THE UNIVERSITY OF BRITISH COLUMBIA

FACULTY OF APPLIED SCIENCE (Engineering)

ELEC 341: Systems and Control **Updated**: Sept, 2024

Contact Information:

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1. Calendar Entry

ELEC 341: Systems and Control (4) [4-0-0]

Continuous time system analysis by Laplace transforms; system modelling by transfer function and state space methods; feedback, stability and sensitivity; control design; frequency domain analysis.

Pre-requisite: One of {ELEC 202, ELEC 204}.
Co-requisite: None

2. Course Structure

The 13-week term comprises 1 introductory week, 1 midterm evaluation week, 10 instruction weeks, and 1 review week. A supplemental midterm exam is held during the review week, and the final exam is held during the final exam period.

Lectures are in-person and brief recordings are provided to cover bare essentials only. Office hours are online and led by TAs for 2-3 hours/week. When time permits, in-class time tutorials are also held. Piazza is made available through Canvas for student-to-student communication.

3. Course Motivation

The course provides the background to model an electro-mechanical system, and design a controller to satisfy a requirement specification. Students who successfully complete this course have the skills to identify an LTI model of an electro-mechanical system that includes black-box and white-box sub-systems such as power amplifiers, electric motors, sensors, transmissions, mechanisms, and control computers. They can develop a real-time Proportional (P), Lead (PD), Lag (PI) or Lead-Lag (PID) controller to optimize the response of the identified system. The course prepares students to solve practical control problems encountered in ELEC 391, ELEC 491 (Capstone), and industry. It provided the pre-requisite knowledge to successfully complete 4th year electro-mechanical systems and control courses including ELEC 422, 441, 442, 462, 473.

Students are expected to have a solid background in physics, statics and dynamics, linear algebra, Laplace Transforms, circuit analysis, phasors, and frequency domain analysis (Bode plots). Non-ECE students who satisfy the ELEC 204 pre-requisite may require independent study of certain topics that may not have been covered in sufficient depth. MATLAB experience is a strong asset.

4. Course Learning Outcomes

By the end of the course, students should be able to:

- Demonstrate fluency in Matlab & Simulink.
- Develop an LTI model of a linear sub-system.
- Develop a 2nd order linear approximation from a (black-box) step response.
- Model an LTI electrical sub-system in the complex frequency domain.
- Model an LTI mechanical sub-system in the complex frequency domain.
- Develop an LTI model of an electro-mechanical sub-system including motors and transmissions.
- Reduce a linear system containing junctions and loops using BD/SFG manipulation.
- Model a MIMO linear system using state-space representation.
- Design an optimal Proportional (P) controller.
- Design an optimal Lead (PD) controller.
- Design an optimal Lag (PI) controller.
- Design an optimal Lead-Lag (PID) controller.
- Heuristically tune a linear or non-linear control system using Impedance (Z) control.

5. Course Content

Course Introduction & Review (2-4 Lecture Hours)

- Course Outline
- Review of Mathematical and Electrical Pre-Requisites
- Matlab & Simulink Tutorial (time permitting)

Part 1 – System Identification (20 Lecture Hours)

- Sub-System Identification
  - Transfer Function
  - Approximate Transfer Functions
  - 2nd Order Systems
  - 2nd Order Approximations
  - Mechanical Systems
  - Electro-Mechanical Analogy
- System Identification
  - System Models
  - Motors & Transmissions
  - Block Diagrams & BD Manipulation
  - State-Space
  - State-Space Examples

Part 2 – Controller Design (20 Lecture Hours)

- Feedback Control
- Gain Margin
- Controller Identification
- Controller Delay
- Proportional/Derivative (PD) Control
- Phase Margin
- Lead (PD) Controller Design
- Lag (PI) Controller Design
- Lead-Lag (PID) Controller Design
- Impedance Control

6. Course Activities, including Evaluation and Grading

All course notes, assignments, supplement material, and exams are provided on Canvas.

