Toronto Metropolitan University

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

Course Outline (W2024)

ELE639: Controls Systems

Instructor(s)	Dr. Gosha Zywno [Coordinator] Office: ENG463 Phone: (416) 979-5000 x 556105 Email: gzywno@torontomu.ca Office Hours: Tuesdays, 4:30 - 6:00 pm, Wednesdays, 4:30 - 6:00 pm (Virtual)
Calendar Description	Introductory course in control theory: system modeling, simulation, analysis and controller design. Description of linear, time-invariant, continuous time systems, differential equations, transfer function representation, block diagrams and signal flows. System dynamic properties in time and frequency domains, performance specifications. Basic properties of feedback. Stability analysis: Routh-Hurwitz criterion, Root Locus method, Bode gain and phase margins, Nyquist criterion. Classical controller design in time and frequency domain: lead, lag, lead-lag compensation, rate feedback, PID controller. Laboratory work consists of experiments with a DSP-based, computer-controlled servomotor positioning system, and MATLAB and Simulink assignments, reinforcing analytical concepts and design procedures.
Prerequisites	ELE 532 and CEN 199
Antirequisites	None
Corerequisites	None
Compulsory Text(s):	1. ELE639: Lecture Notes, the lecture notes are available from the secure course website as PDF downloadable files. 2. MATLAB User Manual (including Control Systems Toolbox and Simulink) the Mathworks, Inc., Copyright 1995-2024, available for download on the Departmental Network as Matlab help files.
Reference Text(s):	1. Control Systems Engineering, Norman S. Nise, 8th edition 2019, Wiley Inc.
Learning Objectives (Indicators)	At the end of this course, the successful student will be able to: 1. Demonstrates competency in modeling and analysis of a SISO, continuous, LTI control system in a single feedback loop configuration, including specific tasks of defining a system analytical description, its stability and its dynamic response. Uses relevant computer simulation software, MATLAB and Simulink. Identifies and carries out steps required in performing system stability and dynamic response analysis. (**2b**) 2. Implements a PID controller on a real-time control system (servomotor), including obtaining experimental data. Applies the control theory learned to predict performance of the PID-controlled servomotor. (**3a**) 3. Describes the differences between theoretical (linear) model and the implemented design on a real-life system. Assesses accuracy of the results, verifying experimental data and explaining sources of possible discrepancies. (**3b**)

4. Identifies and carries out steps required in designing an in-the-loop controller (PID and Lead-Lag) for a low order LTI system in order to meet a set of specifications. (**4b**), (**4a**)
5. Evaluates the chosen controller design by verifying its performance against a set of criteria, is able to explain differences between expected and actual results. (**4c**)
6. Demonstrates proficiency in the use of high-performance engineering modeling and analysis software, including Matlab, Control Systems Toolbox and Simulink, for control system analysis and design, in this course and for subsequent engineering practice. (**5a**)
7. Accomplishes several tasks requiring efficiency in managing own time and tasks to achieve individual and team goals, including meeting various deadlines. (**6b**), (**6a**)
8. Produces a professionally prepared technical report using appropriate format, grammar, and citation styles, with figures and tables chosen to illustrate points made, with appropriate size, labels and references in the body of the report. Reports are graded on correctness, completeness, grammar, quality of graphics and layout. (**7a**)
9. Responds appropriately to verbal questions from instructors, formulating and expressing ideas, using appropriate technical terminology - assessed through comprehensive lab interviews. (**7b**)
10. Knows the role of the engineer in society, including responsibility for protecting the public interest (**8b**)

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
1.5 hours of lab per week for 12 weeks
0.0 hours of tutorial per week for 12 weeks

Teaching Assistants

Shahab Ghorbani, B.Sc., M.A.Sc. Ph.D. (shahab.ghorbani@torontomu.ca)
Sina Soleymanpour, B.Sc., M.A.Sc. Ph.D. Candidate
(sina.soleymanpour@torontomu.ca)
Ali Nazari, B.Sc., M.A.Sc. Ph.D. Candidate
(ali.nazari@torontomu.ca)

Course Evaluation

Theory	
Quizzes	13 %
Midterm Exam	22 %
Final Exam	40 %
Laboratory	
Lab Projects	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

Mid-term test: Week 7, Wednesday, February 28, 2024 (Date to be confirmed). It will be conducted online, as a take-home test, with individual versions, problem-solving questions, to be uploaded to D2L using Assignments feature. It covers Weeks 1 to 6.

