

Course Outline (W2025)

ELE639: Controls Systems

| | |
|---|---|
| Instructor(s) | Dr. Soosan Beheshti [Coordinator] Office: ENG425 Phone: (416) 979-5000 x 554906 Email: soosan@torontomu.ca Office Hours: Mondays 11am-12pm |
| 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. |
| Reference Text(s): | 1. Automatic Control Systems, 10th edition, B.C. Kuo and F. Golnaraghi, 2017 Mc Graw Hill 2. Control Systems Engineering, Norman S. Nise, 8th edition 2019, Wiley Inc. 3. Modern Control Systems, 14th edition 2021, R. C. Dorf, R. H. Bishop Pearson Prentice Hall |
| Learning Objectives (Indicators) | At the end of this course, the successful student will be able to: <ol style="list-style-type: none"> 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) |

| | |
|--|--|
| | <ol style="list-style-type: none"> 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) <p>NOTE: Numbers in parentheses refer to the graduate attributes required by the Canadian Engineering Accreditation Board (CEAB).</p> |
|--|--|

| | |
|----------------------------|---|
| 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 | Rana Danesh, rana.danesh@torontomu.ca Lucas Krome, lucas.krome@torontomu.ca Eric Levy, eric.j.levy@torontomu.ca Shayan Sepahvand, shayan.sepahvand@torontomu.ca |
|----------------------------|--|

| Course Evaluation | <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="2" style="text-align: left;">Theory</th> </tr> </thead> <tbody> <tr> <td>Quizzes (2 x 7%)</td> <td style="text-align: right;">14 %</td> </tr> <tr> <td>Midterm Exam</td> <td style="text-align: right;">25 %</td> </tr> <tr> <td>Final Exam</td> <td style="text-align: right;">40 %</td> </tr> <tr> <th colspan="2" style="text-align: left;">Laboratory</th> </tr> <tr> <td>Labs 1 - 3 (3 x 7% in pairs)</td> <td style="text-align: right;">21 %</td> </tr> <tr> <td>TOTAL:</td> <td style="text-align: right;">100 %</td> </tr> </tbody> </table> <p>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).</p> | Theory | | Quizzes (2 x 7%) | 14 % | Midterm Exam | 25 % | Final Exam | 40 % | Laboratory | | Labs 1 - 3 (3 x 7% in pairs) | 21 % | TOTAL: | 100 % |
|------------------------------|--|---------------|--|------------------|------|--------------|------|------------|------|-------------------|--|------------------------------|------|---------------|--------------|
| Theory | | | | | | | | | | | | | | | |
| Quizzes (2 x 7%) | 14 % | | | | | | | | | | | | | | |
| Midterm Exam | 25 % | | | | | | | | | | | | | | |
| Final Exam | 40 % | | | | | | | | | | | | | | |
| Laboratory | | | | | | | | | | | | | | | |
| Labs 1 - 3 (3 x 7% in pairs) | 21 % | | | | | | | | | | | | | | |
| TOTAL: | 100 % | | | | | | | | | | | | | | |

| | |
|---------------------|--|
| Examinations | <p>-Quizzes are scheduled on Weeks 4 and 11, approximately 50 minutes, during the first hour of the regular lecture hours: Quiz 1 on January 29 and Quiz 2 on March 26.</p> <p>-Midterm Exam is in Week 7, February 26, two and half hours, problem-solving, during the regular lecture hours (covers Weeks 1-6 of lecture notes).</p> <p>- Final Exam is scheduled during the Fall 2024 term undergraduate exam period (covers Weeks 1-13 with emphasis on Weeks 6, 8-13 of lecture notes).</p> |
|---------------------|--|

| | |
|--|---|
| <p>Other Evaluation Information</p> | <p>Lab marks are based on attendance, successful completion of pre-lab problems, participation, and completion of experiment steps, lab interviews, and lab reports. Students will have the responsibility to achieve a working knowledge of the software packages that will be used in the lab. Students will work in groups of two or as assigned by their TA. Lab Attendance and demonstrating your work to the TA is mandatory.</p> |
| <p>Teaching Methods</p> | <ul style="list-style-type: none"> - In person lectures are in DCC204 Wednesdays 3-6pm. - PDF version of the lecture notes will be posted before the lecture. The purpose of uploading the notes before the lecture is for the students to have a copy of the lecture in front of them during the lecture. For efficient learning of the topic, having the lecture notes are highly recommended. - All lab sessions are scheduled in person in ENG413. |
| <p>Other Information</p> | <ul style="list-style-type: none"> - 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. Please have the course code ELE639 in the title of your email and cc your TA for Lab related communications. - There are three lab projects. All partners shall contribute equally to the lab reports. All lab reports have to be uploaded to D2L via Assignment feature and in a pdf format before the start of the lab session when the report is due. - All assignment and lab/tutorial reports must have the standard cover page 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. - Practice Problems/Assignments: Assignment problems and solutions will be provided on D2L. The assignments will neither be collected nor graded; they are provided only as a study guide. You are strongly recommended to attempt to solve the problems on your own without looking at the solutions first. If you have any questions about an assignment problem or its solution, please consult the course instructor or the teaching assistant during their consulting hours. |

Course Content

| Week | Hours | Chapters / Section | Topic, description |
|--------|-------|--------------------|--|
| Week 1 | 3 | | Information session, introduction, and general concepts of feedback and control. Laplace Transform, Differential Equations - Review from BME532 |

| | | | |
|------------|---|--|---|
| Week 2 | 3 | | Transfer functions, Block diagrams, Signal flow graphs, State Diagram |
| Week 3 | 3 | | Mason's Gain (SFG gain formula), State Diagram (cont.), SFG and initial conditions, Modeling physical systems |
| Week 4 | 3 | | Quiz1, Stability of LIT systems, Relative stability, Routh-Hurwitz criterion, Steady-state- error analysis |
| Weeks 5 &6 | 6 | | Time domain analysis (transient response specifications), Transient response of 1st and 2nd order systems. Standard second order model. Higher order dynamics, pole-zero cancellation, dominant poles, reduced order models |
| Week 7 | 3 | | Midterm |
| Week 8 | 3 | | Root locus method of system analysis in Laplace domain |
| Week 9 | 3 | | System frequency Response, Correlation of frequency and time domain, open and closed loop frequency response, Bode Plot, Gain and phase margins, relative stability |
| Week 10 | 3 | | Polar plots, Nyquist Criterion, Nyquist criterion in relation with Root loci |
| Week 11 | 3 | | Quiz 2, Fundamental principles of PID controllers design, Ziegler-Nichols PID tuning formula |
| Week 12 | 3 | | Controller design in the frequency domain: lead design & lag design controllers. |
| Week 13 | 3 | | lag and lead-lag controllers. Final Exam Review |

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

| Week | L/T/A | Description |
|------------|-------|---|
| 2,3,4 | L/T | Lab1: Introduction to Simulink, Open-Loop vs. Closed-Loop, Transient Response and Stability |
| 5,6,7,8 | L/T | Lab 2: Open-Loop vs. Closed-Loop (second and higher order systems), Root Locus in Matlab, Modeling DC motor |
| 9,10,11,12 | L/T | Lab 3: Simulation & Real-Time Project: Control of a Servo Positioning System. PID controller. 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 further 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 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.