

**ECE481: DIGITAL CONTROL SYSTEMS  
COURSE OUTLINE**

**SPRING 2021**



**People**

- Instructor Dan Davison, [ddavison@uwaterloo.ca](mailto:ddavison@uwaterloo.ca)
- I answer email quickly, so please contact me anytime with any question related to the lectures or course notes or tests.
  - You can alternatively post questions on the YouTube comments section for each lecture or tutorial.
  - I am happy to arrange a weekly live online drop-in “office hour” session if the class would find that useful. We’ll have to find a time slot that works for everyone.
- Lab instructor Carmen Caradima, [carmen.caradima@uwaterloo.ca](mailto:carmen.caradima@uwaterloo.ca)
- Email Carmen questions related to the lab or lab reports.
- Lab TA Mahsa Parsapour, [mahsa.parsapour@uwaterloo.ca](mailto:mahsa.parsapour@uwaterloo.ca)
- Mahsa’s main job in the course is to grade deliverables associated with the lab, and to be an additional resource to help students with questions about the lab.

**Mode of operation**

- Schedules This course, like most or all of your courses this term, is being run remotely. To give you maximum flexibility, I am running this course completely asynchronously. You will need to be disciplined to make and keep a daily, weekly, and monthly schedule. To help you, I have broken up the course into manageable chunks and distributed them over the term (see page 5).
- Weekly email Every weekend I will send the class an email outlining the upcoming week’s activities and deadlines. I will also keep the LEARN Calendar up to date.
- Lecture videos Each week I will create three YouTube videos, corresponding to what would have been the usual 3 hours of lecture content. The videos are based 100% on the course notes (see page 6) and will be released by 8:30am (Waterloo time) normally every Monday, Wednesday, and Friday throughout the term. You

should watch the videos, imagining you are in a lecture. Have your course notes in front of you with a pen; work out examples and fill in the blanks in your course notes as you go through the videos. Pause and think about things. Do not rush through the videos or try to multitask. You can ask me questions about the video content by posting comments under the YouTube video, or by sending me email. Links to all videos will be posted on LEARN. See the schedule on page 5.

**Tutorial videos** By 8:30am (Waterloo time) roughly every second Thursday I will post a video on YouTube that goes through some old exam questions related to material covered recently in lectures. No new course material will be included in the tutorial videos. They are a resource to help you review, study, and work through the course content. Links to all videos will be posted on LEARN. See the schedule on page 5.

**Tests** The course has six LEARN-based randomized **60-minute multiple-choice tests**. Each test deals with course content covered up to approximately 1 week before the test date. The test must be written within a specified window on the test day; and I will poll the class to determine a time interval that works for everyone. See the schedule on page 5. Note that:

- There are **6 tests** in total, worth **80% of your course grade**. I will drop the lowest score for each student. Each of the remaining 5 tests is worth 16% of the final course grade.
- Tests are to be done individually. You may not communicate directly or indirectly with any person except the course instructor.
- Tests are open book in the sense that you may consult your course notes. You may not use any other resources,
- You must have access to LEARN to write the tests.

**Fine print:** Any test missed without a valid reason scores a grade of zero. If one test is missed for a valid reason, the remaining 5 tests are each worth 16% of the final grade. If two tests are missed for a valid reason, the remaining 4 tests are each worth 20% of the final grade. Students who miss more than 2 tests (for any reason, valid or not) will get a grade of INC in the course until a make-up test can be arranged. The instructor makes the ultimate determination about the validity of a reason for missing a test.

**Labs** This course normally has in-person labs. This term we will have to be satisfied with simulations that can be run off campus. Simulations are not as impressive, but most learning outcomes can still be met, and the lab is still fun.

