Introduction to Continuous Control Systems
EEME E3601

Course Number: EEME E3601

Course Title: Introduction to Continuous Control Systems

Lecture Hours: 2.5

Credits: 3

Instructor: Homayoon Beigi <hb87@columbia.edu>

Prerequisites: Linear Algebra, Ordinary Differential Equations

Textbooks:

Required:
Farid Golnaraghi and Benjamin C. Kuo, “Automatic Control Systems,” 10^{th} Edition, McGraw Hill, New York, 2017.

Reference:
Homayoon Beigi, “Fundamentals of Speaker Recognition”, Springer, New York, 2011.
Thomas E. Fortman and Konard L. Hitz, “An Introduction to Linear Control Systems,” Control and Systems Theory Vol. 5, Marcel Dekker, Inc, New York, 1977.

Grading:

Homework (30%):
- Problems solving and coding assignments.

Midterm Exam – In-Class (30%)

Final Exam – In-Class (40%)

Course Description:

Introduction to continuous systems with the treatment of classical and state-space formulations. Mathematical concepts, complex variables, integral transforms and their inverses, differential equations, and relevant linear algebra. Classical feedback control, time/frequency domain design, stability analysis, Laplace transform formulation and solutions, block diagram simplification and manipulation, signal flow graphs, modeling physical systems and linearization. state-space formulation and modeling, in parallel with classical single-input single-output formulation, connections between the two formulations. Transient and steady state analysis, methods of stability analysis, such as root locus methods, Nyquist stability criterion, Routh Hurwitz criterion, pole/zero placement, Bode plot analysis, Nichols chart analysis, phase lead and lag compensators, controllability, observability, realization of canonical forms, state estimation in multivariable systems, time-variant systems. Introduction to advanced stability analysis such as Lyapunov stability and simple optimal control formulation. May not take for credit if already received credit for MEEE E4600.

Note:

More advanced Lyapunov and optimal treatment and solutions are left to more advanced courses: see MEEE 6610 Nonlinear and Adaptive Control. A full treatment of discrete control systems will be covered in a subsequent course: see EEME E4601 Discrete Control Systems. Matlab will be used for simulations and the coding assignments.

Lectures:

Week 1

Introduction to Control Theory

- Terminology
- Types of Control Systems
- Sample Plants and Suitable Associated Control Systems
- Nonlinear Systems, Linear Time-Variant and Time Invariant Systems
- General Mathematical Forms
- Block Diagrams
- Sensor Data Collection Examples

Week 2

Control Problem Components
Review of Linear Algebra Concepts

Week 3

Review of Complex Variable Theory
Continuity and Analyticity
Power Series Representation – Taylor and Laurent
Review of Function Relations

Week 4

Laplace Transform and Laplace Inversion
Partial Fraction Expansion

Week 5

Review of Linear Differential Equations
Dynamic and Electrical System Plant Formulation
Simple Block Diagrams
Proportional Control
Integral Control and steady state response

Week 6

Derivative Control and transient response
PI, PD, PID Control
State-Space Representation
Controllability Canonical Form
Series Solutions for Scalar First Order ODEs
Series Solutions for Matrix First Order ODEs and the Martix Exponential

Week 7

Block Diagram Manipulation and Signal Flow Graphs
Routh-Hurwitz Criteria for Stability
Bode Diagrams
Laplace and Fourier Transform Visualization

Week 8

Midterm (First half of class)
Root Locus Plot – Rules and Examples

Week 9
Root Locus Plot – Rules and Examples (continued)
Nyquist Stability Criterion
Nichols Chart

Week 10
Phase Lead/Lag Compensator
Eigenvalue-Eigenvector Formulation
Generalized Eigenvalue problem formulation and solution
Transformations – ie, Similarity Transform
Jordan Block Form
Eigenvector Solution to the General Controllable Canonical Equations

Week 11
Controllability, Observability, and Realizability
Second Order System Examples
Formulating External Disturbances
Formulating State Observer and State Feedback
Luenberger Observer

Week 12
Time-Variant Systems
Nonlinear Systems
Linearization
Lyapunov Stability Analysis

Week 13
Kalman Filtering
Optimal Control Set-up

Final Exam