UNIVERSITY OF THE PHILIPPINES
College of Engineering

EEE 151 (WFR and WFU)
Analog and Digital Control

COURSE GUIDE

Course Description

This course introduces classical concepts of continuous-time feedback system modeling, analysis, compensation techniques, as well as root-locus, Bode diagrams and Nyquist plots as methods of establishing stability of systems.Introduction to computer-aided design tools for control systems will be given throughout the entire course, where relevant. The digital control system topics include z-transforms and state variable representation of discrete-time systems, generating models for mixed continuous and discrete-time systems, modeling asynchronous sampling, analysis and design by root locus, frequency response, and state-space techniques, as well as controllability, observability and observer design.

Prerequisite: EEE 147 Signals and Systems, ES 101 Mechanics of Particles and Rigid Bodies

Course Objectives

At the end of this course, the student should be able :
To construct a mathematical model, block diagram and signal flow graph for a physical lumped parameter system. To perform stability and sensitivity analysis on systems, design cascade and feedforward compensators to meet transient and frequency response specifications. To use computer-aided control tools to verify root locus, transient and frequency response characteristics of a system.

Course Outline

1. Introduction, Class Policies, Grading, References
2. Introduction to Control Theory
    - What is control systems theory?
    - Motivation for control.
    - Examples of control systems.
    - Basic feedback system.
    - Why feedback?
3. Closed-loop Systems
    - Open-loop vs. closed-loop.
    - Advantages and disadvantages of a closed-loop system.
    - Control system design overview.
4. Mathematical Modeling of Dynamic Systems
    - What is a model? What is a dynamic system?
    - Electrical systems, mechanical systems (translational and rotational), thermal systems and liquid-level systems

5. LTI systems and Differential Equations
    - Linear time-invariant systems.
    - State-space representation.
    - Linearization.
6. Laplace Transforms and Octave
    - Forcing functions.
    - Familiarization with Octave
7. Block Diagrams and Transfer Functions
    - block diagrams and block diagram transformations
    - transfer function
8. SFG and Mason Gain Rule
    - Comparison of block diagrams and SFGs.
    - SFG transformations.
    - Mason gain rule.
9. General Control Systems
    - Some more about transfer functions.
    - General control system, definitions and objectives.
    - LTI response to forcing functions.
10. LTI Steady-state Response
    - System type.
    - Steady-state error.
11. Time Domain Specifications
    - Pole position and time domain relationships
    - Typical time domain specifications
    - First-order systems
    - Second-order systems
12. Performance Specifications
    - Time domain exercises for second-order systems.
    - Characteristic equation.
    - Dominant poles and design issues.
13. Stability
    - Different aspects of stability.
    - BIBO and BIBS stability
    - Pole locations and stability
14. Routh-Hurwitz Stability Test
    - Hurwitz determinants
    - Routh-Hurwitz stability criterion
    - Why do you want to use Routh-Hurwitz stability test?
    - Some examples and issues on using R-H stability test.
15. Root Locus Basics
    - Basic properties
    - Root locus construction
16. Advanced Root Locus
    - Effect of adding poles and zeros.
    - Root contour.
    - Time delay.
    - Root sensitivity.

17. PID Controller
    - Proportional control
    - PD control
    - PID control
18. Introduction to Frequency Response
    - LTI Response to a sinusoid.
    - Magnitude and phase responses.
    - Frequency response of first and second order systems.
    - Polar plots.
19. Bode Plots
    - Charateristics of Bode plots
    - Standard Bode plots
    - Asymptotic plots
20. Bode Plots and Transfer Functions
    - Review of standard Bode plots.
    - Building an asymptotic Bode plot.
    - Identifying a transfer function from a Bode plot.
21. Compensation Using Bode Plots
    - Why use Bode plots to identify transfer functions?
    - Performance parameters in the frequency domain.
    - Compensation techniques.
    - Interpreting Bode plots.
22. Frequency Response Methods : Stability
    - Why study in terms of frequency response?
    - Contour mapping in the complex plane.
    - Cauchy’s theorems.
    - Nyquist stability criterion.
23. Nyquist Diagrams, Gain Margins
    - Practical aspects of using the Nyquist stability criterion.
    - Examples on Nyquist stability criterion.
    - Gain margin.
24. Nyquist Diagrams and Phase Margins
    - Review of gain margin.
    - Phase margin.
    - Remarks about gain margin and phase margin.
    - Put it all together.
25. Digital Control Introduction
    - Definition, advantages, disadvantages
    - Examples
    - z-transform
26. System representation
    - Simulation diagram
    - SFG
    - State-space representation
    - Transfer function
27. Sampling and reconstruction
    - Ideal sampler
    - Starred transform
    - Data reconstruction