- Here's a video that introduces the lab: <https://youtu.be/77ylqplp4yl>
- 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:

- Lab 1 report: worth 6%, due June 15, 11:59pm (Waterloo time)
- Lab 2 report: worth 9%, due July 20, 11:59pm (Waterloo time)
- Lab 3 report: worth 5%, due Aug 4, 11:59pm (Waterloo time)

- See the lab manual for details about the report requirements.
- You must have access to Matlab and Simulink to work on the lab.
- Labs should be done individually (not in pairs, as is common for labs). You are allowed to consult with others in the class to share ideas and approaches, but each person must individually write up their own lab reports and create their own code. See the lab manual for details on acceptable group work.
- Use of “homework services” such as chegg.com and coursehero.com is prohibited.
- 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.

Matlab

You need to have access to Matlab. The university has a license for unlimited access to Matlab for all students. You can access Matlab in several ways:

- Download and run Matlab on your own computer
- Access Matlab through the “Matlab online cloud”
- Run Matlab on a university computer by remote desktop (via EngLab)

For details, see:

- <https://uwaterloo.atlassian.net/wiki/spaces/ISTKB/pages/284525621/Download+or+use+MATLAB+online>
- <https://englab.uwaterloo.ca/>

**Summary of grading scheme**

Tests	80%
Labs	<u>20%</u>
	100%
*Bonus marks	4%

\*As an incentive to help you not get behind, most of the 36 lecture videos explain how a random subset of the class can get a 0.5% bonus mark. Correctly answer the simple question within 24 hours of the nominal lecture time, and you get the bonus. The maximum overall bonus per student is 4%.

### Tips for online learning

<b>do...</b>	<b>don't...</b>
<ul style="list-style-type: none"><li>- create a dedicated study space at home without distractions</li><li>- treat each online course as seriously as you would treat an in-person course</li><li>- break up all your courses into manageable chunks</li><li>- keep up with material: create a daily, weekly, and monthly schedule and stick to it</li><li>- write notes with a pen and paper (science shows you learn better this way than just by typing)</li><li>- engage in lectures (whether live or pre-recorded), read books and notes</li><li>- ask questions if you are confused</li><li>- reach out to instructors and classmates</li></ul>	<ul style="list-style-type: none"><li>- think online courses are necessarily easy</li><li>- procrastinate</li><li>- get distracted by games or videos or email when you are studying</li><li>- passively learn, just listening to videos and superficially reading notes</li><li>- binge watch videos or cram for tests</li><li>- throw away your morals and plan to cheat</li><li>- assume you are alone</li></ul>

Here are some good resources that should help prepare you for an online term...

- [Common mistakes to avoid as a new online student](#)
- [Getting Ready to learn online](#)
- [What makes a successful online learner](#)
- [8 strategies for getting the most out of an online class](#)

Here are some tips specifically about writing online tests/exams:

- [Tips for taking online exams](#)
- [Online exam tips you'll be thankful for](#)

