Université Concordia University

Department of Electrical & Computer Engineering
Concordia University

ELEC 372: Fundamentals of Control Systems

Fall 2017

Lectures: Mondays and Wednesdays: 10:15 am – 11:30 am; Location: FG B040

Tutorials: Section RA: Tuesdays, 11:45 am – 12:35 pm; Location: H 562
Section RB: Mondays, 8:45 am – 9:35 am; Location: H 562

Instructor: Dr. Rastko Selmic (rastko.selmic@concordia.ca)

Office Hours: Mondays and Wednesdays: 1:00 pm – 2:00 pm; Location: EV5.169

Teaching Assist.: Maryam Abdollahi (mariam.abdollahi@gmail.com)
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URL: http://users.encs.concordia.ca/~rselmic/elec372

Description:
Mathematical modeling. Transfer functions and signal-flow graphs. Analysis and design of linear feedback control systems. State-variable analysis. Time domain analysis and design of linear control systems. Frequency domain analysis and design of linear control systems. Root-locus methods. Stability. Compensator design for feedback control systems.

Topics:
- Linear Systems and Linear Approximations to Nonlinear Systems; Linear Approximation of Nonlinear Systems. Laplace Transform and Inverse Laplace Transform; Simulation of Dynamic Systems Using MATLAB
- Block Diagrams and Signal-Flow Graphs; Mason's Formula
- Performance of Second Order Systems
- State variable analysis; Transfer Function From the State Equation; Time Response of Dynamical Systems
- Stability of Linear Systems; Input-Output Stability; Routh-Hurwitz Stability Test; Stability of State-Variable Systems
- Feedback Control Systems; Closed-Loop Control Systems; Sensitivity of Control Systems; Disturbance Rejection; Steady-State Error
- Root-Locus Analysis and Design of Feedback Systems; Root Locus Concept; Root Locus Examples; PID, Lead, Lag Controllers
- Frequency Domain Analysis and Design of Feedback Systems; Bode Design; Nyquist Criterion
- State-Variable Feedback; Pole Placement and Ackermann's Formula

Course Learning Outcomes (CLOs):
Upon successful completion of the course, students will be able to:
1. Model feedback control systems
2. Determine the stability of linear time-invariant systems in both time-domain and frequency-domain
3. Assess the transient response of linear time-invariant feedback control systems using both time-domain and frequency-domain techniques
4. Assess the steady-state response of linear time-invariant feedback control systems using both time-domain and frequency-domain techniques
5. Design compensators (controllers) for linear time-invariant feedback control systems using both time-domain and frequency-domain techniques

Prerequisites: Signals and Systems II (ELEC 364) or Continuous-Time Signals and Systems (ELEC 242)

Text: R.C. Dorf and R.H. Bishop, Modern Control Systems, 13th edition, Pearson, Hoboken, New Jersey, 2017, ISBN-10: 0134407628, ISBN-13: 9780134407623.

Reference Books:
1. N.S. Nise, *Control Systems Engineering*, Wiley, 2015, ISBN #: 1118170512
2. K. Ogata, *Modern Control Engineering,* Pearson, 2009, ISBN # 0136156738

Recommended Software:
MATLAB + Control Systems Toolbox

Other Course Material:
Homework, suggested problems, and other required course material will be distributed either during the lectures in classroom or posted on the Moodle system.

Tutorials:
In the scheduled tutorials, suggested problems will be solved and students' questions will be answered.

Grading Scheme:
Each student will be awarded a letter grade based on the following weighting of grades:

- Homework & Project:	5%
- Quizzes:	10%
- Lab:	15%
- Mid-term Exam:	25%
- Final Exam:	45%

The dates for the mid-term and final examinations will be announced in due course of time.

Homework:
Homework will provide hands on experiences related to the theoretical concepts covered in the class. Homework should be submitted before the start of the lectures. No late homework will be accepted. Some homework may require computer simulations using MATLAB. In case of a

simulation assignment, please plot your results and submit your documented (commented) source code.

Quizzes:
A short 15-minute quiz will follow homework submission to monitor students' learning. The quiz will be held in class prior to the lecture after the submission of the homework.

