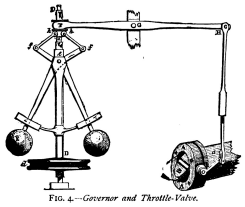
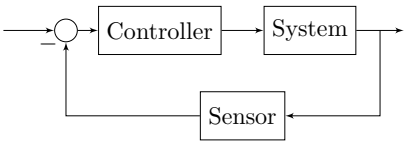
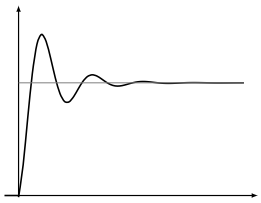
ECE 380 Analog Control Systems
Spring 2024








> Without control systems there could be no manufacturing, no vehicles, no computers, no regulated environment—in short, no technology.
>
> J. Doyle, B. Francis, A. Tannenbaum
> *Feedback Control Theory (1990)*

> All modern control algorithms for engineering systems are implemented in software.
>
> K. J. Åström, R. Murray
> *Feedback Systems (2020)*

Instructor	Dr. Gennaro Notomista Email: gennaro.notomista@uwaterloo.ca Office: E5 4006

Lab instructor	Sergio Reyes Livera Email: srlivera@uwaterloo.ca Office: E2 2360A

Teaching assistants	Tutorials	Kevin Joseph	k2joseph@uwaterloo.ca
	Lab	Alexander Kitaev	a2kitaev@uwaterloo.ca
	Lab	Alex Lovi	alovi@uwaterloo.ca

Time and place	Lectures	Tuesday, Wednesday 8:30–9:50, E7 5353
	Tutorials	Friday 8:30–9:50, E7 5353
	Office hours	Thursday 14:30–16:30, E5 4006

Website	`learn.uwaterloo.ca/`
	`https://piazza.com/uwaterloo.ca/summer2024/ece380sec001`
	`https://www.gnotomista.com/teaching/ece380_spring2024.html`

Description
This course will introduce students to the mathematical modeling of systems and to the analysis and design of feedback control systems. The course will be divided into four modules, corresponding to the following topics:

- Mathematical models of systems
- Linear system theory
- Analysis of feedback control systems
- Controller synthesis

Each topic will be presented during lectures and reinforced via homeworks. Moreover, throughout the term, a project will walk the students through the implementation of a controller for an autonomous mobile robot, which will be demonstrated on a real robotic platform in the UWaterloo Robohub.

Prerequisites ECE 207 or MATH 213

Reading
The course textbook is:

(DB) Richard C. Dorf, Robert H. Bishop, *Modern Control Systems*, 13th edition, Pearson, 2016

Other useful resources are:

(AM) K. J. Åström, R. Murray, *Feedback Systems. An Introduction for Scientists and Engineers*, 2nd edition, Princeton University Press, 2021 `https://fbswiki.org/wiki/index.php/Main_Page`
(N) Norman S. Nise, *Control Systems Engineering*, 8th edition, John Wiley & Sons, 2019

Deliverables and grading

- Homeworks (`5%`)
  - Handled via Crowdmark
  - 5 homeworks (HW1, ..., HW5, in the following), each worth 1%
- Lab (`20%`)
  - Handled via Crowdmark
  - Carried out in groups
  - Labs 1, 2, 3, 4, 5 are worth 2%, 4%, 4%, 5%, 5%, respectively
  - More details in the lab manual on the course website
- Project (`5%`)
  - Handled via LEARN
  - Carried out in groups (same groups of the lab)
  - 2 tasks (PT1 and PT2, in the following), worth 2% and 3%, respectively
  - More details in the project description on the course website
- Exams (`70%`)
  - 1 midterm, 1 final
  - Total worth `max{20% midterm + 50% final, 70% final}`

Laboratory

- Lab related information can be found on LEARN, in the lab course outline. Please see highlights below.
- All lab-related postings (files or news notifications), the lab manual, the lab calendar, lab group formation will be carried out on LEARN and/or Crowdmark.
- All lab submissions are to be done electronically on LEARN and/or Crowdmark.
- Laboratory work is done in groups of two students from the same lab section and from the same lecture section, unless there is an odd number of students in a lab section, in which case there will be (at least) one group of one. Both lab partners are responsible for verifying that the group submission was uploaded to LEARN and/or Crowdmark.