28. Pulse transfer function
    - z-transform and starred transform
    - Open-loop transfer function
32. Closed-loop transfer function
    - Derivation using SFGs
    - State variable forms

Mode of Delivery

Course Site
Most of the course resources can be found at http://202.92.132.69:8888/manuel under EEE 151. Please go through the site so you would be familiar with the available materials. Especially important is the section on Academic Integrity. Other materials not found on the site will be emailed to you directly.

Communications Plan
Our main mode of communications is via email. I will be using your email address as registered under CRS. Please make sure you are able to access that particular email account.

Announcements will be sent through email. Email from me concerning this class will always contain the phrase “eee 151” in the subject line. If you have questions, comments or will be submitting a requirement, please send it by using email reply to the original email. Refrain from creating new subject lines unless you want to bring up a matter that does not fall under previously sent headings.

I would be generally available via email, during class hours, and consultation hours. For questions related to the lecture material, please send them through email at this time. If the question is simple enough, I will send the answer as an email reply. If the question needs some discussion that would be difficult to do via email, then I would send a zoom link so we can discuss the question online.

Teaching Strategy and Learning Activities
A schedule of topics will be followed. Please refer to the course guide and recent emails for the actual dates of activities and deadlines of deliverables.

Additional learning activities for the course would be reading references and watching videos related to the topics in control. Students should keep an eye on the scheduled list of topics so that they can pace themselves appropriately and be ready for assessment activities. It is also expected that students would solve book problems to increase familiarity with the material being discussed.

The following lab exercises will be given throughout the semester to reinforce the concepts discussed in the lectures. See section on “Lab Experiments” for additional details.

Lab experiment 1. Modeling of a heater system
- The plant and temperature output
- Model fitting
- Model verification

Lab experiment 2. Steady-state responses of Different Controllers
- Closed-loop control
- Design of proportional and integral controllers
- Comparison of theoretical and actual responses.

Lab experiment 3. PID control (if time permits)

- Design of a PID controller to meet specifications
- PID controller construction

<u>Assessment Strategy and Activities</u>

The primary mode of assessment would be through two exams. Quizes may also be used to assess student performance but is intended more to give the student an idea of how he/she is keeping pace with the material. Quizes will be held during class hours (see schedule of activities). The quiz will be conducted in class. Students will be given a quiz at the beginning or towards the end of the class and will collected after the alloted time.

Exams will be conducted physically in a designated room at EEEI. Please check the schedule of activities for any conflicts.

Course Materials

The following are materials that will be provided for the course

- Course guide
- Lecture slides
- Reading assignments
- Links to relevant videos

Study Schedule

The table below shows the schedule of topics to be taken up and the dates for quizes and exams. The student must keep the schedule in mind to keep pace with the requirements.

Please note that according to the UP Academic Credit Transfer System (ACTS), 1 academic credit (unit) = 38-48 hrs of student workload (including 13-16 hours of academic instruction). Thus, 3 academic credits (units) = (a minimum of) 114 hours of student workload for the semester.

With EEE 151 being equivalent to 3 academic units, this approximately translates to eight hours of student workload per week. The in class lectures and lecture videos are designed not to exceed three hours per week. Quizes will take at most one hour of student work per week. This leaves about four hours of student work that the student should use to review material, read references, and solve practice problems.