**Detailed Schedule of activities**

**Lec** = lecture video released by 8:30am (Waterloo time)

**Tut** = tutorial video released by 8:30am (Waterloo time)

**Test** = 60-minute randomized test on LEARN (time to be determined)

**Lab** = lab report due date; submit in LEARN dropbox by 11:59pm (Waterloo time)

<b>Monday</b>	<b>Tuesday</b>	<b>Wednesday</b>	<b>Thursday</b>	<b>Friday</b>
May 10 <b>Lec 0 (welcome)</b> <b>Lec 1</b>	May 11	May 12 <b>Lec 2</b>	May 13	May 14 <b>Lec 3</b>
May 17 <b>Lec 4</b>	May 18	May 19 <b>Lec 5</b>	May 20 <b>Tut 1</b>	May 21 <b>Lec 6</b>
May 24 <i>Holiday!</i>	May 25 <b>Test 1</b>	May 26 <b>Lec 7</b>	May 27	May 28 <b>Lec 8</b>
May 31 <b>Lec 9</b>	June 1	June 2 <b>Lec 10</b>	June 3 <b>Tut 2</b>	June 4 <b>Lec 11</b>
June 7 <b>Lec 12</b>	June 8 <b>Test 2</b>	June 9 <b>Lec 13</b>	June 10	June 11 <b>Lec 14</b>
June 14 <b>Lec 15</b>	June 15 <b>Lab 1</b>	June 16 <b>Lec 16</b>	June 17 <b>Tut 3</b>	June 18 <b>Lec 17</b>
June 21 <b>Lec 18</b>	June 22	June 23 <b>Lec 19</b>	June 24	June 25 <b>Lec 20</b>
June 28 <b>Lec 21</b>	June 29 <b>Test 3</b>	June 30 <b>Lec 22</b>	July 1 <i>Holiday!</i>	July 2 <i>Holiday!</i>
July 5 <b>Lec 23</b>	July 6	July 7 <b>Lec 24</b>	July 8 <b>Tut 4</b>	July 9 <b>Lec 25</b>
July 12 <b>Lec 26</b>	July 13 <b>Test 4</b>	July 14 <b>Lec 27</b>	July 15	July 16 <b>Lec 28</b>
July 19 <b>Lec 29</b>	July 20 <b>Lab 2</b>	July 21 <b>Lec 30</b>	July 22 <b>Tut 5</b>	July 23 <b>Lec 31</b>
July 26 <b>Lec 32</b>	July 27 <b>Test 5</b>	July 28 <b>Lec 33</b>	July 29 <b>Tut 6</b>	July 30 <b>Lec 34</b>
Aug 2 <i>Holiday!</i>	Aug 3 (M sched.) <b>Lec 35</b>	Aug 4 (R sched.) <b>Lab 3</b>	Aug 5 (F sched.) <b>Lec 36</b>	Aug 6 <i>Study day</i>
<b>Test 6</b> will be centrally scheduled during the final assessment period				

## Resources

- Course notes  
(required) Tests are based entirely on the video material, which, in turn, is based entirely on a set of course notes. **The course notes are for sale in two packages in the W Store, and can be ordered online via the “My Booklook” system.** A softcopy of the notes is also available on LEARN, although I strongly recommend you purchase a hardcopy since you will learn the material better if you write things down during the video sessions.
- YouTube videos  
(required) As mentioned above, I will post on YouTube pre-recorded lectures, based 100% on the course notes, and pre-recorded tutorials that go through relevant questions from old exams. Links to all videos will be given in LEARN as they become available. Alternatively, you can access all videos through the playlist:  
<https://www.youtube.com/playlist?list=PLc6mUrCrMKSI4BxCKHrHmBEdh5hh-Aluy>  
I strongly recommend that you watch the videos faithfully each week, and fill in the blanks and write comments on your copy of the course notes. Think and engage when going the videos, don't passively sit by or try to multitask. And do not try to binge watch or speed up videos—it won't work.
- LEARN page  
(required) The course has a LEARN page. Any course announcements, handouts, or material prepared for tutorials will be included on it. In addition, brief “answers” to the blanks in the lecture notes are posted, but those comments are not as substantial as everything contained in the YouTube videos. Links to all videos will be posted on LEARN. Finally, the course tests are run through LEARN.
- Old exams  
(optional) I've assembled a collection of old midterm and final exam questions, most with answers included. This resource is available on LEARN.
- Other books  
(optional) All the topics in this course are well established and included in any book that deals with digital control systems.

## How this course fits into the ECE curriculum

This course builds on classical control theory from a first control course (ECE380 or equivalent) and assumes good working knowledge of Laplace transforms, transfer functions, Bode plots, block diagrams, and basic control tools (Routh-Hurwitz test, root locus plots, Nyquist plots). Familiarity with z-transforms is an asset, but not required.

## Course objective, content, and outcomes

The main objective of this course is to study both practical and theoretical issues that arise when a controller is implemented on a computer to control a continuous-time plant.

On the next page is a summary of the major topics and outcomes of the course...

