UNIVERSITY OF THE PHILIPPINES
College of Engineering

EE 231
Advance Feedback Control Systems

COURSE GUIDE

Course Description

Transfer functions. Block diagrams. Signal flow graphs. Root locus,Bode, Nyquist and polar plots. Sensitivity. Stability. Compensation techniques. Multivariable systems. Disturbance rejection. Robust control. Adaptive control. State-variable representation and feedback. State-space design. Optimal control, computer simulations. Design projects

Prerequisite: EEE 101 or equivalent

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 physical systems. To perform stability and sensitivity analysis on systems, design cascade and feedforward compensators to meet transient and frequency response specifications using root locus, Bode and Nyquist plots. To explain key concepts in multivariable control, robust control, adaptive control and quadratice optimal control. 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
   - Overview of EE 231 topics
   - Control system
2. Mathematical Modeling of Dynamic Systems
   - Electrical systems,
   - Mechanical systems (translational and rotational),
   - Thermal systems and liquid-level systems
3. LTI systems, Differential Equations, Laplace Transforms
   - Linear time-invariant systems.
   - State-space representation.
   - Linearization.
4. Block Diagrams and Transfer Functions
   - block diagrams and block diagram transformations
   - transfer function
5. SFG and Mason Gain Rule
   - Comparison of block diagrams and SFGs.
   - SFG transformations.
   - Mason gain rule.
6. General Control Systems

- Some more about transfer functions.
- General control system, definitions and objectives.
- LTI response to forcing functions.

7. LTI Steady-state Response
   - System type.
   - Steady-state error.
8. Time Domain Specifications
   - Pole position and time domain relationships
   - Typical time domain specifications
   - First-order systems
   - Second-order systems
9. Performance Specifications
   - Time domain exercises for second-order systems.
   - Characteristic equation.
   - Dominant poles and design issues.
10. Stability
    - Different aspects of stability.
    - BIBO and BIBS stability
    - Pole locations and stability
11. Root Locus Basics
    - Basic properties
    - Root locus construction
12. Advanced Root Locus
    - Effect of adding poles and zeros.
    - Root contour.
    - Time delay.
    - Root sensitivity.
13. PID Controller
    - Proportional control
    - PD control
    - PID control
14. Introduction to Frequency Response
    - LTI Response to a sinusoid.
    - Magnitude and phase responses.
    - Frequency response of first and second order systems.
    - Polar plots.
15. Bode Plots
    - Charateristics of Bode plots
    - Standard Bode plots
    - Asymptotic plots
16. Bode Plots and Transfer Functions
    - Review of standard Bode plots.
    - Building an asymptotic Bode plot.
    - Identifying a transfer function from a Bode plot.
17. Compensation Using Bode Plots
    - Why use Bode plots to identify transfer functions?
    - Performance parameters in the frequency domain.
    - Compensation techniques.
    - Interpreting Bode plots.

18. Frequency Response Methods : Stability
    - Why study in terms of frequency response?
    - Contour mapping in the complex plane.
    - Cauchy's theorems.
    - Nyquist stability criterion.
19. Nyquist Diagrams, Gain Margins
    - Practical aspects of using the Nyquist stability criterion.
    - Examples on Nyquist stability criterion.
    - Gain margin.
20. Nyquist Diagrams and Phase Margins
    - Review of gain margin.
    - Phase margin.
    - Remarks about gain margin and phase margin.
21. Multivariable Control.
22. Robust Control
23. Adaptive Control
24. Quadratic Optimal Control

Mode of Delivery

Course Site

This course will be delivered remotely. Most of the course resources can be found at http://202.92.132.69:8888/manuel under EE 231. 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.

What will be sent through email? Announcements, links to lecture videos, homeworks, and exams will be sent through email. Email from me concerning this class will always contain the phrase "ee 231" in the subject line. If you have questions, comments or will be submitting a homeworks and exam, 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 and zoom during class 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

The main mode of teaching for this course is through lecture videos, and discussions during class hours via email or video call whichever is appropriate. A schedule of topics will be followed. This will try to closely match how the course is conducted during a regular semester. Links to lecture videos will be made available at least a week before the particular topic is to be scheduled to be taken up. Since the videos were recorded in earlier semesters, please take note that dates mentioned in the videos (e.g. quiz dates, exam dates, lab schedule) may not apply. 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.

