Toronto Metropolitan University

Department of Electrical, Computer, & Biomedical Engineering
Faculty of Engineering & Architectural Science

Course Outline (F2023)

ELE809: Digital Control System Design

Instructor(s)	Dr. Y. C. Chen [Coordinator] Office: ENG458 Phone: (416) 979-5000 x 556090 Email: yaochen@torontomu.ca Office Hours: Refer to D2L
Calendar Description	This course deals with the theory on the design of digital control systems and their implementation. Major topics include: State-space system model. Discrete-time signals and systems; z-transform. Sampling: the ideal sampler, data reconstruction, quantization effects. Discrete equivalents to continuous-time transfer functions. Stability analysis: Jury's stability test; root locus; Nyquist stability criterion. Design of digital control systems: transform techniques; stat-space techniques. Hardware and software aspects in implementation. Laboratory work will include experiments on PID controller, and sate feedback controller design of an electro-mechanical system.
Prerequisites	ELE 639
Antirequisites	None
Corerequisites	None
Compulsory Text(s):	1. ELE809 Laboratory Manual, F2023 Edition, Y.C. Chen. Available through D2L.
Reference Text(s):	1. Digital Control Engineering, 2nd Edition, M. Sami Fadali and A. Visioli, Academic Press, 2012. Also available online through TMU Library.
Learning Objectives (Indicators)	At the end of this course, the successful student will be able to: 1. Use control engineering knowledge to understand and design digital control systems (**1d**) 2. Develop mathematical models for digital control systems design (**2b**) 3. Design digital PID controller and digital state feedback controllers (**4b**) 4. Design and implement various digital controllers using MATLAB to control a DC motor (**5a**) **NOTE:***Numbers in parentheses refer to the graduate attributes required by the Canadian Engineering Accreditation Board (CEAB).*
Course Organization	3.0 hours of lecture per week for 13 weeks 2.0 hours of lab per week for 12 weeks 0.0 hours of tutorial per week for 12 weeks
Teaching	Bita Azad, bita.azad@torontomu.ca

Assistants	
Course Evaluation	<table><tr><th>Theory</th><th></th></tr><tr><td>Mid-Term Exam</td><td>25 %</td></tr><tr><td>Final Exam (Theory Part)</td><td>40 %</td></tr><tr><th>Laboratory</th><th></th></tr><tr><td>Lab Work</td><td>25 %</td></tr><tr><td>Final Exam (Lab Part)</td><td>10 %</td></tr><tr><td>TOTAL:</td><td>100 %</td></tr></table> **Note:** In order for a student to pass a course, a minimum overall course mark of 50% must be obtained. In addition, for courses that have both **"Theory and Laboratory"** components, the student must pass the Laboratory and Theory portions separately by achieving a minimum of 50% in the combined Laboratory components and 50% in the combined Theory components. Please refer to the **"Course Evaluation"** section above for details on the Theory and Laboratory components (if applicable).
Examinations	Mid-Term exam will be announced on D2L. Final exam will be held during exam period.
Other Evaluation Information	None
Other Information	Lecture and laboratory schedules are tentative and subject to change. Consult D2L for updates.

Course Content

Week	Hours	Chapters / Section	Topic, description
1	1	1	Topic 1: Introduction Comparison of digital and analog control systems overview of the control problem and design approach.
1-2	3	2	Topic 2: Mathematical Models for Discrete-Time Systems Linear difference equation z-transform and properties discrete transfer function systems with delay.

2-3	4	3	Topic 3: Sampling and Reconstruction of Continuous-Time Signals Sample and hold spectrum of sampled signals Nyquist sampling theorem and aliasing data reconstruction.
3-4	3	3, 4	Topic 4: Analysis of Discrete-Time Signals and Systems Discrete-time signals response of discrete-time systems stability analysis techniques (Jury stability criterion root locus Nyquist criterion) transient and steady state characteristics.
4-8	12	7, 8	Topic 5: State-Space System Model Concept of states state variables state vector state space state-space equations modeling of physical systems using state-space models stability controllability and observability similarity transformation canonical forms discrete-time state-space models (with and without input delay).
8-9	3	6	Topic 6: Design using Transform Techniques Emulation of continuous-time design (discrete equivalents by numerical integration/differentiation hold equivalents and zero-pole mapping) PID control direct digital design: z-plane design using root locus frequency domain design with w-transform.
9-12	10	9	Topic 7: State Space Design Regulator design using pole placement technique Ackermann formula observer design reduced-order observer servo control system design robust control and disturbance rejection actuator and sensor delays.
13	1		Topic 8: Implementation and Practical Consideration Sample rate selection supporting hardware and software effects of quantization. (Lecture Notes)

