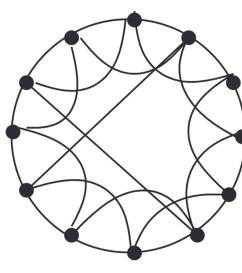
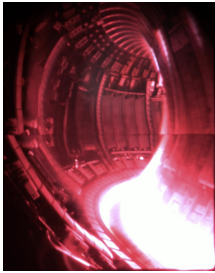


**ECE 481 / 780 T01 Digital Control Systems / Sampled Data Control Systems**  
**Spring 2025**



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<b>Time and place</b>	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://learn.uwaterloo.ca/)  
<https://piazza.com/uwaterloo.ca/spring2025/ece481ece780t01>  
[https://www.gnotomista.com/teaching/ece481\\_ece780t01\\_spring2025.html](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 Chakraborty, *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**

<u>ECE 481</u>	<u>ECE 780 T01</u>
<ul style="list-style-type: none"> <li>• Homeworks (20%)               <ul style="list-style-type: none"> <li>– 2 homeworks</li> <li>– 10% each</li> </ul> </li> <li>• Midterm (30%)</li> <li>• Lab (25%)               <ul style="list-style-type: none"> <li>– Labs 1, 2, 3, and demo are worth 4%, 6%, 7%, 8%, respectively</li> </ul> </li> <li>• Project (25%)               <ul style="list-style-type: none"> <li>– Final project report: 20%</li> <li>– Project code: 5%</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Homeworks (50%)               <ul style="list-style-type: none"> <li>– 2 homeworks</li> <li>– 25% each</li> </ul> </li> <li>• Project (50%)               <ul style="list-style-type: none"> <li>– Final project report: 40%</li> <li>– Project code: 10%</li> </ul> </li> </ul>

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

Jul 9	Controllability and pole placement	9 [1], 7 [2]	
Jul 11	Observability and output feedback	9 [1], 7 [2]	
Jul 16	Optimal control	11 [1], 1 [3]	
Jul 18	Model predictive control	2 [3]	HW 2
Jul 21	Robohub session, 14:00–17:00		Lab 3
Jul 22			Lab demo

## OPTIMIZATION- AND LEARNING-BASED CONTROL

Jul 23	Reinforcement learning	2 [3]	
Jul 25	Nonlinearities		
<b>Jul 25</b>	<b>Nonlinearland, 17:00–18:00, E7 7303/7363</b>		
Jul 28	Robohub session, 14:00–17:00		
Jul 30	Robohub session, 8:30–14:30		
Aug 4			Project final report