Engineering Faculty Document No. 155-25
March 06, 2025

TO: The Faculty of the College of Engineering

FROM: The Faculty of the School of Mechanical Engineering

RE: ME 37500 – Systems, Measurements, and Control II – Change in the Course Format

The faculty of the School of Mechanical Engineering has the following change to ME 37500 (Systems, Measurements, and Control II). The action is now submitted to the Engineering Faculty with a recommendation for approval.

Current format: Two 50-minute lectures per week + a three-hour weekly lab session during odd weeks + 1-hour recitation during even weeks.

Proposed Format: Two 50-minute lectures per week + a three-hour lab session every week.

Rationale: The current course design of ME 375: Systems, Measurements, and Control II has a disconnect between laboratory assignments and lecture content. Laboratory exercises should reinforce key principles taught in class, but the misalignment between the two creates confusion and reduces the effectiveness of hands-on learning. By revising the course to better integrate lab work with lecture topics, students will gain a more cohesive and meaningful learning experience that enhances their theoretical and applied understanding of systems, measurements, and control.

The original course also included content that was originally added to support a robot-based final project, which required students to purchase their own robots. However, due to hardware limitations, the model-based control algorithms taught in class could not be implemented on the robot. As a result, students relied on heuristic control or finite state machines to control the robot rather than applying control theory or model-based design principles. This misalignment undermines the core learning objectives of the course, highlighting the need for a curriculum revision that ensures students can effectively apply theoretical knowledge using suitable hardware testbeds.

To address these issues, several key changes have been made to the course structure. The lecture schedule has been adjusted to consist of two 50-minute lectures per week, supplemented by a three-hour weekly lab session. Each lab topic is now directly aligned with the lecture content from the previous week, ensuring that students can immediately apply theoretical knowledge in a hands-on setting. The lecture content that was removed as a part of this change will be incorporated in ME 365: Systems, Measurements, and Control I or is not needed as it was only added to support the robot project. The semester project using the robot has been eliminated, allowing for a stronger focus on core control theory concepts. In the lab, students will gain experience with at least two different hardware apparatus, working with the same hardware for multiple weeks to develop and refine their skills. Furthermore, the lecture material is now aligned with a required textbook, providing consistency in material presentation across sections and ensuring that all students have access to a structured learning resource. These revisions create a more cohesive and effective learning experience, while also preparing those students interested in specializing in control or robotics with the knowledge base to take senior elective courses or pursue graduate study.

J. Panchal

Jitesh Panchal
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ME 37500
SYSTEMS, MEASUREMENTS and CONTROL II

Course Outcomes [Related ME Program Outcomes in brackets]

1. Students will understand the mathematical theory governing closed-loop system stability and performance. [1]
2. Students will learn how to design single-input-single-output linear feedback control algorithms to achieve closed-loop stability and specified system performance objectives. [1,2]
3. Students will learn how to implement control algorithms on physical hardware. [1,6]
4. Students will improve their technical communication skills through laboratory assignments. [3,5]

System Response (7 lectures)

1. Introduction to feedback control systems
2. Model linearization
3. Time-domain response of first and second-order systems
4. Impact of poles and zeros
5. Linear stability definition and analysis
6. Analysis of steady-state error
7. Sensitivity analysis

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Controller Design (19 lectures)

1. Common control laws for output-feedback
2. Direct pole placement
3. Root locus
   a. Diagrams
   b. Controller design
4. Stability analysis in the frequency domain
   a. Stability margins
   b. Nyquist stability criterion
5. Frequency domain controller design
6. Effect of time delays

Laboratory Experiments

Lab 1: Measurement and Instrumentation using MATLAB/Simulink
Lab 2: I/O Connections between MATLAB/Simulink and hardware
Lab 3: Dynamic Model Linearization and Validation
Lab 4: Open-loop Control
Lab 5/6: Control via Direct Pole Placement (Part 1 & 2)
Lab 7/8: PI Controller Design (Part 1 & 2)
Lab 9/10: Root Locus Controller Design (Part 1 & 2)
Lab 11/12: Frequency Domain Controller Design (Part 1 & 2)

COURSE NUMBER: ME 37500

COURSE TITLE: System, Measurements and Control II

REQUIRED COURSE OR ELECTIVE COURSE: Required

TERMS OFFERED: Fall, Spring and Summer

TEXTBOOK/REQUIRED MATERIAL:
Feedback Control of Dynamic Systems by G. Franklin, J.Powell, and A. Emami-Naeini (8th Ed., 2018)

PRE-REQUISITIES:
ME 36500: Systems, Measurements and Control I
MA 26500: Linear Algebra

COORDINATING FACULTY: Neera Jain

COURSE DESCRIPTION: This course builds on the measurement, system modeling, and system /analysis fundamentals introduced in ME 36500 (Systems, Measurements and Control I), with an emphasis on closed-loop feedback control theory and design. The mathematical tools necessary for analyzing closed-loop stability and performance (e.g. steady-state error, transient performance characteristics) are presented. Pole placement, root locus, and frequency domain methods are used to design feedback control algorithms. Hands-on assignments are utilized to reinforce fundamental systems, measurement, and control concepts, including the implementation of control algorithms in simulation and on physical hardware.

COURSE OUTCOMES [Related ME Program Outcomes in brackets]:

1. Students will understand the mathematical theory governing closed-loop system stability and performance. [1]
2. Students will learn how to design single-input-single-output linear feedback control algorithms to achieve closed-loop stability and specified system performance objectives. [1,2]
3. Students will learn how to implement control algorithms on physical hardware. [1,6]
4. Students will improve their technical communication skills through laboratory assignments. [3,5]

ASSESSMENTS TOOLS:

1. Weekly homework assignments.
2. Weekly laboratory assignments.
3. Two 1-hour midterm exams.
4. One comprehensive final exam.

NATURE OF DESIGN CONTENT: In this course, the students will learn how to design, synthesize, and implement different types of output feedback control algorithms. The course is structured such that students will learn about common types of control laws and how to decide which type may be suitable for a particular type of system or performance requirements. In other words, there is no "one size fits all" solution, and instead, students will gain an understanding and appreciation for the toolbox that enables them to design novel control algorithms for different systems.

RELATED ME PROGRAM OUTCOMES:

1. Engineering fundamentals
2. Engineering design
3. Communication skills
4. Ethical/Prof. responsibilities
5. Teamwork skills
6. Experimental skills
7. Knowledge acquisition

PROFESSIONAL COMPONENT:

1. Engineering Topics: Engineering Science – 2.5 credits (83.3%)
   Engineering Design – 0.5 credit (16.7%)

COMPUTER USAGE: Students will primarily use MATLAB/Simulink for both homework assignments and in the laboratory. Students will build on skills they obtained in ME 36500 (numerical simulation of ODEs) and practice simulating closed-loop dynamical systems through programming both in MATLAB and in Simulink. In the laboratory, Simulink will be used to interface with a microcontroller, and students will build their own Simulink diagrams to implement and test various controller designs.

COURSE STRUCTURE/SCHEDULE:

Lecture – 2 50-minute lectures per week.
Laboratory – Weekly, 180 minutes.

PREPARED BY: Neera Jain

REVISION DATE: February 6, 2025