Laboratory(L)/Tutorials(T)/Activity(A) Schedule

Week	L/T/A	Description

2	Tutorial	Tutorial 1
3	Lab 1	Proportional Control
4	Tutorial	Tutorial 2
5,6,8	Lab 2	Digital PID Control Design (No lab or tutorial in Week 7)
9	Tutorial	Tutorial 3
10	Tutorial	Tutorial 4
11-12	Lab 3	State Feedback Position Control and Observer Design
13	Tutorial	Tutorial 5

University Policies

Students are reminded that they are required to adhere to all relevant university policies found in their online course shell in D2L and/or on the Senate website

Important Resources Available at Toronto Metropolitan University

- The Library provides research workshops and individual assistance. If the University is open, there is a Research Help desk on the second floor of the library, or students can use the Library's virtual research help service to speak with a librarian.
- Student Life and Learning Support offers group-based and individual help with writing, math, study skills, and transition support, as well as resources and checklists to support students as online learners.
- You can submit an Academic Consideration Request when an extenuating circumstance has occurred that has significantly impacted your ability to fulfill an academic requirement. You may always visit the Senate website and select the blue radio button on the top right hand side entitled: Academic Consideration Request (ACR) to submit this request.

  For Extenuating Circumstances, Policy 167: Academic Consideration allows for a once per semester ACR request without supporting documentation if the absence is less than 3 days in duration and is not for a final exam/final assessment. Absences more than 3 days in duration and those that involve a final exam/final assessment, require documentation. Students must notify their instructor once a request for academic consideration is submitted. See Senate Policy 167: Academic Consideration.
- If taking a remote course, familiarize yourself with the tools you will need to use for remote learning. The Remote Learning Guide for students includes guides to completing quizzes or exams in D2L Brightspace, with or without Respondus LockDown Browser and Monitor, using D2L Brightspace, joining online meetings or lectures, and collaborating with the Google Suite.
- Information on Copyright for Faculty and students.

Accessibility

- Similar to an accessibility statement, use this section to describe your commitment to making this course accessible to students with disabilities. Improving the accessibility of your course helps minimize the need for accommodation.
- Outline any technologies used in this course and any known accessibility features or barriers (if applicable).
- Describe how a student should contact you if they discover an accessibility barrier with any course materials or technologies.

Academic Accommodation Support

Academic Accommodation Support (AAS) is the university's disability services office. AAS works directly with incoming and returning students looking for help with their academic accommodations. AAS works with any student who requires academic accommodation regardless of program or course load.

- Learn more about Academic Accommodation Support.
- Learn how to register with AAS.

Academic Accommodations (for students with disabilities) and Academic Consideration (for students faced with extenuating circumstances that can include short-term health issues) are governed by two different university policies. Learn more about Academic Accommodations versus Academic Consideration and how to access each.

Wellbeing Support

At Toronto Metropolitan University, we recognize that things can come up throughout the term that may interfere with a student's ability to succeed in their coursework. These circumstances are outside of one's control and can have a serious impact on physical and mental well-being. Seeking help can be a challenge, especially in those times of crisis.

If you are experiencing a mental health crisis, please call 911 and go to the nearest hospital emergency room. You can also access these outside resources at anytime:

- **Distress Line:**24/7 line for if you are in crisis, feeling suicidal or in need of emotional support (phone: 416-408-4357)
- **Good2Talk:**24/7-hour line for postsecondary students (phone: 1-866-925-5454)
- **Keep.meSAFE:** 24/7 access to confidential support through counsellors via My SSP app or 1-844-451-9700

If non-crisis support is needed, you can access these campus resources:

- **Centre for Student Development and Counselling:** 416-979-5195 or email csdc@torontomu.ca
- **Consent Comes First - Office of Sexual Violence Support and Education:** 416-919-5000 ext 3596 or email osvse@torontomu.ca
- **Medical Centre:** call (416) 979-5070 to book an appointment

We encourage all Toronto Metropolitan University community members to access available resources to ensure support is reachable. You can find more resources available through the Toronto Metropolitan University Mental Health and Wellbeing website.