for stability (sign test, Routh-Hurwitz test).

6. Basic Feedback Control
   Disturbance rejection, sensitivity, tracking of reference signals, PID controller design.

7. Root Locus Design
   Rules for drawing the root-locus, lead and lag dynamic compensator design.

8. Dynamic Compensator Design Using Bode Plots
   Improving phase margin by lead compensation, improving low frequency behaviour by lag compensation, improving phase margin by lag compensation, lead-lag compensation.

9. Nyquist Plots
   Construction of Nyquist plots, Nyquist stability test, quantifying stability robustness, using Nyquist plots for design.

10. Modern Control Theory
    State-space representations of linear systems, nonlinear systems and linearization, linear state feedback.

Laboratory Details

Table 1: Important laboratory dates

Lab	Name	Release date	Report due	Weight
1	System Identification	Jan. 13	Jan. 27	3%
2	2nd Order Systems	Jan. 27	Feb. 10	5%
3	Motion Control	Feb. 10	Mar. 10	5%
4	PID Analysis	Mar. 10	Mar. 24	6%
5	Lead and Lag Design	Mar. 31	Apr. 14	6%

Lab Manual: The lab manual can be found under the course account on LEARN.

- There are 5 lab modules, which together constitute 25% of your final grade. The labs weights and due dates in Table 1.
- Lab group formation, report submission and feedback will be carried out on LEARN.
- Lab data will be posted on LEARN prior to the start of each Lab.

Lab submissions:

- Lab reports are due at 11:59 pm Eastern on the date specified in Table 1 and the course webpage. Please verify that you have uploaded your submission on time, the document is complete, and it is under the group account of the correct course number.
- All submissions are to be done electronically through the course website (LEARN) and must be in the pdf format.
- Revised submissions prior to the deadline are accepted; in such cases, the most recent file will be marked.
- Both lab partners are responsible for verifying that the group submission was uploaded to LEARN; the file submitted will show on the list of files in the group account.
- Late lab reports will incur a penalty of 1% per hour in the first 24 hours, and 100% thereafter, unless prior arrangements are made or a valid reason presented within a week from the missed deadline. In no case will a lab report be accepted more than a week past the deadline; if a valid reason exists for being unable to hand in the lab within the week following the deadline, then a solution tailored to each particular situation will be offered by the Lab Instructor.

MATLAB Access:

- You must have access to Matlab and Simulink to work on the lab. Details about the version of Matlab and the toolboxes required can be found in the lab manual.
- Alternatively, you can remotely log into on-campus computers that are run by Engineering Computing and most Engineering departments:
    1. Connect to the campus VPN (instructions: https://uwaterloo.ca/information-systems-technology/services/virtual-private-network-vpn)
    2. Go to the EngLab web page: https://englab.uwaterloo.ca/
    3. Click on a workstation to start a remote desktop. (Mac users will first need to install the Microsoft Remote Desktop 10 app.)
    4. Sign in to the workstation using your usual nexus account information.

Rules about group work in labs:

- Labs are done in groups of two, unless there is an odd number of students in the class, in which case there will be (at least) one group of one. Each group submits one report per lab. Note: Each group member is expected to actively participate in each part of the lab.
- The instructor or lab instructor has the authority to split up or re-arrange groups for academic reasons, including the possibility or requiring certain students to work alone.
- Under no circumstances are students allowed to access, in any form, ECE/SE380 lab reports or answers or results from previous terms. Such access will be treated as an academic offence under Policy 71.
- Each group is allowed to consult with students in the class to share ideas and approaches, but each group must write up their own lab reports and create their own code.
- Turnitin: Text matching software Turnitin will be used in this course on the submitted lab reports. Turnitin stores all submissions on a US server. If you do not want your lab reports to be scanned by Turnitin, then let the Lab Instructor know so that your lab reports will be manually checked for plagiarism.

General University of Waterloo Guidelines

Academic Integrity: In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. Check http://www.uwaterloo.ca/academicintegrity/ for more information.

Grievance: A student who believes that a decision affecting some aspect of their university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4, http://www.adm.uwaterloo.ca/infosec/Policies/policy70.htm.

When in doubt please be certain to contact the department's administrative assistant who will provide further assistance.

Discipline: A student is expected to know what constitutes academic integrity—check http://www.uwaterloo.ca/academicintegrity/ to avoid committing an academic offence, and to take responsibility for their actions. A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about rules for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate Associate Dean. For information on categories of offences and types of penalties, students should refer to Policy 71, Student Discipline, http://www.adm.uwaterloo.ca/infosec/Policies/policy71.htm.

For typical penalties check Guidelines for the Assessment of Penalties, http://www.adm.uwaterloo.ca/infosec/guidelines/penaltyguidelines.htm.

Appeals: A decision made or penalty imposed under Policy 70 (Student Petitions and Grievances) (other than a petition) or Policy 71 (Student Discipline) may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72 (Student Appeals) http://www.adm.uwaterloo.ca/infosec/Policies/policy72.htm.

Note for Students with Disabilities: AccessAbility Services, located in Needles Hall, Room 1401, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with AccessAbility Services at the beginning of each academic term.

Turnitin.com: Text matching software (Turnitin) may be used to screen assignments in this course. Turnitin is used to verify that all materials and sources in assignments are documented. Students' submissions are stored on a U.S. server, therefore students must be given an alternative (e.g., scaffolded assignment or annotated bibliography), if they are concerned about their privacy and/or security. Students will be given due notice, in the first week of the term and/or at the time assignment details are provided, about arrangements and alternatives for the use of Turnitin in this course.

It is the responsibility of the student to notify the instructor if they, in the first week of term or at the time assignment details are provided, wish to submit alternate assignment.