Laboratory:
Lab coordinator: Mr. Dan Li (H851-03, dan.li@concordia.ca)
The laboratory is located at H832-6. The lab manual can be downloaded from lab website http://users.encs.concordia.ca/~realtime/elec372/index.html. The lab schedule is posted on Moodle. You must attend only the lab section you are registered in.

Project:
A simulation-based project will be assigned. It can be done in groups of two students. The project will involve the analysis, design, and evaluation of a controller for a specific system. The evaluation will be based on theoretical analysis and computer simulations using MATLAB's Control System Toolbox. The project assignment will be posted on Moodle.

Course Schedule:
The following course schedule is subject to change based on the class performance. Homework and quiz schedule is tentative and will be discussed in class.

Week	Topics	Comments
Week 1	Introduction to Control Systems Sections 1.1-1.3	
Week 2	Mathematical Models of Systems and Linearization Sections 2.1 – 2.3	
Week 2	Review of the Laplace Transform and Its Inverse, IVT, FVT Section 2.4	Homework #1 assigned
Week 3	Transfer Functions and ODE Solutions Section 2.5	
Week 3	Block Diagrams and Mason's Formula Sections 2.6 – 2.7	Homework #1 due Homework #2 assigned
Week 4	State Variable Models Sections 3.1 – 3.3	Quiz #1
Week 4	From State Equations to Transfer Functions Sections 3.6 – 3.7	Homework #2 due Homework #3 assigned
Week 5	Feedback Control Systems Characteristics Sections 4.2, 4.6	Quiz #2
Week 5	Time-Domain Analysis, Second Order Systems Sections 5.1 – 5.3	Homework #3 due Homework #4 assigned
Week 6	Steady State Error, Review Section 5.6	
Week 6	**Mid term Exam**	Homework #4 due

Week 7	Stability of Linear Systems Section 6.1	
Week 7	Routh-Hurwitz Stability Test Section 6.2	Homework #5 assigned
Week 8	Root Locus Technique Sections 7.1-7.2	
Week 8	Root Locus Technique Sections 7.3-7.4	Homework #5 due Homework #6 assigned
Week 9	Frequency Response Methods Sections 8.2 – 8.4	Quiz #3
Week 9	Frequency Domain Analysis: Nyquist Criterion Sections 9.2 – 9.3	Homework #6 due Homework #7 assigned
Week 10	Frequency Domain Analysis: Nyquist Criterion Section 9.4	
Week 10	Design of Feedback Control: Lead Compensators Sections 10.3 – 10.4	Homework #7 due Homework #8 assigned
Week 11	Design of Feedback Control: Lead Compensators Section 10.5	Quiz #4
Week 11	Design of Feedback Control: Lag Compensators Section 10.8	Homework #8 due
Week 12	Design of Feedback Control: Lag Compensators Section 10.8	Homework #9 assigned
Week 12	Design of State Variable Feedback Sections 11.1-11.2	
Week 13	Design of State Variable Feedback Section 11.3	Homework #9 due
Week 13	Course Review	
Final	**To be announced by the Registrar**	

Expectations of Originality Form:
The students are required to review, complete, and submit the Expectations of Originality form: https://www.concordia.ca/encs/students/sas/expectation-originality.html

Graduate Attributes:
The courses in the engineering programs include the development of a set of graduate attributes. The attributes relevant to and covered by ELEC 372 are:

- **Problem Analysis (PA)**: Problem identification and formulation; modeling; problem solving; analysis.
- **Investigation (INV)**: Background and hypothesis formulation; designing experiments; conducting experiments and collection of data; analysis and interpretation of data.
- **Use of Engineering Tools (UET)**: Ability to use appropriate tools, techniques, and resources; demonstrate awareness of limitations of tools; create and extend tools as necessary.

The above attributes are taught and assessed throughout the course. PA attributes will be assessed using the mid-term exam, the final exam, and assigned project. INV and UET will be assessed in the lab work.

Bellman's Principle of Optimality:
An optimal policy has the property that whatever the initial state and the initial decisions are, the remaining decisions must constitute an optimal policy with regard to the state resulting from the first decision.

“If you don't do the best with what you have happened to have got, you will never do the best with what you should have had.”