Chapter	Major topics	Major outcomes
<b>Chapter 1</b> <b>What is this course all about?</b>  [approx. 5 “lecture hours”]	<ul style="list-style-type: none"> <li>- course objective</li> <li>- introduction to main course concepts</li> </ul>	<ul style="list-style-type: none"> <li>- state the main objective of the course</li> <li>- manipulate sampled-data block diagrams</li> <li>- explain the design steps in emulation and direct design</li> </ul>
<b>Chapter 2</b> <b>Practical aspects of modelling</b>  [approx. 4.5 “lecture hours”]	<ul style="list-style-type: none"> <li>- general approach for modeling</li> <li>- system identification techniques</li> </ul>	<ul style="list-style-type: none"> <li>- explain and apply several system identification methods</li> </ul>
<b>Chapter 3</b> <b>Practical ways of coping with nonlinearities</b>  [approx. 6 “lecture hours”]	<ul style="list-style-type: none"> <li>- cancellation and linearization of nonlinearities</li> <li>- stiction, saturation, limit cycles</li> </ul>	<ul style="list-style-type: none"> <li>- apply practical methods of dealing with static nonlinearities and stiction</li> <li>- apply linearization and limit cycle analysis to nonlinear control systems</li> </ul>
<b>Chapter 4</b> <b>Discretization methods</b>  [approx. 3 “lecture hours”]	<ul style="list-style-type: none"> <li>- discretization in direct design</li> <li>- discretization in emulation</li> </ul>	<ul style="list-style-type: none"> <li>- explain how discretization arises in direct design and emulation</li> <li>- calculate various discretizations</li> </ul>
<b>Chapter 5</b> <b>Theory of discrete-time linear systems</b>  [approx. 6.5 “lecture hours”]	<ul style="list-style-type: none"> <li>- review of z-transform basics</li> <li>- stability of discrete-time systems</li> <li>- intuition about the z-plane</li> <li>- Bode plots in discrete time</li> </ul>	<ul style="list-style-type: none"> <li>- manipulate discrete-time block diagrams</li> <li>- work comfortably in the z-plane</li> <li>- interpret discrete-time Bode plots</li> </ul>
<b>Chapter 6</b> <b>Controller design for sampled-data systems</b>  [approx. 8.5 “lecture hours”]	<ul style="list-style-type: none"> <li>- emulation: a trick to partially account for the sampler and hold</li> <li>- direct design: discrete-time versions of all major tools (root locus, Nyquist plots, ...)</li> </ul>	<ul style="list-style-type: none"> <li>- explain and apply the “<math>T/2</math> trick” for emulation design</li> <li>- apply control tools (root locus, Nyquist theory, etc.) to discrete-time control systems</li> </ul>
<b>Chapter 7</b> <b>A more detailed look at sampled-data systems</b>  [approx. 2.5 “lecture hours”]	<ul style="list-style-type: none"> <li>- stability of sampled-data systems</li> <li>- inter-sample behaviour in sampled-data systems</li> <li>- guarantees in emulation and direct design</li> </ul>	<ul style="list-style-type: none"> <li>- determine pathological sampling frequencies and evaluate stability of a sampled-data system</li> <li>- explain guarantees of stability and inter-sample behaviour associated with emulation and direct design</li> </ul>

## Standard university statements

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 <a href="#">the Office of Academic Integrity</a> for more information.]
Grievances	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 <a href="#">Policy 70, Student Petitions and Grievances, Section 4</a> . 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 to avoid committing an academic offence, and to take responsibility for his/her actions. [Check <a href="#">the Office of Academic Integrity</a> for more information.] 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 <a href="#">Policy 71, Student Discipline</a> . For typical penalties, check <a href="#">Guidelines for the Assessment of Penalties</a> .
Appeals	A decision made or penalty imposed under <a href="#">Policy 70, Student Petitions and Grievances</a> (other than a petition) or <a href="#">Policy 71, Student Discipline</a> may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to <a href="#">Policy 72, Student Appeals</a> .
Note for students with disabilities	<a href="#">AccessAbility Services</a> , 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 AccessAbility Services at the beginning of each academic term.
Turnitin.com	Text matching software (Turnitin®) will be used in this course on the submitted lab reports. Turnitin® stores all submissions on a U.S. server. If you do not want your lab reports to be scanned by Turnitin®, let the instructor know and your lab reports will be manually checked for plagiarism.