	The final exam will be scheduled during the exam period, three hours duration. The exam is comprehensive, but with emphasis on the design aspects of the course, and is closed-book.
Other Evaluation Information	Please note that the three labs are of different weights: 7%, 9% and 9%, respectively. Course evaluation includes both individual effort (midterm, final exam, D2L quizzes) and group work (lab reports, group activities). In order for a student to pass a course with "Theory and Laboratory" components, in addition to earning a minimum overall course mark of 50%, 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.
Teaching Methods	ELE639 lecture will be delivered in person. Classes are: Mondays (12:10 - 1:00 pm) in DSQ23, and Wednesdays (8:10 - 10:00 am) in DSQ10. All lab sessions are scheduled in person in ENG413.
Other Information	1. All students shall adhere to the rules of Academic Integrity, and shall acquaint themselves with the Student Code of Academic Conduct and all other relevant policies. All relevant university policies found on Toronto Metropolitan University (TMU) Senate website: http://torontomu.ca/senate/course-outline-policies. Any suspected breach of Academic Integrity such as cheating or plagiarism will be investigated with the participation of the Academic Integrity Officer. Please check the course D2L website for more information on current policies. 2. In accordance with the Policy on TMU Student E-mail Accounts (Policy 157), TMU requires that any electronic communication by students to TMU faculty or staff be sent from their official TMU email account. 3. There are three projects to be completed in the lab - two computer simulation projects (SIMULINK & Matlab) and a real-time control experiment with a servomotor. The first two lab projects (simulations) focus on the stability and performance analysis on the PID Controller, and the third project is the feedback control design of the DC servo motor system in the Control Systems Lab (ENG413). In simulation projects, students will work with unique data sets that are frequently modified. Labs 1 & 2 are to be completed in pairs. Lab 3 is to be completed in groups of four. Simulation projects (Lab 1 & 2, and Part A of Lab 3) are expected to be completed mostly outside the lab. For the real-time experiment in the Controls Lab (Part B of Lab 3), students have to take measurements on the servo that is only accessible during scheduled lab hours in ENG413. All partners shall contribute equally to the lab reports. All lab reports have to be uploaded to D2L via Assignment feature before the start of the lab session when the report is due. 4. Please note that the lab report marks may be adjusted at the end of the course to equalize differences between sections and different Teaching Assistants' grading styles. 5. All of the required course-specific written reports will be assessed not only on their technical/academic merit, but also on the communication skills exhibited through these reports. 6. All assignment and lab/tutorial reports must have the standard cover page which must be signed by the student(s) prior to submission of the work. Submissions without the cover page will not be accepted. Cover pages for each ELE639 lab experiment can be downloaded from the course D2L shell. Students can also use a Standard Assignment/Lab Cover Page found on the departmental web site.

Course Content

Week	Hours	Chapters / Section	Topic, description

Week 1	3	Chapter 1	Goals for the course and course logistics. Review of terminology, objectives, and control system analysis/design procedures. General concepts of feedback and control - open vs. closed loop systems. Introduction to Matlab & Simulink. Models: transfer functions & block diagrams. Laplace Transform review (ELE532).
Week 2	3	Chapter 2	System stability, Routh Array, Routh-Hurwitz Criterion.
Week 3	3	Chapter 3	Models: block diagrams vs. signal flow graphs. Masons Gain.
Week 4	3	Chapter 4, 5	Step response specifications. Time domain analysis. Steady state errors.
Week 5	3	Chapters 6, 7	Time domain analysis - transient response of 1st and 2nd order systems. Standard second order model. Higher order dynamics, dominant poles, reduced order models.
Week 6	3	Chapters 8, 9	System control in time domain - classical three mode controller - characteristics of P, PD, PI and PID control. PID Controller tuning. Top-down design of a simple controller (PD, PI, lead).
Week 7	3	Review	Review. Midterm Test.
Week 8	3	Chapter 10	Root locus method of system analysis, Proportional Control design from Root Locus plot - choosing gain.
Week 9	3	Chapter 10	Root locus method of system analysis continued. PID Controller design from Root Locus plot - choosing gain and time constants.
Week 10	3	Chapter 11, 12	Stability in frequency domain: gain and phase margins. Polar plots. Frequency response of a closed loop system. Closed loop second order model in frequency domain. Phase margin of a second order system.
Week 11	3	Chapter 12, 13	Correlation between frequency response and time domain response as a basis of frequency response design. Controller design in frequency domain: lead controllers.

Week 12	3	Chapter 13	Controller design in frequency domain: lag and lead-lag controllers.
Week 13	3	Review	Course wrap-up, review, Q & A, review of past exams. What next? Overview of contemporary trends in control.

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

Week	L/T/A	Description
2, 3	Lab 1	Simulation Project: Stability of Control Systems under Proportional, PI and PD Control. Two 1.5-hours sessions + extra time outside the lab as required. Individual data sets assigned to lab partners. Simulink simulations to analyze system stability under P, PD & PI Control.
4, 5, 6, 7	Lab 2	Simulation Project: Performance of Control Systems under P Control, PD Control and PI Control. Four 1.5-hours sessions + extra time outside the lab as required. Individual data sets assigned to lab partners. Simulink simulation to analyze the system response under P, PI, PD and PID Control.
8,9,10,11	Lab 3	Simulation & Real-Time Project: Control of a Servo Positioning System. Four 1.5-hours sessions + extra time outside the lab as required. Creating the simulation and tuning the PID Controller for a DC Servo. Investigating the effect of nonlinearities on the system operation, Anti-Windup Control all simulation. Next, introduction to Real-Time Control Interface, setting up data collection protocols, tuning the PID Controller on the real servomechanism. Investigating the real-time effect of nonlinearities on the system operation, Anti-Windup Control on real-time servo.

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 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 a student is requesting accommodation due to a religious, Aboriginal and/or spiritual observance, they must submit their request via the online Academic Consideration Request (ACR) system **within the first two weeks of the class or, for a final examination, within two weeks of the posting of the examination schedule**. If the required absence occurs within the first two weeks of classes, or the dates are not known well in advance as they are linked to other conditions, these requests should be submitted with as much lead time as possible in advance of the required absence.

- 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.