Course: EW305 Linear Control Engineering

Credits: 4 credits – 3 recitation hours – 2 laboratory hours

Course Description: This course provides a foundation in classical control engineering covering mathematical modeling, time and frequency response analysis, and design of linear compensators. The lecture material is supported by a series of laboratory projects on the modeling and analysis of physical systems and the design and implementation of control systems.

Pre-requisites:
EW202 Principles of Mechatronics

Co-requisites:
EW301: Modeling and Simulation

Course Coordinator: Associate Professor Levi DeVries

Textbook: Control Systems Engineering, 8th Edition, N. Nise

Course Objectives:
Lecture 1: Learning objectives
- Apply the Laplace transform derivative property with initial conditions
- Determine the transfer function from a differential equation
- Apply the initial and final value theorems
- Compute the poles and zeros of a transfer function

Lecture 2: Learning objectives
- Convert a complex number between rectangular and polar form
- Perform basic mathematical operations on complex numbers
- Evaluate a transfer function at a complex number

Lecture 3, 4, and 5: Learning objectives
- Compute the inverse Laplace transform using partial fraction expansion techniques for real and distinct roots
- Compute the inverse Laplace transform using partial fraction expansion techniques for complex roots
- Identify the relationship between the roots of the Laplace transform and the time response of the system
- Compute the inverse Laplace transform using partial fraction expansion techniques for real, repeated roots
- Compute the impulse response given a transfer function
- Compute the frequency response (magnitude and phase) given a transfer function and a frequency

Lecture 6: Learning objective:
- Determine the stability of a transfer function from its poles

Lecture 7: Learning objectives: Compute the steady-state response
- By applying the final value theorem given a transfer function model and an input Laplace transform
- Given the open-loop DC gain and a step input with known magnitude

Lectures 8 and 9: Learning objectives

- Determine the DC gain and time constant from a 1st order transfer function
- Predict and sketch the response of a 1st order system given a transfer function model and a step input with known magnitude
- Determine the DC gain and time constant given the step response of a 1st order transfer function and the step input magnitude
- Compile a 1st order transfer function given the DC gain and time constant

Lectures 10, 11, and 12: Learning objectives
- Distinguish between overdamped, critically damped, and underdamped 2nd order systems
- Compute the damping ratio and undamped natural frequency from a 2nd order transfer function
- Describe the impulse response of an underdamped 2nd order system
- Describe the resonance of an underdamped 2nd order system
- Determine the DC gain, damping ratio, and undamped natural frequency from a 2nd order transfer function
- Predict and sketch the response of a 2nd order system given a transfer function model and a step input with known magnitude. Annotate the sketch with settling time, time to peak, peak value, and steady-state value of the response.
- Determine the DC gain, damping ratio, and undamped natural frequency given step response data from a 2nd order transfer function and the step input magnitude
- Compile a 2nd order transfer function given the DC gain, damping ratio, and undamped natural frequency

Lecture 13 and 14: Learning objectives
- Apply Mason's gain formula to compute a closed-loop transfer (from any input to any output) from a given block diagram

Lectures 15, 17, 18, and 19: Learning objectives
- Sketch the root locus from the open-loop transfer function and compute the following as applicable
    - Asymptotes
    - Imaginary axis crossing
    - Breakaway point

Lectures 16, 20, 21, and 22: Learning objectives
- Compute a specification region and design point given percent overshoot and settling time specifications
- Design a proportional controller given a percent overshoot specification
- Design a proportional controller given a settling time specification

Lecture 23: Learning objectives
- Describe the limits of proportional control
- Describe the effect of integral and derivative control actions

Lecture 24: Learning objective
- Design a PD compensator given the open-loop transfer function and transient response specifications
    - Compute design point and compensator angle
    - Determine if design is feasible
    - Compute compensator parameters
    - Compile compensator transfer function
    - Compute gain
    - Verify design by computing the closed-loop poles

Lecture 25: Learning objectives
- Describe the limitation of a PD compensator

- Design a lead compensator given the open-loop transfer function and transient response specifications

Lecture 26: Learning objective
- Predict steady-state error in a closed-loop system using
  - The final value theorem
  - Type number and error constants

Lecture 27: Learning objective
- Design a PI compensator given the open-loop transfer function and transient response specifications

Lecture 28 and 29: Learning objectives
- Describe the qualitative effect of closed-loop zeros or extra closed-loop poles
- Redesign a compensator to meet the transient response specifications when the closed-loop transfer function does not match the 2nd order assumption

Lecture 30: Learning objective
- Design a PI-lead compensator given the open-loop transfer function and transient response specifications

Lecture 31: Learning objective
- Select a compensator given the open-loop transfer function and transient response specifications

Topics:
- Laplace transforms
- Transfer functions
- Solution to differential equations using partial fraction expansion and inverse Laplace transform
- System response to step, ramp and sinusoidal inputs
- Stability
- Steady-state behavior
- First order system response and system identification
- Second order underdamped system response and system identification
- Block diagram reduction
- Root locus plotting and analysis
- Proportional control design
- Proportional-Derivative control design
- Lead compensator design
- Proportional-Integral control design
- Proportional-Integral Derivative control design
- PI-Lead compensator design
- Compensator selection
- Tustin's transformation and difference equation for discrete time system implementation
- DC motor speed and position control

Last Updated: 08-December-2020