Week	**Topics**	**Required Learning Resources**	**Online Activity**	**F2F Activity**
1	Introduction, Class Policies, Grading, References Introduction to Control Theory lectures 00, 01	Lecture		Lectures 21 Aug 2024

2	Closed-loop Systems Mathematical Modeling of Dynamic Systems lectures 02, 03	Lecture		Lectures 28, 30 Aug 2024 Quiz 01
3	LTI systems and Differential Equations Laplace Transforms and Octave lectures 04, 05	Lecture		Lectures 04, 06 Sep 2024 Quiz 02 Quiz 03 Lab 1 intro
4	Block Diagrams and Transfer Functions SFG and Mason Gain Rule lectures 06, 07	Lecture		Lectures 11, 13 Sep 2024 Quiz 04 Quiz 05
5	General Control Systems LTI Steady-state Response lectures 08, 09	Lecture		Lectures 18, 20 Sep 2024 Lab 1 progress
6	Time Domain Specifications Performance Specifications lectures 10, 11	Lecture		Lectures 25, 27 Sep 2024 Quiz 06
7	Stability lecture 12 Control System Modeling Lab 01	Lecture Laboratory equipment		Lecture 02 Oct 2024 Quiz 07 Lab checking 04 Oct 2024
8	Routh-Hurwitz Stability Test Root Locus Basics lectures 13, 14	Lecture		Lectures 09, 11 Oct 2024 Quiz 08
9	Advanced Root Locus PID Controller lecture 15, 16	Lecture		Lectures 16, 18 Oct 2024 Quiz 09
10	Exam 1	Lecture		Exam 1 23 Oct 2024

				9-11 AM
11	Introduction to Frequency Response lecture 17			Lecture 30 Oct 2024 Lab 2 intro
12	Bode Plots Bode Plots and Transfer Functions lectures 18, 19	Lecture		Lectures 06, 08 Nov 2024
12	Compensation Using Bode Plots lecture 20 Controller Steady-state errors Lab 02 Frequency Response Methods: Stability lecture 21	Lecture Laboratory equipment		Lecture ~~13 Nov 2024~~ 08 Nov 2024 Open lab work 13 Nov 2024 ~~Lab checking~~ Lecture 15 Nov 2024 Quiz 10
13	Nyquist Diagrams, Gain Margins Nyquist Diagrams and Phase Margins lecture 22, 23	Lecture		Lecture 20 Nov 2024 ~~Lab workshops~~ Lecture 22 Nov 2024
14	Controller Steady-state errors Lab 02	Laboratory equipment		~~Lecture~~ Open lab work 27 Nov 2024 Circuit verification 29 Nov 2024
15	Exam 2			Exam 2 06 Dec 2024 815-945 AM, 10-1130 AM

Course Requirements
Exams – [50 + 2(10-n)]%
Quizzes – (2n)%
Lab exercises – 30%

where n is the number of quizzes given throughout the semester

Grading

92 - 100	1.0
88 - < 92	1.25
84 - < 88	1.5
80 - < 84	1.75
76 - < 80	2.0
72 - < 76	2.25
68 - < 72	2.5
64 - < 68	2.75
60 - < 64	3.0
< 60	5.0

Lab Experiments

The activities related to lab exercises are mostly conducted in an open lab setting. With the exception of checking/verifying your lab work, all other activities will be done during the open lab schedule. The schedule of the open labs will be discussed further in class. Students should form groups of two, with the members of the group required to be in the same EEE 151 section. Circuit components and other necessary materials should be procured by the group.

The lab activities will be introduced and discussed in class. As much detail as possible will be provided in class so that the group will be able to work on their own during open lab hours. Lab work entails constructing/building the circuit, testing, debugging, and data gathering. It is expected that students will allocate time for the lab work in order to complete the lab activity. The course guide indicates the deadline of lab work. Checking of the lab work will be done on the weeks of 04 October 2024 and 15 November 2024, respectively for Lab experiment 1 and Lab experiment 2. The exact days and times of the checking will be announced as the deadline approaches.

On the day and time of the checking, you will be given one hour to demonstrate that your circuit works as intended. Needless to say, this one hour is not enough if you are still building, debugging and testing your circuit. It is expected that you did all the necessary work to produce a working circuit before the day of the checking. You will also be asked to submit your data before the day of the checking so I can verify correctness of your data. Only once your data is verified that you will be allowed to proceed to the "checking" phase of the activity. During the one hour checking period, you will be asked to reproduce the data you have submitted beforehand. Groups who are not able to reproduce the submitted data will by default given a grade of zero for the lab experiment. However, if the student is able to demonstrate a successful run of the experiment, then the student will be allowed to resubmit the gathered data to replace the previous submission. A grade deduction will be given instead of the default zero.

To allow the students in the group to have time to work together, some of the class lectures will be short or a recorded video may be provided. These will also "compensate" students for their work during non-lecture hours.