ENGR4220 – ENGR6220
Feedback Control Systems

Syllabus for Spring 2016 - M. Haidekker

1 Course Information

The analysis and design of continuous and time-discrete linear feedback control systems with a focus on frequency domain models. Simulation using Scilab/Scicos to design controllers for steady-state error reduction and optimal transient response to varied inputs. Prerequisites: ENGR 4210 (Linear Systems) or instructor's consent.

Offered: Every spring semester
Credits: 3 credit hours
Class: Lectures on Tuesday and Thursday
Prerequisite: ENGR4210 *Linear Systems*

Feedback controls are ubiquitous and fundamental to modern engineering. Whether it is a component in a simple water tank or the sophisticated control systems in aeronautics and robotics, feedback controls make technology safer, faster, more reliable, if not possible in the first place. Feedback systems can also be found in unexpected areas, for example in biology or economics. In this class, we will understand what feedback controls are, and we will learn how to master feedback controls in three major steps:

1. We will learn how to describe and characterize the process to be controlled
2. We will learn how to determine the performance of feedback systems in terms of stability and dynamic response
3. We will learn how to design feedback controls to meet desired performance criteria.

Linear systems and feedback controls make extensive use of mathematical models. However, in this class, we will always stay close to practical applications. The class is strongly based on hands-on projects where the theoretical concepts can be tested in practice.

Consistent with this philosophy, there will be *quizzes* and a semester project. The quizzes can be regarded as short homeworks with a theoretical emphasis. These will allow you to strengthen your understanding of the theory and to assess your preparation for the exams. The larger-scale semester project involves a strong practical component with both a computer simulation and an actual realization of a feedback control system. The semester project will allow you to relate theory to the practical implementation of feedback control systems.

2 Instructor

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3 Syllabus – Topical Outline

Note: The course syllabus is a general plan for the course; deviations may be necessary and will be announced to the class by the instructor.

Lecture block	Topic
1	Introduction to feedback control systems with examples
2	System description with differential equations
3	Mathematical treatment of feedback systems in the Laplace domain
4	State-variable description of feedback systems
5	Time-discrete systems, finite-difference equations, z-transform
6	Formal description with block diagrams and signal flow graphs
7	Linearization of nonlinear elements
8	Numerical simulation of control systems with Scilab and Xcos
9	Disturbances and steady-state response of feedback systems
10	Dynamic performance and transient response of feedback systems
11	Stability criteria for continuous and time-discrete systems
12	Controller and compensator design
13	The root locus design method
14	Frequency-domain design methods, Bode diagrams and Nyquist design
15	The PID controller

4 Class Materials

- Textbook: *Linear Feedback Controls – The Essentials*, by M.A. Haidekker. Elsevier 2013, ISBN 978-0-124-05875-0 [1]
- Supplemental reading: *Modern Control Systems*, by Dorf RC, Bishop RH. Pearson/Prentice Hall, ISBN 0-13-600152-1
- Supplemental reading: *Feedback and Control Systems*, by DiStefano JJ, Stubberud AR, Williams IJ. Schaum's Outlines, ISBN 0-07-017052-5

A class web page exists at `http://photonics.engr.uga.edu/controls`, and course details, homework assignments and announcements can be found on that web page. Students are encouraged to visit that web page frequently.

5 Grading Policy

Grades will be assigned by a percentage of earned grade points. Grade points are awarded following the fill-the-bucket principle for:

- Quizzes (about 25% of the total score)
- Semester project (about 20% of the total score)
- Midterm exam (about 25% of the total score)
- Final exam (about 30% of the total score)

Grades are related to the percentage of earned grade points as follows:

Grade points (%)	Grade
95 or more	A
90 or more	A-
85 or more	B+
80 or more	B
75 or more	B-
70 or more	C+
65 or more	C
60 or more	C-
55 or more	D+
50 or more	D

The minimum passing score is 50% of the achievable score.

[1] This textbook is available on-line through the UGA library. Students are provided with a link for free download

6 Reference to the University Honor Code and Academic Honesty Policy

As a University of Georgia student, you have agreed to abide by the University's academic honesty policy, A Culture of Honesty, and the Student Honor Code. All academic work must meet the standards described in A Culture of Honesty found at: `http://www.uga.edu/honesty`. Lack of knowledge of the academic honesty policy is not a reasonable explanation for a violation. Questions related to course assignments and the academic honesty policy should be directed to the instructor.

