447MCDO1

Master Course Description

No:EE 447

Title: CONTROL SYSTEM ANALYSIS I

Credits: 4

[UW Course

Catalog Description](http://www.washington.edu/students/crscat/ee.html#ee447)

Coordinator: Sam Burden, Assistant Professor, Electrical & Computer Engineering

Goals: For students to acquire the necessary tools for the analysis and design of linear feedback control systems.

Learning Objectives:

At the end of this course students will be able to:

1. *Linearize* a nonlinear system around an operating point.
2. *Represent* a linear system in state space and transfer function form.
3. *Determine* the effects caused by including feedback in a system.
4. *Determine* if a system is stable.
5. *Understand* a system's sensitivity and its noise and disturbance rejection properties.
6. *Use* Python to model, design and simulate systems.
7. *Determine* the performance of a system both analytically and from simulation.
8. *Apply* root locus, frequency response and full-state feedback methods to design a feedback control system to meet specific performance requirements.
9. *Design* a full-state observer for a system.

Textbook:

N. S. Nise, *Control Systems Engineering*, John Wiley & Sons, 6th edition, 2010.

Reference text:

K. J. Astrom and R. M. Murray, *Feedback Systems*, Princeton University Press, Version v3.0i (2018-09-30).

Prerequisites by Topic:

1. Differential equations
2. Linear Algebra
3. Laplace transform analysis of linear circuits and systems

4. Ability to write differential equations of describing electrical and mechanical systems.
5. Familiarity with the use of Python for scientific computing.

Topics:

1. **Feedback principles:** introduce mathematical modeling tools (linear differential equations, transfer functions, block diagrams), and apply them to shape system behavior (attenuate disturbances, follow references, and provide robustness). (2 classes)
2. **Modeling and examples:** further develop mathematical modeling tools (nonlinear differential equations, transfer functions, block diagrams) and apply them to a variety of physical phenomena using a combination of pen-and-paper analysis and scientific computing. (2 classes)
3. **Dynamics, differential equations, stability:** qualitative and quantitative analysis of nonlinear system behavior, including simulation, stability, and parameter dependence. (2 classes)
4. **Linear differential equations, linear input/output systems, linearization:** qualitative and quantitative analysis of linear system behavior and its relation to nonlinear system behavior. (2 classes)
5. **State and output feedback:** controllability and design of stabilizing controllers; observability and design of estimating observers. (2 classes)
6. **Transfer functions:** frequency domain modeling, poles and zeros, block diagrams, Bode plots. (2 classes)
7. **Computational tools:** modeling, analysis, simulation, and visualization using Python and the Control Systems Toolbox. (1 class)
8. **Frequency domain analysis and design:** stability criteria of Nyquist and Bode; sensitivity and performance specifications; root-locus. (2 classes)
9. **Proportional-integral-derivative (PID) control:** ubiquity, hierarchical design, tuning, and implementation issues including integrator windup. (2 classes)

Course Structure: The class meets for two lectures a week (TuTh). There is weekly homework due; Grading is based on homework, one midterm exam, a final exam, and a project. The grading percentages and nature of the exams are left to the discretion of the instructor.

Computer Resources: The course uses Python for homework problems. The students complete an average of 2 hours of computer work per week.

Outcome Coverage:

(1) **Problems** — *An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.* (H) This course builds on the students' foundations in signal processing, differential equations, and linear algebra to derive and apply techniques for feedback control of linear systems to solve the following types of problems: (i) construct mathematical models of physical systems (differential / difference equations, transfer functions); (ii) analyze sta-

bility and parametric sensitivity properties of the mathematical models (eigenvalues / roots of characteristic polynomials, Routh-Hurwitz stability criteria); (iii) synthesize feedback controllers that achieve specified performance objectives in time- and/or frequency-domain (rise time, settling time, crossover frequency).

(2) **Experiment** — *An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.* (M) Students learn to apply computational tools to conduct the following types of experiments with mathematical models of physical systems: (i) evaluate open-loop system response in time- and/or frequency-domain (step response, Nyquist diagram); (ii) evaluate closed-loop system response in time- and/or frequency-domain (step response, Nyquist diagram, Bode plot); (iii) simulate the effect of disturbances, perturbations, and real-world implementation (discretization, delay, linearization).

Prepared By: Sam Burden

Last revised: 2019/05/20