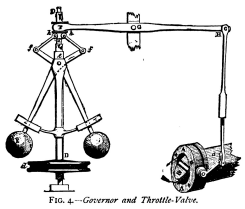
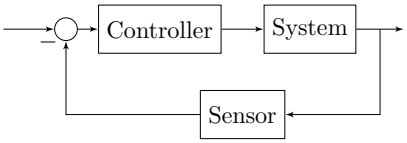
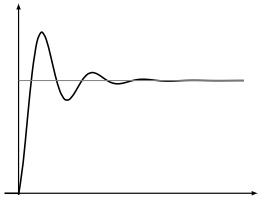
SE 380 Introduction to Feedback Control
Fall 2023







> 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)*

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Time and place	Lectures	Monday, Wednesday, Friday 11:30-12:20, STC 0060
	Tutorials	Thursday 16:30-17:20, STC 0040
	Office hours	Tuesday 15:00-17:00, E5 4006

Website	`learn.uwaterloo.ca/` `https://www.gnotomista.com/teaching/se380_fall2023.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 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 (15%)
  - 5 homeworks (referred to as HW1, ..., HW5, in the following)
  - HWi worth 3% for all i
  - Handled via Crowdmark
- Project (15%)
  - 3 tasks (referred to as PT1, PT2, PT3, in the following)
  - PTi worth 3+i%
  - Handled via LEARN
  - Carried out in groups
  - More details in the project description on the course website
- Exams (70%)
  - 1 midterm, 1 final
  - Total worth max{30% midterm + 40% final, 70% final}

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

Week	Date	Subject	Reading	HW/PT due
	MATHEMATICAL MODELS OF SYSTEMS			
1	W, Sep 6	Introduction to control systems	1 (DB)	
	F, Sep 8	Examples of control systems	1 (DB)	
2	M, Sep 11	From differential equations to state space	2, 3 (DB)	
	W, Sep 13	Linearization	2 (DB)	
	F, Sep 15	Laplace transform	2 (DB)	HW1
3	M, Sep 18	Transfer function	2 (DB)	
	W, Sep 20	Examples of transfer functions	2 (DB)	
	F, Sep 22	Frequency response	8 (DB)	
4	M, Sep 25	Bode plots	8 (DB)	
	W, Sep 27	Examples of bode plots	8 (DB)	
	LINEAR SYSTEM THEORY			
	F, Sep 29	System stability	3, 6 (DB)	HW2
5	M, Oct 2	Performance	5 (DB)	
	W, Oct 4	First and second order systems	5 (DB)	
	F, Oct 6	Midterm review		PT1
	Oct 9-13	**Reading week — no class**		
6	M, Oct 16	**Midterm exam, 11:30-12:20, location TBD**		
	W, Oct 18	Lower-order approximations	5 (DB)	
	F, Oct 20	System identification		
	ANALYSIS OF FEEDBACK CONTROL SYSTEMS			
7	M, Oct 23	Block diagrams	2 (DB)	PT2
	W, Oct 25	Stability of interconnected systems	4 (DB)	
	F, Oct 27	Routh-Hurwitz criterion	6 (DB)	
8	M, Oct 30	Nyquist plot	9 (DB)	
	W, Nov 1	Bode plot	9 (DB)	
	CONTROLLER SYNTHESIS			
	F, Nov 3	Loop shaping	10 (DB)	HW3
9	M, Nov 6	Integral control	7 (DB)	
	W, Nov 8	Lead-lag compensators	10 (DB)	
	F, Nov 10	PID controller	7 (DB)	HW4
10	M, Nov 13	Root locus	7 (DB)	
	W, Nov 15	Examples of control design		
	F, Nov 17	Back to state space	11 (DB)	HW5
11	M, Nov 20	Pole placement	11 (DB)	
	W, Nov 22	Pole placement	11 (DB)	
	F, Nov 24	Control for software & software for control		PT3
12	M, Nov 27	Robohub sessions		
	W, Nov 29	Robohub sessions		
	F, Dec 1	The separation principle		
13	M, Dec 4	Final review		
		Final exam date, time, location TBD		