Toronto Metropolitan University

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

Course Outline (F2025)

ELE809: Digital Control System Design

Instructor(s)	Dr. Mohamad Shahab [Coordinator] Office: ENG451 Phone: (416) 979-5000 x 556686 Email: mshahab@torontomu.ca Office Hours: 2-4 PM on Mondays or by appointment
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. Fadali and Visioli, "Digital Control Engineering," 2nd Edition, Academic Press (Elsevier), 2013. **Note**:E-book available online through TMU Library. Check the course shell on D2L (https://courses.torontomu.ca/) for more information on accessing the e-book. According to the textbook's publisher, purchasing options include both print & e-book versions of the textbook with costs between C$100-C$160. 2. ELE809 Laboratory Manual. Available through D2L.
Reference Text(s):	1. Phillips, Nagle and Chakrabortty, "Digital Control System Analysis and Design," 4th Edition, Pearson, 2015. 2. Franklin, Powell and Workman, "Digital Control of Dynamic Systems," 3rd Edition, Pearson, 1997.
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. Digital control systems require a detailed understanding of the system dynamics. Use mathematical models (differential equations, and transfer functions) to represent real-world systems accurately and convert from analog to digital for controlling purposes. (**1d**)

2. Develop mathematical models using state-space representations for digital control systems design. The design involves setting performance objectives, such as stability, accuracy, speed, and robustness, tailored to specific applications like aerospace, automotive, robotics, or industrial automation. Digital systems process discrete signals. Designing digital controllers involves handling sampling, aliasing, quantization, and computational constraints, which require an understanding of digital signal processing. Balance idealized mathematical designs with physical realities, such as nonlinearities, delays, and actuator limits. (**2b**)
3. Feedback is central to control systems. Design and analyze feedback loops to ensure desired system performance while mitigating the effects of noise, disturbances, and uncertainties. Depending on complexity, design digital PID controller and digital state feedback controllers with and without disturbance. (**4b**)
4. Design and implement a digital controller using MATLAB to control a DC motor. Implementation involves interfacing with hardware like microcontrollers, which meet real-world constraints like power, size, and environmental conditions. (**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 Assistants

- Tafan Ali [tafan.ali@torontomu.ca] for Section 1
- Esraa Alaa Aldeen [esraa.alaaaldeen@torontomu.ca] for Section 2
- Muhammad Shaheer Khan [muhammadshaheer.khan@torontomu.ca] for Section 3

Course Evaluation

Theory	
Quizzes	5 %
Mid-term exam	20 %
Final exam	50 %
Laboratory	
Lab work (5%+10%+10%)	25 %
TOTAL:	100 %

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

- Check the lab/tutorial schedule for the quizzes' scheduling.
- The **Mid-term Exam** will be in Week 6, on Tuesday, 07 October 2025, during the lecture time. Details will be announced on D2L (https://courses.torontomu.ca/) and during class.
- The **Final Exam** will be held during the university's final examination period. The duration will be 3 hours. The final exam covers all course material.

	• All quizzes and exams are closed-book examinations. A formula/cheat sheet is allowed during the mid-term and final exams. Instructions for this will be announced on D2L (https://courses.torontomu.ca/) and in class.
Other Evaluation Information	Information about Prelab and Lab reports requirements and submissions is provided in the Lab manual. Check the lab/tutorial schedule for submission due dates. Late submissions will incur a penalty. Lab/tutorial attendance is mandatory. Each student must attend the lab/tutorial session on the day and at the time specified for their section.
Teaching Methods	• Lectures are held in person in the designated classroom and on the specified day and time. • Lecture slides as well as lab material are uploaded to the course shell on D2L (https://courses.torontomu.ca/). • During lectures, the slides will be expanded with additional notes. • Laboratory sessions include practicing & writing MATLAB codes and implementing on a DC motor module in the designated laboratory room. • Practice problems will be provided.
Other Information	Announcements, including exam/quiz information, will be announced in class and posted to the course shell on D2L (https://courses.torontomu.ca). Email policy: In accordance with the Policy on TMU Student E-mail Accounts (Policy 157), the university requires that any electronic communication by students to TMU faculty or staff be sent from their official university email account. Use of GenAI: Students may use Generative AI (e.g. ChatGPT, Grammarly, Perplexity) **only** for minor grammar correction. This includes translating individual words and correcting spelling, punctuation and basic grammar issues. Failure to stay within these limits will be considered a breach of Policy 60.

