

E&CE 484: Digital Control Applications

Instructor: Prof. Daniel Miller (EIT-3116, ext. 35215, miller@uwaterloo.ca)

- We will be using Piazza this term for course and lab discussions. This should minimize duplicate questions and maximize efficiency.
- I will be holding an office hour each week via WEBEX on Tuesday at 11:30am, starting on September 15. I'll send details before the first office hour.
- You can contact me by email about questions related to the lectures, course notes/slides, and quizzes; please put ECE484 in the subject line to maximize the speed of response.

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

- Carmen is in charge of the lab: email her questions related to the lab or lab reports.

TAs:

1. Fatemeh Ahmadloo (fahmadlo@uwaterloo.ca)
 - Will be running the tutorial; available for general questions about the course content.
2. Abhinav Dahiya (a4dahiya@uwaterloo.ca)
 - Is involved in all aspects of the lab: will be grading the deliverables, and will be available to answer lab questions.
3. Ilyas Farhat (i2farhat@uwaterloo.ca)
 - His time is split between the lab and other duties; w.r.t. the lab, he will be grading the deliverables, and will be available to answer lab questions.

Schedule: Due to UW restrictions, this course will be run online. This is very strange for most of us, and definitely for me. You will need to be disciplined to keep up in your courses. I have created a detailed schedule to help you do this (see page 6).

- Lecture videos for the coming week will be posted on Learn every weekend; since some videos are short, three lectures-worth may incorporate more than three videos. These videos are based on slides, which, in turn, are based on the course notes.
- I will have an **office hour on WEBEX every week at 11:30am on Tuesday**, starting the second week of class, i.e. September 15. It is **optional**, and will not be recorded.

- Fatemeh will be holding an **online tutorial on WEBEX every week at 12:30pm on Thursday**. Ilyas will help to facilitate the Q&A part of the tutorial. This is also **optional**, but it will be recorded and uploaded to LEARN.

Reference Text: There are a number of standard reference texts for this course, e.g.

- Digital Control Systems Analysis and Design, 3rd ed., Phillips and Nagle.
- Digital Control Systems Analysis and Design, 4th ed., Phillips, Nagle and Chakraborty.

Usually I would put these books on reserve in the library; this is not allowed this term. However, you can still borrow library books; hence, if needed, you can borrow one of the above books or another on digital control.

Coursenotes:

- I have posted the coursenotes on LEARN.
- Based on these, I have created slides which are used in the videos; in past years I typically used the blackboard. They will be posted on LEARN, as needed, for the videos. **You may wish to use the videos and slides as your primary learning tool**, and refer to the notes for any needed clarification.

Lab Information: Lab related items will be posted periodically on LEARN. Lab group formation, signups, report submissions, and feedback will be carried out on LEARN.

Piazza: This term we will be using Piazza for class discussions. The system is highly catered to getting you help fast and efficiently from classmates, the Lab Instructor, the TAs, and myself. Rather than emailing questions to the teaching staff, I encourage you to post your questions on Piazza. If you have any problems or feedback for the developers, email team@piazza.com. Find our class signup link at

<https://piazza.com/uwaterloo.ca/fall2020/ece484>

Grading: This grading scheme is the default one, subject to the comment below about missed quizzes:

1. We have a lab worth 20%.
2. We have three quizzes, and you get the **best two out of three**, yielding 40%. These quizzes will be run on LEARN; we will have a “practise quiz” during Week 3 to verify that the technology works.
3. There is a final exam, worth 40%.

Notes about quizzes, the exam, and missed quizzes:

- Quiz schedule: I have booked them for Friday Oct. 2, Friday Oct. 30, and Friday Nov. 27th. The exact time (or window) that they will be held will be determined after a discussion with the class.
- Quiz and Exam rules: Tests are open book in the sense that you may consult your course notes and material posted in the course LEARN site. Use of any other resource (including file-sharing services such as chegg.com, coursehero.com, stackexchange.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 quizzes:
 - If you miss a quiz for any reason, then the missed quiz scores a grade of zero.
 - If you miss two quizzes, both for valid reasons, then the written quiz will be given a weight of 20% and the final exam mark will be given a weight of 60%.
 - If you miss three quizzes, all for valid reasons, then the quiz mark will be given a weight of 20%, the final exam mark will be given a weight of 60%, and you will receive an INC until a makeup quiz (which will be the source of the quiz mark) can be arranged.
 - The instructor makes the ultimate determination about the validity of a reason for missing a quiz.

EngLab: 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.

WEBEX: WebEx lets you join meetings by using just the web browser:

```
https://help.webex.com/en-us/9eed9t/Get-Started-Joining-a-Meeting-Event-or-Training-Session-with-the-Webex-Web-App#:~:
text=The%20Cisco%20Webex%20web%20app,view%20and%20interact%20with%20others.
```

(You need to append these three lines together to get the complete web address.)

The Lab:

This course normally has in-person labs. This term we will be using a MATLAB simulation for the plant model. This makes the lab less challenging, since it is not feasible to model all of the nonlinearities. However, you will still achieve the main learning outcomes.

