ELE639: Controls Systems

Instructor(s)
- Gosha Zywno [Coordinator]
  - Office: ENG463
  - Phone: (416) 979-5000 x 6105
  - Email: gzywno@ryerson.ca
  - Office Hours: Tue 2:15-4:15 pm, Thur 4:15-5:15 pm

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

Corequisites
- None

Compulsory Text(s):
1. ELE639: Course Notes, by M.S. Zywno, PhD, Copyright 2019. The notes are available from the secure course website as PDF downloadable files. Solutions manual is also available for download (login: https://my.ryerson.ca)

Reference Text(s):
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)

**NOTE:** Numbers in parentheses refer to the graduate attributes required by the Canadian Engineering Accreditation Board (CEAB).

<table>
<thead>
<tr>
<th>Course Evaluation</th>
<th>Theory</th>
<th>8 %</th>
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<tbody>
<tr>
<td></td>
<td>Course Activities</td>
<td>8 %</td>
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<td></td>
<td>Term Test</td>
<td>22 %</td>
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<td></td>
<td>Final Exam</td>
<td>45 %</td>
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<tr>
<td>Laboratory</td>
<td>Lab Projects</td>
<td>25 %</td>
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<td>TOTAL:</td>
<td>100 %</td>
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**Examinations**

- One mid-term test will be scheduled (date TBA): 90 minutes, problem-solving type, closed book.
- The final exam will be scheduled during exam period: three hours, problem-solving type, closed book. The exam is comprehensive, but with emphasis on the design aspects of the course.

**Other Evaluation Information**

- Please note that the three labs are of different weight: 7%, 9% and 9%, respectively.
- Course evaluation includes both individual effort (term test, final exam and quizzes) and group work (lab reports, homework).
- Course activities are part of the ongoing and semester-long evaluation: there are graded activities in every week of classes.
- The graded Course Activities include individual in-class assessments (iClicker quizzes), and design-type homework assignments.
1. All students shall adhere to the rules of Academic Integrity, and shall acquaint themselves with the Student Code of Academic Conduct. Any suspected breach of Academic Integrity such as cheating or plagiarism, will be investigated with the participation of the Academic Integrity Officer.

2. 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. In the simulation projects students will work with non-repeating data sets that are updated each year - the project will be completed in pairs. Please note that the simulation projects can be completed outside the lab.

The real-time control experiment will be completed in groups of three. Please note that this experiment can only be completed in the lab, and that no extra lab access hours are available.

3. All partners shall contribute equally to the lab reports. When submitting a lab report, students will be interviewed by lab instructors with questions relevant to the completed project. As well, partners will be asked to describe their contributions. Any student found not to have adequately contributed to the project, will be asked to re-do the project on their own.

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 students registered in ELE639 are expected to participate throughout the course in Course Activities that will support their understanding of the course material. They will include answering questions using iClickers, working on a problem in small groups, completing take-home assignments, etc., for which they will be earning Course Activity Points. All students are expected to purchase iClickers, or download an equivalent app for a tablet/mobile, and to use them during class quizzes.

Course Activities are worth 8% of the final grade. Activities will take place every week. There are no make-up arrangements for the missed Course Activities.

### Course Content

<table>
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<tr>
<th>Week</th>
<th>Hours</th>
<th>Chapters / Section</th>
<th>Topic, description</th>
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<tbody>
<tr>
<td>Week 1</td>
<td>3</td>
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<td>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 and Simulink. Models: transfer functions and block diagrams. Laplace Transform review (ELE532) (Chapter 1)</td>
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<td>Week 2</td>
<td>2</td>
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<td>System stability Routh Array Routh-Hurwitz Criterion (Chapter 2)</td>
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<td>Week 2 and 3</td>
<td>4</td>
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<td>Models: block diagrams vs. signal flow graphs. Mason's Gain. (Chapter 3)</td>
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<td>Week 4</td>
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<td>Step response specifications. Time domain analysis. Steady state errors. (Chapters 4 5)</td>
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<td>Week 5</td>
<td>3</td>
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<td>Time domain analysis - transient response of 1st and 2nd order systems. Standard second order model. Higher order dynamics dominant poles reduced order models. (Chapters 6 7 8)</td>
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<td>Week 6</td>
<td>3</td>
<td>System control in time domain - classical three mode controller - characteristics of P PD PI and PID control. PID Controller tuning Top-down design of simple controller (PD PI lead). (Chapters 8 9)</td>
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<td>Week 7 and 8</td>
<td>6</td>
<td>Root locus method of system analysis Proportional Control design from Root Locus plot - choosing gain. PID Controller design from Root Locus plot - choosing gain and time constants. (Chapter 10)</td>
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<tr>
<td>Week 9 and 10</td>
<td>6</td>
<td>Stability in frequency domain: gain and phase margins. Polar plots and Nyquist criterion. Frequency response of a closed loop system. Closed loop second order model in frequency domain. PHase margin of second order system. (Chapters 11 12)</td>
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<td>Week 11 and 12</td>
<td>6</td>
<td>Correlation between frequency response and time domain response as a basis of frequency response design. Controller design in frequency domain: lead lag and lead-lag controllers. Chapter 13)</td>
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<td>Week 13</td>
<td>3</td>
<td>What next? Overview of contemporary trends in control. Course wrap-up review questions and answers review of past exams.</td>
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Policies & Important Information:

