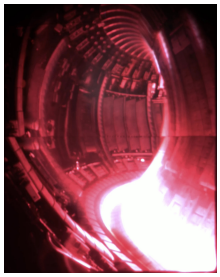
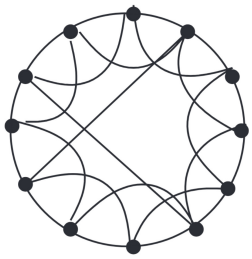
ECE 481 / 780 T01 Digital Control Systems / Sampled Data Control Systems
Spring 2025



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Lab instructor	Sergio Reyes Livera Email: srlivera@uwaterloo.ca Office: E2 3340

Time and place	Lectures	Wednesday	13:00–14:20	E7 4433
		Friday	13:00–14:20	E7 4437
	Tutorials	Friday	16:00–16:50	E7 4437
	Office hours	Wednesday	10:00–12:00	E5 4006

Website	`learn.uwaterloo.ca/`
	`https://piazza.com/uwaterloo.ca/spring2025/ece481ece780t01`
	`https://www.gnotomista.com/teaching/ece481_ece780t01_spring2025.html`

Description
This course will introduce students to modeling, analysis, and control of discrete time and sampled data control systems. The course will be divided into five modules, corresponding to the following topics:

1. Review of continuous time control systems
2. Emulation design of digital controllers
3. Discrete time control systems
4. Direct design of digital controllers
5. Optimization- and learning-based control

Each module will be presented during lectures and reinforced via computer simulations, homeworks, and labs. Moreover, throughout the term, a project will walk the students through the implementation of a digital controller on a real autonomous mobile robot in the UWaterloo Robohub.

Prerequisites

- ECE 380 for ECE 481
- No formal prerequisites for ECE 780 T01

Prior knowledge of linear algebra, feedback control systems, and mathematical optimization can make life a bit easier.

Reading
The suggested course textbooks are:

[1] Charles L. Phillips, H. Troy Nagle, Aranya Chakrabortty, *Digital Control System Analysis and Design*, Pearson, 2015

[2] Gene F. Franklin, J. David Powell, Abbas F. Emami-Naeini, *Feedback Control of Dynamic Systems*, Pearson, 2019

[3] Dimitri P. Bertsekas, *Reinforcement Learning and Optimal Control*, Athena Scientific, 2019

Additional reading material will be provided as appropriate.

Deliverables and grading

ECE 481

- Homeworks (20%)
  - 2 homeworks
  - 10% each
- Midterm (30%)
- Lab (25%)
  - Labs 1, 2, 3, and demo are worth 4%, 6%, 7%, 8%, respectively
- Project (25%)
  - Final project report: 20%
  - Project code: 5%

ECE 780 T01

- Homeworks (50%)
  - 2 homeworks
  - 25% each
- Project (50%)
  - Final project report: 40%
  - Project code: 10%

Extra project points will be assigned to the groups participating in the *1st edition of the Robotics Quidditch tournaments* together with ECE486 / ECE687 students!

Lab details
The lab will consist of the control of a ball and beam system. The work will be carried out in groups of at most 2 people (same as the project groups). More details in the lab manual on the course website.

Project details
The project will consist of the control of a flapping wing robot. The work will be carried out in groups of at most 2 people (same as lab groups). More details in the project description on the course website.

Project details: Alternative for MASc and PhD students
The project will consist of the solution to a problem in the student's research area using the techniques covered during the course.

Audit policy
Either the homeworks or the project must be completed to audit the course.

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
May 7	Introduction to digital control systems	1 [1], 8 [2]	
	REVIEW OF CONTINUOUS TIME CONTROL SYSTEMS		
May 9	Modeling	4 [1], 3, 4 [2]	
May 14	Stability	4 [1], 3, 7 [2]	
May 16	Performance	4 [1], 3, 6 [2]	
May 21	Control	4 [1], 4, 5, 6 [2]	
May 23	Control	4 [1], 7 [2]	
	EMULATION DESIGN OF DIGITAL CONTROLLERS		
May 28	Sample and hold	8 [2]	Lab 1
May 30	Controller discretization	8 [2]	
Jun 1			HW 1
	DISCRETE TIME CONTROL SYSTEMS		
Jun 4	Discrete time signals and z-transform	2 [1], 8 [2]	
Jun 6	Discrete LTI systems	2 [1], 8 [2]	
Jun 8			Project proposal
Jun 11	Stability	7 [1], 8 [2]	
Jun 13	Performance	7 [1], 8 [2]	
Jun 16-20	**Midterm week — no class**		
Jun 16	Robohub session, 14:00–17:00		
Jun 18	**Midterm exam, 13:00–14:30, E7 4433**		
Jun 25	Sampling	3 [1], 8 [2]	
Jun 27	Sampled data systems	3 [1], 8 [2]	Lab 2
Jun 30	Robohub session, 14:00–17:00		
Jul 2	**Monday schedule — No class**		
Jul 4	Sampled data systems	8 [2]	

Jul 6			HW 2
Jul 7	Robohub session, 14:00–17:00		
	DIRECT DESIGN OF DIGITAL CONTROLLERS		
Jul 9	Controllability	9 [1], 7 [2]	
Jul 11	Pole placement	9 [1], 7 [2]	
Jul 14	Robohub session, 14:00–17:00		
Jul 16	Observability	9 [1], 7 [2]	
Jul 18	Output feedback	9 [1], 7 [2]	
Jul 21	Robohub session, 14:00–17:00		Lab 3
Jul 22			Lab demo
	OPTIMIZATION- AND LEARNING-BASED CONTROL		
Jul 23	Optimal control	11 [1], 1 [3]	
Jul 25	Reinforcement learning	2 [3]	
Jul 28	Robohub session, 14:00–17:00		
Jul 30	Model predictive control	2 [3]	
Aug 4			Project final report