- Here's a video that introduces the lab:
<https://learn.uwaterloo.ca/d2l/le/content/587665/viewContent/3196468/View>
- The lab manual is available on LEARN in the “labs” folder.
- The lab is worth 20% of your final grade.
- The lab has three parts and requires submission of three reports: the tentative schedule is
 - Lab 1 report: worth 6%, due Wednesday October 7th at 11:59pm EST
 - Lab 2 report: worth 8%, due Thursday November 5th at 11:59pm EST
 - Lab 3 report: worth 6%, due Tuesday November 24th at 11:59pm EST
- See the lab manual for details about the report requirements.
- You must have access to Matlab and Simulink to work on the lab.
- Labs are done in teams 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 team is allowed to consult with others in the class to share ideas and approaches, but each team must write up their own lab reports and create their own code. See the lab manual for details on acceptable group work.

Note: Each group member is expected to actively participate in each part of the lab. We reserve the right to split up groups if one of the partners is neglecting their duties.
- Lab reports should be submitted in the associated LEARN dropboxes. Any report (including any associated project code) submitted late will lose marks, at the discretion of the lab instructor, at a rate of 1% per hour.
- **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.

High Level Course Objective: To study practical and theoretical issues that arise when a controller is implemented on a computer to control a continuous-time plant.

Calendar Description: Dynamic system modeling: linear, nonlinear, state-space, sample data systems, computer simulation, system identification. Discrete system stability and dynamic performance. Nonlinear system analysis, limit cycles. Digital control system design: emulation methods, z -domain, frequency domain, pole placement. Implementation of digital controllers. Laboratory projects in computer control of mechatronic and other systems.

Detailed Course Description:

1. Introduction to Sampled Data Control: [1 lectures]

The plant, the controller, the standard setup. The rationale for sampled-data control.

2. Continuous-Time Performance Specifications and Some Modelling Issues: [7 lectures]

Stability, transient response, steady-state response, frequency response, handling non-linear models, a brief introduction to system identification.

3. The Pole Placement Design Technique: [5 lectures]

The pole placement design technique, with and without steady-state requirements. How to handle transient specifications. Three design examples.

4. Emulation Techniques for Discrete-Time Controller Design: [7 lectures]

A review of discrete-time systems and the z -transform. Several discretization (emulation) techniques and their limitations. A detailed discrete-time pole placement design using the emulation approach. A review of frequency domain lag design; a detailed lag design using the emulation approach.

5. Sampled Data Systems: [4 lectures]

Analysis of closed-loop sampled-data systems at the sample points. Frequency domain analysis of inter-sample behaviour.

6. Discrete-Time Systems: [6 lectures]

Stability of the closed-loop system at the sample points; stability of the complete sampled-data system; pathological sampling. Various techniques to determine closed-loop stability in the discrete-time domain: Routh Hurwitz using the bilinear transformation, the Jury test, the Nyquist criterion, converting continuous-time specifications to discrete-time specifications.

7. The Direct Design of Digital Controllers: [6 lectures]

The frequency domain method (v -plane) and the pole placement method in the direct design approach. A detailed design example of each.

Schedule¹ of Activities and Approximate Course Coverage

Week 1: September 8-11 (Introduction; OL and CL stability; TD Analysis)

Week 2: September 14-18 (TD specs; FD specs; static nonlinearities)

Week 3: September 21-25 (Linearizing dynamic systems; System ID; PP)

Week 4: September 28 - Oct 2 (PP+step/ramp tracking; trans. perf.; Design Ex. 1)

- Friday October 2nd: Quiz 1 (covers to the end of Week 3).

Week 5: October 5-9 (Ch. 3 Design Examples 2/3; Review of DT signals/systems)

- Wednesday October 7th: Lab 1 report due at 11:59 EST.

Week 6: October 12-16: Reading week.

Week 7: October 19-23 (Discretization techniques; PP design example)

Week 8: October 26-30 (Lag design review; Lag design example; Intro to SD Systems)

- Friday October 30th: Quiz 2 covers to the end of Week 7.

Week 9: November 2-6 (Ch. 1 example analysed; FD analysis of SD systems)

- Thursday November 5th: Lab 2 report due at 11:59 EST.

Week 10: November 9-13 (Closed-loop stability of DT and SD systems; pathological sampling; using RH in the DT domain; Jury test)

Week 11: November 16-20 (Nyquist analysis in DT setting)

Week 12: November 23-27 (PP direct design; a design example)

- Tuesday November 24th: Lab 3 report due at 11:59pm EST.
- Friday November 27th: Quiz 3 covers to the end of Week 11.

Week 13: November 30 - December 4 (FD direct design; a design example)

Acronyms:

- OL = open-loop and CL = closed-loop
- TD = time domain and FD = frequency domain
- PP = pole placement
- SD = sampled-data and DT = discrete-time
- RH = Routh Hurwitz

¹Subject to small changes.

General UW 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

www.uwaterloo.ca/academicintegrity/
for more information.]

Grievance: A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4,

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

www.uwaterloo.ca/academicintegrity/

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. For information on categories of offences and types of penalties, students should refer to Policy 71, Student Discipline,

www.adm.uwaterloo.ca/infosec/Policies/policy71.htm.

For typical penalties check Guidelines for the Assessment of Penalties,

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)

www.adm.uwaterloo.ca/infosec/Policies/policy72.htm.

Note for Students with Disabilities: The Accessibility Services Department (ASD), 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 the ASD at the beginning of each academic term.