1. Students are required to obtain and maintain a Ryerson e-mail account for timely communications between the instructor and the students;
2. Any changes in the course outline, test dates, marking or evaluation will be discussed in class prior to being implemented;
3. Assignments, projects, reports and other deadline-bound course assessment components handed in past the due date will receive a mark of ZERO, unless otherwise stated. Marking information will be made available at the time when such course assessment components are announced.
4. If you have taken the course previously and are currently looking to get a laboratory exemption, then you must fill out this form: http://www.ee.ryerson.ca/guides/ECE-LabExemptionForm.pdf
5. Refer to our Departmental FAQ page for information on common questions and issues at the following link: https://www.ryerson.ca/academicintegrity/.

Missed Classes and/or Evaluations

When possible, students are required to inform their instructors of any situation which arises during the semester which may have an adverse effect upon their academic performance, and must request any consideration and accommodation according to the relevant policies as far in advance as possible. Failure to do so may jeopardize any academic appeals.

1. Health certificates - If a student misses the deadline for submitting an assignment, or the date of an exam or other evaluation component for health reasons, they should notify their instructor as soon as possible, and submit a Ryerson Student Health Certificate AND an Academic Consideration Request form within 3 working days of the missed date. Both documents are available at https://www.ryerson.ca/senate/forms/medical.pdf. If you are a full-time or part-time degree student, then you submit your forms to your own program department or school;
2. Religious, Aboriginal and Spiritual observance - If a student needs accommodation because of religious, Aboriginal or spiritual observance, they must submit a Request for Accommodation of Student Religious, Aboriginal and Spiritual Observance AND an Academic Consideration Request form within the first 2 weeks of the class or, for a final examination, within 2 weeks of the posting of the examination schedule. If the requested absence occurs within the first 2 weeks of classes, or the dates are not known well in advance as they are linked to other conditions, these forms should be submitted with as much lead time as possible in advance of the absence. Both documents are available at www.ryerson.ca/senate/forms/relobserverforminstr.pdf. If you are a full-time or part-time degree student, then you submit the forms to your own program department or school;
3. Academic Accommodation Support - Before the first graded work is due, students registered with the Academic Accommodation Support office (AAS - www.ryerson.ca/studentlearningsupport/academic-accommodation-support) should provide their instructors with an Academic Accommodation letter that describes their academic accommodation plan.

Academic Integrity

Ryerson's Policy 60 (the Academic Integrity policy) applies to all students at the University. Forms of academic misconduct include plagiarism, cheating, supplying false information to the University, and other acts. The most common form of academic misconduct is plagiarism - a serious academic offence, with potentially severe penalties and other consequences. It is expected, therefore, that all examinations and work submitted for evaluation and course credit will be the product of each student's individual effort (or an authorized group of students). Submitting the same work for credit to more than one course, without instructor approval, can also be considered a form of plagiarism.

Suspicion of academic misconduct may be referred to the Academic Integrity Office (AIO). Students who are found to have committed academic misconduct will have a Disciplinary Notation (DN) placed on their academic record (not on their transcript) and will normally be assigned one or more of the following penalties:

1. A grade reduction for the work, ranging up to an including a zero on the work (minimum penalty for graduate work is a zero on the work);
2. A grade reduction in the course greater than a zero on the work. (Note that this penalty can only be applied to course components worth 10% or less, and any additional penalty cannot exceed 10% of the final course grade. Students must be given prior notice that such a penalty will be assigned (e.g. in the course outline or on the assignment handout);
3. An F in the course;
4. More serious penalties up to and including expulsion from the University.

The unauthorized use of intellectual property of others, including your professor, for distribution, sale, or profit is expressly prohibited, in accordance with Policy 60 (Sections 2.8 and 2.10). Intellectual property includes, but is not limited to:

1. Slides
2. Lecture notes
3. Presentation materials used in and outside of class
4. Lab manuals
5. Course packs
6. Exams

For more detailed information on these issues, please refer to the Academic Integrity policy (https://www.ryerson.ca/senate/policies/pol60.pdf) and to the Academic Integrity Office website (https://www.ryerson.ca/academicintegrity/).

Important Resources Available at Ryerson
1. The Library (https://library.ryerson.ca/) provides research workshops and individual assistance. Inquire at the Reference Desk on the second floor of the library, or go to library.ryerson.ca/guides/workshops.

2. Student Learning Support (https://www.ryerson.ca/studentlearningsupport) offers group-based and individual help with writing, math, study skills and transition support, and other issues.