ECE 3111: Systems Analysis and Design

Credits and contact hours: 4 Credits (Two 75-min lectures and one 50-min discussion session per week)
Instructor: Liang Zhang
Textbooks: **Nise, Norman S., Control Systems Engineering, 7th Edition. Wiley, 2015.**
Access to MATLAB and MATLAB Control Systems Toolbox is required.
Other supplemental materials: PowerPoint Slides of Lecture Notes

***Specific course information*:**

a. *Catalog Description*: Modeling, analysis and design of control systems using frequency and time-domain methods. Differential equation, Transfer function, signal flow graph and state variable representations of continuous and discrete-time systems. Linearization of nonlinear systems. Transient and frequency response of second order systems. Stability of linear systems with feedback; Routh Hurwitz, Root locus, Bode and Nyquist methods. Controllability and observability. Computational methods for analysis of linear systems. Team-based design projects involving modeling, classical compensator design and state variable feedback design.

b. *Prerequisite*: ECE 3101 and prerequisite or co-requisite: MATH 2210Q; open only to students in the School of Engineering

c. *Required, elective, or selected elective:* Required (EE), Selected elective (CMPE)

***Specific goals for the course*:**

a. *Specific outcomes of instruction*: Students will be able to
   - Model continuous and discrete-time control systems.
   - Linearize nonlinear systems at desired equilibria.
   - Analyze control systems using both frequency and time-domain methods.
   - Design feedback controllers using various techniques (e.g., Bode/Nyquist design, PID tuning, root locus).
   - Apply MATLAB/Simulink to the analysis and design of control systems.

b. *ABET Criterion 3 Student Outcomes addressed by the course*:

   (1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics

   Students learn to apply time-domain and frequency domain techniques to the modeling and analysis of engineering systems (e.g., electrical, mechanical and rotational systems).

   (2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors

   Students work on a project to model a physical or biological system, including the sensors/actuators, and design controllers to meet desired performance characteristics, cost and reliability constraints of a system. MATLAB/Simulink implementation and extensive testing is also required.

(3) an ability to communicate effectively with a range of audiences

Students write technical project reports in a required format on the background/modeling/analysis/design of a practical control system.

(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

The wide applicability of systems engineering techniques in cyber-physical systems, robots, physiological systems, medicine, transportation, smart buildings, smart grid, economics, business and other societal systems is emphasized through homework problems and design projects.

(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

n/a

(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions

Students learn to use MATLAB/Simulink as experimentation platform on three-phase design projects involving (i) modeling (ii) analysis and (iii) feedback controller design and validation. Students learn the ability to interpret the relationship between the frequency and time-domain responses of linear systems.

(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

n/a

Topics covered:

- Review of Linear Systems and Laplace Transforms
- Modeling electrical, mechanical and rotational systems.
- State-space representation of continuous time systems; Eigenvectors, state variable transformations. Linearization of nonlinear systems.
- Signal flow graph models. Mason's rule.
- Step response and frequency response plots of 2^{nd} order systems.
- Advantages of feedback, stability and sensitivity, noise/disturbance rejection, Introduction to Bode Design, PID controllers
- Routh Hurwitz test for stability of continuous time systems. Steady-state error.
- Root locus methods for stability, transient analysis, Design via Root Locus
- Modal form. Controllability and observability.
- Sampling and discrete system models. State equation solution. Sampling theorem. Z-transforms. Jury test for stability of discrete time systems. State equations for discrete time systems; solution methods.
- Nyquist plot and Nyquist stability test.