7 Course Learning Objectives

By the end of this course, students should have:

1. obtained an understanding of the effect of feedback in linear systems
2. gained the ability to quantitatively describe a given system (e.g., equations, block diagram)
3. gained the ability to predict the stability behavior, and the dynamic and steady-state response of feedback control systems
4. acquired the ability to apply various feedback control analysis and design methods
5. learned how to simulate a feedback control system in software
6. learned how to design and build a closed-loop system to meet a required behavior

8 Additional ABET-Relevant Information

8.1 Student Learning Outcomes

For Course Learning Objectives, see Section 7. Overall, this course contributes to the following Student Learning Outcomes:

a. An ability to apply knowledge of mathematics, science, and engineering (yes)

b. An ability to design and conduct experiments, as well as to analyze and interpret data (yes)

c. An ability to design a system, component, or process to meet desired needs (yes)

d. An ability to function on multi-disciplinary teams (yes)

e. An ability to identify, formulate, and solve engineering problems (yes)

f. An understanding of professional and ethical responsibility (no)

g. An ability to communicate effectively (yes)

h. The broad education necessary to understand the impact of engineering (no)

i. A recognition of the need for, and an ability to engage in life-long learning (no)

j. A knowledge of contemporary issues (no)

k. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice (yes)

The course learning objectives relate to the Student Learning Outcomes in detail as follows:

Course Learning Objective	Relationship to Student Outcome						
	a	b	c	d	e	g	k
1. Understand the effect of feedback in linear systems	✓	–	–	–	✓	–	–
2. Describe & characterize a system (equations, block diagram)	✓	–	–	–	✓	–	✓
3. Predict stability and response	✓	–	✓	–	✓	–	✓
4. Master analysis and design methods	✓	✓	–	–	–	–	✓
5. Simulate a feedback system in software	✓	✓	✓	–	✓	–	✓
6. Design a closed-loop system	✓	✓	✓	✓	✓	✓	✓

8.2 Assessment of Learning Objectives

1. Understand the effect of feedback in linear systems: This introductory topic is predominantly covered in the first half of the semester. Assessment is based on percent scores of:

   - HW 1: Two-point control (basic principle of feedback, application of simple math do predict system response)
   - HW 3: Dynamic response (examining the effect of a controller with variable parameters, application of mathematics for analysis)
   - Midterm (choice of controllers and controller parameters, application of mathematics)

2. Describe & characterize a system (equations, block diagram): The mathematical tools are taught in the first half of the semester. Assessment is based on percent scores of:

   - HW 2: Block diagrams (schematical description of control systems)
   - HW 3: Dynamic response (open- and closed-loop comparison, block diagram description)
   - Midterm (choice of controllers and controller parameters, application of mathematics)

3. Predict stability and response: Stability and quantitative assessment of the system response is taught in the middle third of the semester. Assessment is based on percent scores of:

   - HW 4: Stability (Stability determination, how to achieve stability)
   - HW 5: Software simulation (optimization of the dynamic response given design goals and constraints)

4. Master analysis and design methods: Throughout the semester, formal methods to analyze and design a system are taught. Assessment is based on percent scores of:

   - HW 2: Block diagrams (block diagram manipulation rules)
   - HW 4: Stability (Routh-Hurwitz method)
   - HW 6: Absolute and relative stability in the frequency domain (Bode diagrams)
   - HW 7: Pole placement in the s-domain (Evans root-locus method)

5. Simulate a feedback system in software: After mastering the mathematical foundations, students use simulation tools to meet given design goals. Assessment is based on percent scores of:

   - HW 5: Software simulation (optimization of the dynamic response given design goals and constraints, comparison of math-based theory with simulation)

6. Design *and build* a closed-loop system: Students pursue a hands-on semester project whose underlying goal is to stabilize an unstable system. Assessment is based on the successful completion of the semester project with the following sub-goals:

   - Percent of teams that met the design goals
   - Number of awards won by exceeding the design goals in a previously defined fashion

- Peer-evaluation of student presentations combined with grade score given for written project reports
- Peer-evaluation of teamwork quality