EEL 4657C: Linear Control Systems

1. **Course Objectives**
   EEL 4657 is an introductory course on the analysis and design of Linear Control Systems. The material presented emphasizes the classical analysis and design control systems to achieve overall system stability and acceptable performance. The class of Linear Time Invariant (LTI) Single-input Single Output (SISO) systems is of primary focus, although a more general introductory treatment is also given in terms of state space and transfer matrix representations of Multi-input Multi-output (MIMO) systems. This course is built on material covered in pre-requisite or co-requisite courses such as EEL 3112 (Electrical Circuits II) and EEL 3135 (Signals and Systems), as well as mathematical preliminaries with particular emphasis on the solution of ordinary differential equations using Laplace transform techniques. The course also exhibits control systems as a multidisciplinary subject finding applications in electrical, chemical, mechanical, biomedical, and other branches of engineering.

   The goal of the course is to provide access to the basic design and analysis tools used in practical control systems as well as to give an exposure of the student to the general area of linear systems theory which appears so very often in all branches of engineering. We consider such topics as the philosophy, benefits and costs of negative feedback, stability, robustness and performance specifications as well as system analysis and design for Single-input Single-output systems. The major tools of classical analysis, The Root Locus, the Nyquist Diagram and the associated Nyquist Stability Criterion and Bode Plots are developed and illustrated. While the main results are developed for continuous time systems using the mathematical formalism of the Laplace transform, we also provide an introductory coverage of discrete-time systems using the Z-transform. Throughout our discussion of the classical theory, we interweave hints of the more rigorous design methods of both the state-space as well as the optimal frequency domain approaches. For example, in dealing with differential equations and Laplace transforms, MIMO systems are presented as quite simple extensions of SISO systems within the state-space setting, leading naturally to the generalization of SISO transfer functions to MIMO transfer matrices. We also introduce the notion of an optimization over the set of all stabilizing controllers to attain the best possible performance or robustness measures. The treatment of these latter aspects at this point is very general and non-rigorous; the intent is purely motivational for an appreciation of more advanced material the student may encounter later.

   Lab schedules and details for the laboratory section of the class will be provide in class and online. Labs will typically begin during the second week of the semester. Matlab/Simulink will be used to integrate with laboratory velocity and position motor systems and with a ball and beam rig. Students will be required to implement Lead/Lag and PID controllers using a microprocessor students are familiar with from EEL3744 (Microprocessor Applications).

2. **Catalog Description**
   EEL 4657- Linear Control Systems - Pre-requisites: Circuits II and Signals and Systems. Theory and Design of Linear Control Systems

   Pre-requisites
   EEL 3112, EEL 3135, and EEL3744

   An undergraduate course in electrical circuits and signals and systems provides a desirable background for some of the material to be covered in the course. Specifically, it would be helpful for students to have a sound grasp of the concepts of transfer functions, time and frequency response, and Laplace Transform analysis.

   A basic knowledge of z-transforms and solving difference equations would also be helpful in the discrete-time material. In addition, matrices and linear algebra concepts will be used in the introduction of the state variables approach that is covered in this class. Knowledge of microprocessors will also be useful in implementing controlling analog controllers in digital form.

3. **Instructor**
   Haniph A. Latchman
   Office location: NEB 463
   Telephone: (352) 392-4950
   E-mail address: Latchman@list.ufl.edu
   Web site: www.list.ufl.edu

4. **Teaching Assistants**
   a. Ding-Shin Kuo   dkuo@ufl.edu
      - Office Hours: T 7-8, W 8-9, R 6-8   NEB222
   b. Ana Covic   anaswim@ufl.edu
      - Office Hours: MWF 5, T 6   NEB222
   c. Derya Tansel   derya.tansel@ufl.edu
      - Office Hours: RF 8-9   NEB222