- Due dates for submissions can be found in the Lab Calendar, available on LEARN.
- At the end of their lab session, each group must submit their raw data to LEARN. Raw data consists of lab measurements, typically captured in a spreadsheet, and all relevant plots/screen captures.
- 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 is presented within a week from the missed deadline. Under no circumstances will a lab report be accepted more than a week past the deadline.
- Lab attendance is mandatory for each student. Missing a significant portion of a lab session without a valid reason will result in a reduction in the lab report grade (for that student only). The grade reduction will be proportional to the fraction of the lab session missed, where missing an entire lab session (without a valid reason) results in a 100% reduction in the lab report grade. In cases where a student misses part of a lab session, the lab instructor is the one who determines the mark reduction.

Rules for group work in the lab

- Students work in groups of two. Both partners must do all of the lab work, and attend all lab sessions (see above). All ECE 380 lab submissions are group submissions.
- The instructor or lab instructor has the authority to split up or re-arrange groups for academic reasons, including the possibility of requiring certain students to work alone.
- Under no circumstances are students allowed to access, in any form, ECE/SE 380 lab reports or answers or results from previous terms. Such access will be treated as an academic offence under Policy 71. The use of "homework services" such as chegg.com and course-hero.com is prohibited.
- You are allowed to talk with other students currently enrolled in the course about the lab content, but each group must write up their lab reports completely independently.
- Outside lab hours, lab-related questions will be answered on Piazza, to the extent possible.

Policy on academic integrity

Academic integrity To maintain a culture of academic integrity, members of the University of Waterloo are expected to promote honesty, trust, fairness, respect and responsibility. A student is expected to know what constitutes academic integrity, to avoid committing academic offences, 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 course instructor, academic advisor, or Graduate Associate Dean. When misconduct has been found to have occurred, disciplinary penalties will be imposed under Policy 71 - Student Discipline. For information on categories of offenses and types of penalties, students should refer to Policy 71 - Student Discipline, `https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-71`.

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, `https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-70`.

Discipline A student is expected to know what constitutes academic integrity (`https://uwaterloo.ca/academic-integrity`) to avoid committing an academic offence, and to take responsibility for his/her 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.

Appeals A student may appeal the finding and/or penalty in a decision made under Policy 70 - Student Petitions and Grievances (other than regarding a petition) or Policy 71 - Student Discipline if a ground for an appeal can be established. Read Policy 72 - Student Appeals, `https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-72`.

Note for students with disabilities The Office for persons with Disabilities (OPD), located in Needles Hall, Room 1132, 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 the OPD at the beginning of each academic term.

Academic Integrity Office (UW) `https://uwaterloo.ca/academic-integrity/`.

Schedule

Date	Subject	Reading	Deliverable due
	MATHEMATICAL MODELS OF SYSTEMS		
May 7	Introduction to control systems	1 (DB)	
May 8	Examples of control systems	1 (DB)	Lab/project groups
May 14	From differential equations to state space	2, 3 (DB)	
May 15	Linearization	2 (DB)	
May 21	Transfer function	2 (DB)	
May 22	Examples of transfer functions	2 (DB)	Lab1
	LINEAR SYSTEM THEORY		
May 28	System stability	3, 6 (DB)	HW1
May 29	Performance	5 (DB)	
Jun 4	First and second order systems	5 (DB)	
Jun 5	Lower-order approximations and system identification	5 (DB)	Lab2
Jun 11	Frequency response	8 (DB)	HW2
Jun 12	Bode plots	8 (DB)	
Jun 17-21	**Midterm week — no class**		
Jun 20	**Midterm exam, 13:30–14:45, E7 4043/4053/5343/5353**		
Jun 25	Examples of bode plots	8 (DB)	
	ANALYSIS OF FEEDBACK CONTROL SYSTEMS		
Jun 26	Stability of interconnected systems	2, 4 (DB)	Lab3
Jul 2	Routh-Hurwitz criterion	6 (DB)	HW3
Jul 3	Nyquist and Bode criteria	9 (DB)	PT1
	CONTROLLER SYNTHESIS		
Jul 9	Root locus	7 (DB)	HW4
Jul 10	Control design using root locus	7 (DB)	Lab4
Jul 16	PID controller	7 (DB)	
Jul 17	Loop shaping	10 (DB)	
Jul 23	Lead-lag compensators	10 (DB)	HW5
Jul 24	Back to state space	11 (DB)	Lab5
Jul 30	Pole placement	11 (DB)	PT2
	TBD	**Final exam**	