Posted **Lecture Notes** are the slides used in class to supplement the discussion. They include formal examples, Matlab-generated figures, and other material. Students are expected to attend lectures, annotate the slides, and take their own notes.

Posted **Recordings** are brief videos that cover all material presented in class. They are intended to augment, but not replace, in-class lectures. Their purpose is to assist students to review lecture material, and to catch up on missed lectures. In-class lectures are not recorded.

8 Assignments are due throughout the term. All assignments are equally weighted.

A **2-Part Graded Project** must be completed. Part 1 is due mid-way through the term, and Part 2 due at the end of the term. Part 1 involves system identification. Part 2 involves controller design.

Part 1 has ½ the weighting of Part 2, but is graded twice, once when Part 1 is submitted, and a second time when Part 2 is submitted. The results from Part 1 are used in Part 2, and must be correct to receive marks for Part 2.

A **Mid-Term Exam** is held mid-way through the term. The mid-term exam covers all material in Part 1 (System Identification) of the course.

A **Final Exam** is held during the formal exam period. The final exam covers all material presented in the course. A passing grade on the final exam is required to pass the course.

Matlab Grading Scripts are provided for all assignments, projects, and exams. Students submit an automatically generated grade summary which is recorded. Students are encouraged to fix as many errors as possible before submitting their grade summary.

A **Supplemental Midterm Exam** is scheduled during the term and made available to any student that misses the midterm exam. If the supplemental midterm exam is not written, a grade of 0 is entered for the midterm exam grade. No grade re-allocations will be considered for any student. The supplemental midterm exam may not be used to improve the midterm grade.

A **Supplemental Final Exam** is scheduled in the subsequent term and made available to any student that misses the final exam. If the supplemental final exam is not written, a grade of 0 is entered for the final exam grade.

Matlab Grading Scripts are **NOT PROVIDED** for any supplemental exam. All supplemental exams are written using a lockdown browser and the online version of Matlab. Solutions are provided in an examination booklet and are graded on final answer only.

The following weighting is applied.

- Assignments 20%
- Project 20%
- Mid-Term Exam 20%
- Final Exam 40%

7. Assessment Policies

- Attendance at lectures is optional but students are responsible for all material presented.
- Any work submitted after the last day of the term is not graded.
- All work is submitted through Canvas.
- All grades posted on Canvas are unofficial.
- Each student may re-submit up to 2 assignments after the posted deadline. Grades are updated at the end of the term, and the student must have indicated on Canvas which 2 assignments they have chosen to re-submit. Projects and Exams are not eligible for re-submission.

8. Assessment Strategies and Learning Outcomes

A student's command over course material is assessed as follows.

- Lecture weeks 1-5.
  - Assignments 1-5
  - Project Part-1
  - Mid-Term Exam

- Lecture weeks 6-10.
  - Assignments 6-8
  - Project Part-2

- Lecture weeks 1-10, inclusive.
  - Final Exam

9. Texts and Bibliography (including any required materials)

- There is no required text for this course.
- The following resources are provided on Canvas:
  - Course notes
  - Supplemental material
  - Mini-lecture recordings
  - Matlab Grading scripts
  - Custom Matlab functions
  - Practice problems & exams

10. UBC Academic Honesty and Standards

The academic enterprise is founded on honesty, civility, and integrity. As members of this enterprise, all students are expected to know, understand, and follow the UBC codes of conduct regarding academic integrity. At the most basic level, this means submitting only original work done by you and acknowledging all sources of information or ideas and attributing them to others as required. This also means you should not cheat, copy, or mislead others about what is your work. Violations of academic integrity (i.e., misconduct) lead to the breakdown of the academic enterprise, and therefore serious consequences arise and harsh sanctions are imposed. For example, incidents of plagiarism or cheating may result in a mark of zero on an assignment or exam and more serious consequences may apply if the matter is referred to the President's Advisory Committee on Student Discipline. Careful records are kept in order to monitor and prevent recurrences. For more information, see:
http://www.calendar.ubc.ca/vancouver/index.cfm?tree=3,286,0,0