5. **Meeting Times**
   MWF 6

6. **Class schedule**
   3 classes per week, 50 minutes each

7. **Meeting Location**
   NEB 101

8. **Material and Supply Fees**
   $160.00

9. **Textbooks and Software Required**
    a. Title: Linear Control Systems – A Neo-classical Approach (in preparation)
       Author: Haniph A. Latchman
       Publication Date:
       ISBN number:
       Available Online as pdf for all students
              Please do not place on any Internet site.

    b. Title: Analog and Digital Control System Design – A Laboratory Manual and Reference Guide
       Author: Haniph A. Latchman and Rami Okasha
       ISBN number: 9781119471851
       Available through the UF Bookstore

       Recommended
    a. Title: Modern Control Systems
       Author: R.C. Dorf and R.H. Bishop
       Publisher: Prentice Hall
       Publication Date: 2010
       Edition: 12

10. **Relationship to ABET Outcomes**
    - **Specific Outcomes of Instruction:** To understand the essentials of mathematical system modeling; to be able to assess stability and performance properties of linear systems, and be able to design lead and lag controllers for linear systems using s-domain and frequency domain techniques.
    - Outcomes Addressed by This Course: EE2, EE3, a, c, e, k (To view how the outcomes of this course fit in with the curriculum)

11. **Course Outline**
    1.0 Introduction and Background
            1.1 Open-loop Vs Closed-loop Control Systems
            1.2 Control Objectives
            1.3 Mathematical Representation of Systems
            1.4 System Classification
            1.5 Control Strategies
            1.6 History of Control Theory and Control Systems
    2.0 Linear Systems Theory and Classical Control
            2.1 Introduction
            2.2 A Motivational Example - Automotive Cruise Control
            2.3 The Laplace transform
            2.4 A State-space Approach
            2.5 A Direct Transfer Function Approach
            2.6 Transfer Function Model Standardization and Simplification
            2.7 Block Diagram Reduction
            2.8 Signal Flow Diagram and Mason's Rule
            2.9 Relationship Between Transfer Function and State-space Models

12. **Attendance and Expectations**
    Class Attendance
    Class attendance is not required but all students are responsible for all material and information disseminated during class sessions as such information may not be posted on websites or otherwise. Quizzes are administered daily, make-up quizzes are only allowed in exceptional circumstances such as documented medical emergency – these should be discussed with the Instructor.

    Assignments
    Homework and other assignments will be given periodically and will be due within the first 5 minutes of class on the designated due-date. Use regular-size paper, staple the sheets together, and put your name and homework number at the top.
    Late homework will be accepted only in exceptional circumstances which need to be discussed with the Instructor for approval. Homework assignments will not be given over the phone. Graded homework will be returned in class or during office hours.

    Exams
    The midterm exam will be given on **Wednesday, February 28th** (time and location TBA). The midterm will be closed-book and closed-notes. The final examination will be comprehensive, but with emphasis on material covered since the midterm exam.
    For the final exam, students will be allowed **one side** of one sheet of letter-sized paper, written in their own original handwriting. The date of the final exam is **Thursday, May 3rd** from 7:30 am to 9:30 am in the usual classroom. Final exams are decided by the registrar's office and can be confirmed online at http://www.registrar.ufl.edu/soc/ or specifically here.

    Labs
    Labs will be completed on a weekly basis. Your lab grade will be out of 100 and will be used to calculate your final course grade as shown under Grading. The following is a list of the lab topics. The Module Fundamentals is due for each module on the last week of that module. A quiz will be given at the beginning of each lab. The μPAD Controls Platform labs will be done at home by all students. Students will demonstrate their results during their designated lab section, and will be evaluated by their TA. At-home labs should be completed **before** coming to your lab section. Reporting to lab without being able to demonstrate will result in a 50% penalty for that lab, assuming completion by the end of the lab section.
    At the end of each module, a module report putting together the contents of all the sections of the module will be due the following week. For example, the Module Fundamentals for Module 1: Modeling is due on the third week of labs, while the Module Report for Module 1 is due on the fourth week of labs. Students will submit these assignments via Canvas.
    Late lab assignments will be accepted only in exceptional circumstances which need to be discussed with your TA for approval.