Lab experiment 1. Modeling and system identification
Lab experiment 2. Compensator design
~~Lab experiment 3. Adaptive control simulations~~

Assessment Strategy and Activities
The primary mode of assessment would be through two exams. Homeworks would 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. Exams will be held during class hours (see schedule of activities) and conducted face-to-face.

Please see http://202.92.132.69:8888/manuel/captured_correctly.txt on how to prepare your submissions. 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
- Lecture videos
- 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 EE 231 being equivalent to 3 academic units, this approximately translates to eight hours of student workload per week. The lecture videos are designed not to exceed three hours per week. Homework will take at most three hours of student work per week. This leaves about two hours of student work that the student should use to review material, read references, and solve practice problems.

Week	**Topics** (please refer to the course outline for detailed topics)	**Learning Outcomes**	**Assessment**
1	Introduction, Class Policies, Grading, References lectures 00, 01 (12 Sep 2023)	Describe what are control systems, and examples of control systems.	
2	Mathematical Modeling of Dynamic Systems LTI systems and Differential Equations Laplace Transforms and Octave lectures 02, 03 (19 Sep 2023)	Familiarize with models of simple electrical, mechanical and thermal systems. Write and solve differential equation models. Demonstrate ability to use Laplace transform to solve ODEs.	HW 01
3	Block Diagrams and Transfer Functions SFG and Mason Gain Rule lectures 04, 05 (26 Sep 2023)	Manipulate and simplify block diagrams. Draw SFGs and use Mason Gain Rule to simplify SFGs.	HW 02
4	General Control Systems LTI Steady-state Response lectures 06, 07 (03 Oct 2023)	Familiarize with other components of a control system and realize the complexity of control systems. Calculate the steady-state response of systems given standard inputs. Relate input functions and system type to error response.	HW 03
5	Time Domain Specifications Performance Specifications lectures 08, 09 (10 Oct 2023)	Define transient response parameters. Relate transient response parameters to pole locations of first order and second order systems. Determine the characteristic equation.	HW 04
6	Break		
7	Stability lecture 10 (24 Oct 2023)	Give a mathematical definition of what stability is. Know how pole locations relate to system stability.	Lab 01 report 31 Oct 2023
8	Root Locus Basics Advanced Root Locus lectures 11,12 (31 Oct 2023)	Sketch root locus by hand given poles and zeros. Describe graphically the effects of additional poles/zeros on the root locus.	HW 05
9	PID Controller lecture 13 (7 Nov 2023)	Understand the components of PID controller. Determine which PID controller to satisfy performance requirements.	

		Compute PID parameters with the aid of root locus.	
10	Exam 1		Exam 1 14 Nov 2023
11	Introduction to Frequency Response Bode Plots lectures 14, 15 (21 Nov 2023)	Define precisely what frequency response is. Draw Bode plots of first order and second order systems.	Lab 02 report 12 Dec 2023
12	Bode Plots and Transfer Functions Compensation Using Bode Plots lectures 16, 17 (28 Nov 2023)	Draw asymptotic Bode plots given a transfer function. Determine the transfer function for a given Bode plot. Design phase-lead/lag network for compensation.	HW 06
13	Frequency Response Methods : Stability Nyquist Diagrams, Gain Margins lectures 18, 19 (05 Dec 2023)	Describe precisely Nyquist stability criterion and how it is used. Compute the gain margin of closed-loop system.	
14	Nyquist Diagrams and Phase Margins lecture 20 (12 Dec 2023)	Explain how additional phase affects the Nyquist diagram. Compute the phase margin of closed-loop systems.	
15	Exam 2		Exam 2 19 Dec 2023
	Multivariable control Robust control	Explain basic concepts on multivariable control and robust control	
	Adaptive Control Quadratic Optimal Control	Discuss controller structures for adaptive control and introduce optimal control	

Course Requirements
Exams – 50%
Lab exercises – 30%
Homeworks – 20%

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