11. Non-Academic Misconduct

Whether you are a student, faculty member, or staff member, mistreatment towards anyone in our Engineering community is not acceptable. Mistreatment is disrespectful or unprofessional behavior that has a negative effect on you or your learning environment, or conduct that is contrary to the principles that support a respectful environment. This includes making demeaning, offensive, belittling, and disrespectful comments, using abusive language, engaging in bullying, harassment, and discrimination. If you have witnessed or been subject to mistreatment, there are people and support resources here to help. Find out how to get support or discuss an issue related to discrimination, bullying, harassment, or sexual misconduct through the non-academic misconduct link below:
https://academicservices.engineering.ubc.ca/degree-planning/non-academic-misconduct-discrimination-and-edi-i-support/

ECE students, faculty, and staff are also welcome to submit comments, suggestions, and requests around Equity, Diversity, Including and Indigeneity (EDII) in the ECE Department to our EDII Suggestion Box. Submissions can be anonymous, and are received directly by the ECE EDII.
Committee for review: https://ece.ubc.ca/engage-with-ece/edii-suggestion-box/

12. Health and Wellness

UBC provides resources to support student learning and to maintain healthy lifestyles, while recognizing that challenges and crises can arise for students. There are resources in ECE and at UBC where students can find can help and support, including wellness, equity, inclusion and indigineity, resources for survivors of sexual violence, and health. Some frequently used resources are as follows:

- ECE Wellness Hub: https://ece.ubc.ca/student-life/student-wellness/
- ECE has an EDI.I committee whose goals are to improve equity, diversity and inclusion in the ECE Department, and support the UBC Indigenous Strategic Plan. The committee welcomes feedback from all students, and can be contacted by emailing help@ece.ubc.ca.
- Central resource for supporting student success (medical and crisis support, Centre for Accessibility, and support for survivors of sexual violence): https://senate.ubc.ca/policies-resources-support-student-success/
- UBC Office of the Ombudsperson for Students: https://ombudsoffice.ubc.ca/how-we-can-help/

UBC values respect for the person and ideas of all members of the academic community. Harassment and discrimination are not tolerated nor is suppression of academic freedom. UBC provides appropriate accommodation for students with disabilities and for religious, spiritual and cultural observances. UBC values academic honesty and students are expected to acknowledge the ideas generated by others and to uphold the highest academic standards in all of their actions. Details of UBC's respectful environment policies, which all students, staff and faculty are expected to follow, can be found here: https://hr.ubc.ca/working-ubc/respectful-environment

13. Academic Concession

The University is committed to supporting students in their academic pursuits. Students may request academic concession in circumstances that may adversely affect their attendance or performance in a course or program. Students who intend to, or who as a result of circumstance must, request academic concession must notify their instructor, dean, or director as specified in the link below. https://www.calendar.ubc.ca/vancouver/index.cfm?tree=3,329,0,0

Students seeking academic concession due to absence from the final exam for any reason must apply to Engineering Academic Services (EAS) within 72 hours of the missed exam. This is a standard practice for all final examinations at UBC. For more information, see:
https://academicservices.engineering.ubc.ca/exams-grades/academic-concession/

14. Land acknowledgment

This course is held on the UBC Point Grey (Vancouver) campus, which sits on the traditional, ancestral, unceded territory of the Coast Salish Peoples, including xʷməθkʷəy̓əm (Musqueam) First Nation, Squamish, Tsleil-Waututh, Stz'uminus, and Stó:lō First Nations. UBC is implementing its Indigenous Strategic Plan, taking a leading role in the advancement of Indigenous peoples' human rights. To learn more about the Faculty of Applied Science's role in building upon the Indigenous Strategic Plan and committing to Truth and Reconciliation, please visit: https://apsc.ubc.ca/EDI.I