Module 1: System Modeling
    1.1: Modeling of Quanser SRV02 System
    1.2: Modeling of OOTB µPAD Controls Platform
    1.3: Model Validation Techniques using OOTB µPAD Controls Platform

Module 2: Position Control
    2.1: Step and Ramp Response of Quanser SRV02 System using PD Controller
    2.2: Step Response of OOTB µPAD Controls Platform using PD Controller
    2.3: Step and Ramp Response of OOTB µPAD Controls Platform using PID Controller

Module 3: Speed Control
    3.1: Step Response of Quanser SRV02 System using Lead Controller
    3.2: Development, Simulation, and Implementation of Lag Controller for OOTB µPAD Controls Platform
    3.3: Development, Simulation, and Implementation of Lead Controller for OOTB µPAD Controls Platform

Module 4: Cascade Control Scenarios
    4.1: Control of a Ball and Beam Using Quanser SRV02 System and Practical PD Controller
    4.2: Gyro Stabilization using OOTB µPAD Controls Platform and PID Controller

Section	Meeting Time	TA
1789	T 9-10	Ding Kuo
2F80	W 11-E1	Ana Covic
2F89	T 11-E1	Ding Kuo
2F90	R E2-E3	Derya Tansel

13. **Grading**

Coursework:
    Quizzes: 10%
    Assignments: 20%
    Midterm: 30%
    Final Exam: 40%

Lab:
    Weekly Evaluation: 10%
    Module Fundamentals: 20%
    Quizzes: 30%
    Module Reports: 40%

Total EEL 4657C grade = 0.75*(coursework grade) + 0.25*(lab grade)

14. **Grading Scale (Subject to a possible curve based on relative class performance)**
    Grades will be assigned dependent on absolute and relative class performance generally according to the following scheme.

90-100	A
85.9-89.9	A-
81.8-85.8	B+
77.7-81.7	B
73.6-77.6	B-
68.5-72.5	C+
64.4-68.4	C
60.3-64.3	C-
56.2-60.2	D+
52.1-56.1	D
48.0-52.0	D-
0-47.9	F

    Please note that "Undergraduate students, in order to graduate, must have an overall GPA and an upper-division GPA of 2.0 or better (C or better). Note: a C- average is equivalent to a GPA of 1.67, and therefore, it does not satisfy this graduation requirement. Graduate students, in order to graduate, must have an overall GPA of 3.0 or better (B or better). Note: a B- average is equivalent to a GPA of 2.67, and therefore, it does not satisfy this graduation requirement. For more information on grades and grading policies, please visit:
    https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx

15. **Make-up Exam Policy**
    Make-up exams must be arranged with the Instructor to be taken prior to the exam that is being made up. Students are responsible for contacting the Instructor as soon as a scheduling conflict with an exam is identified. Make-up exams are only allowed in exceptional cases such as documented medical emergency – these should be discussed with the Instructor.
    Students who do not take an exam and do not make prior arrangements for rescheduling will be assigned a zero grade for that exam.

16. **Honesty Policy**
    All students admitted to the University of Florida have signed a statement of academic honesty committing themselves to be honest in all academic work and understanding that failure to comply with this commitment will result in disciplinary action. This statement is a reminder to uphold your obligation as a UF student and to be honest in all work submitted and exams taken in this course and all others.

17. **Accommodation for Students with Disabilities**
    Students requesting classroom accommodation must first register with the Dean of Students Office. That office will provide the student with documentation that he/she must provide to the course instructor when requesting accommodation.

18. **UF Counseling Services**

Resources are available on-campus for students having personal problems or lacking clear career and academic goals. The resources include:

- UF Counseling & Wellness Center, 3190 Radio Rd, 392-1575, psychological and psychiatric services.
- Career Resource Center, Reitz Union, 392-1601, career and job search services.

19. **Software Use**

All faculty, staff and student of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.