Course Content

Week	Hours	Chapters / Section	Topic, description
1	1	Ch. 1 & Lecture slides	**Introduction:** Comparison of digital and analog control systems, overview of the control problem and design approach
1-2	3	Ch. 2, 3 & Lecture slides	**Mathematical Models for Discrete-Time Systems:** Linear difference equations, z-transform and its properties, discrete transfer function, systems with delay
2-3	3	Ch. 2, 3, 12.2 & Lecture slides	**Sampling and Reconstruction of Continuous-Time Signals:** Sample-and-hold, spectrum of sampled signals, sampling theorem, aliasing, data reconstruction, sample rate selection

3-4	4	Ch. 3, 4 & Lecture slides	**Analysis of Discrete-Time Signals and Systems:** Discrete-time signals, response of discrete-time systems, stability analysis, Jury test, transient and steady state characteristics
4-5	4	Ch. 6, 5.5, 12.4 & Lecture slides	**Control 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, frequency domain design
6			*[Mid-term Exam in Week 6]*
7-10	10	Ch. 7, 8 (excluding 7.4.1, 7.4.2, 8.7) & Lecture slides	**State-Space System Models:** Concept of state variables, state vector, state-space equations, modeling of physical systems using state-space models, stability, discrete-time state-space models, controllability, observability, similarity transformation, canonical forms, linearization of nonlinear systems
10-12	8	Ch. 9 (excluding 9.2.5) & Lecture slides	**State-Space based Design:** State feedback control, pole placement technique, state estimator and observer design, servo control problem, disturbance rejection, actuator and sensor delays
13	3	Ch. 10.4, 12.1 & Lecture slides	**Other topics in digital control:** Intro to optimal control/LQR, Intro to system identification and adaptive control, implementation and practical considerations

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

Week	L/T/A	Description
1	n/a	no lab/tutorial
2	T	Tutorial 1
3	L	Experiment 1: Proportional Control *[Prelab 1 due before session]*

4	T	Tutorial 2 - Quiz 1 *[Lab 1 report due before session]*
5	T	Tutorial 3
6	n/a	no lab/tutorial (Mid-term Exam in Week 6)
7	L	Experiment 2: Digital PID Control Design
8	L	Experiment 2 (continued) *[Prelab 2 due before session]*
9	L	Experiment 2 (continued)
10	T	Tutorial 4 - Quiz 2 *[Lab 2 report due before session]*
11	L	Experiment 3: State Feedback Position Control and Observer Design *[Prelab 3 due before session]*
12	L	Experiment 3 (continued)
13	T	Tutorial 5 *[Lab 3 report due before session]*

University Policies & Important Information

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

Refer to the Departmental FAQ page for furhter information on common questions.

Important Resources Available at Toronto Metropolitan University

- The University Libraries provide research workshops and individual consultation appointments. There is a drop-in Research Help desk on the second floor of the library, and students can use the Library's virtual research help service to speak with a librarian, or book an appointment to meet in person or online.

- 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, always require documentation. Students must notify their faculty/contract lecturer once a request for academic consideration is submitted. See Senate Policy 167: Academic Consideration.

  Longer absences are not addressed through Policy 167 and should be discussed with your Chair/Director/Program to be advised on next steps.

- FAQs Academic Considerations and Appeals
- Information on Copyright for Faculty/Contract Lecturers and students.

Lab Safety (if applicable)

Students are to strictly adhere and follow:

a. The Lab Safety information/guidelines posted in the respective labs,
b. provided in their respective lab handouts, and
c. instructions provided by the Teaching Assistants/Course instructors/Technical Staff.

During the lab sessions, to avoid tripping hazards, the area around the lab stations should not be surrounded by bags, backpacks etc, students should place their bags, backpacks etc against the walls of the labs and/or away from their lab stations in such a way that it avoids tripping hazards.

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.
- Learn about Policy 159: Academic Accommodation of Students with Disabilities

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.