

MAE 660 Feedback Control in Mechanical Engineering

SYLLABUS

Fall Semester 2011

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Course topics:

- mathematical modeling of physical systems – mechanical, electrical, fluid, and thermal systems;
- control system design using Root Locus;
- design of control systems in Frequency Domain, Bode plots;
- State Space modeling;
- Full State Observer design;
- State Space controller design;
- introduction to Optimal Control;
- introduction to Robust Control;

Textbook:

K. Ogata, *Modern Control Engineering*, 4th Edition, Prentice Hall, 2002, ISBN 0-13-060907-2. We will focus on Chapters 3, 4, and 7-12.

Recommended (not required): W. L. Brogan, *Modern Control Theory*, 3rd Edition, Prentice Hall, 1991. Some handouts will also be provided.

Pre-requisites:

MAE460 or an equivalent undergraduate course in automatic controls; proficiency with Matlab and Simulink.

Course objectives:

The overall objective of this class is to provide the students an advanced perspective on linear control theory and practice. This class is intended to reinforce and extend knowledge the students have from MAE 460 or an equivalent undergraduate controls course. Some time will be spent in the beginning covering system modeling — how to start with a description of a physical system and end up with a transfer function/block diagram model or a state space model from which to design a controller. The design

procedures using the Root Locus will be reviewed and expanded. A substantial part of this class will address issues related to the design of control systems in Frequency Domain. Special attention will be given to the use of State Space representation of dynamic systems for modeling and control. Finally, other advanced topics in controls, such as Optimal Control and Robust Control will be addressed at an introductory level, if time permits.

Learning outcomes

At the end of this course, the students should be able to:

- develop mathematical models using the transfer function and the state space representation for mechanical, electrical, pneumatic and hydraulic, and thermal physical system;
- design control systems using Root Locus;
- design control systems in Frequency Domain;
- draw the Bode plots for dynamic systems and use it to evaluate stability and performance characteristics;
- design full state observers;
- design control systems using the State Space representation;
- formulate and solve linear quadratic regulator problems;
- formulate a Robust Control problem to ensure robust stability and performance.

Course structure:

1.5 hour lectures - TR 11.00-12.15 in G24

help/problem sessions - if necessary

Office hours: TR 9.00-10am and 3.30-5.00pm. If necessary and possible, I will gladly schedule individual appointments at different times.

Web Site Access

Use your MIX account to access the eCampus system at <http://ecampus.wvu.edu/>. Lecture notes, handouts, homework, additional material, and announcements will be posted there. ***Check your eCampus e-mail account often.*** Note: You must set up your eCampus account specifically if you want your e-mail messages forwarded to your MIX account.

Exams:

There will be two midterm exams and a comprehensive final exam. All three exams will be closed book.

Homework:

Homework is individual unless it is specifically assigned as a team/group effort. Homework will be assigned for practice and solutions will be provided for you to check your work. You will receive half of the credit just for turning in all the assignments by the due date and show a decent effort to solve the problems. I will grade one or two occasional assignments for the other half of the credits. Homework is due at the beginning of the class on due date. Late submissions are not accepted.

Quizzes:

There will be a few (4-5) announced quizzes on the material covered since the previous quiz (see tentative schedule).

Attendance: You are strongly encouraged to attend lectures, although it is not mandatory. If you miss a class, you are responsible for the material covered in the class, irrespective of your absence. It is a very bad idea to miss a quiz or exam. Unless you notify me in advance of the scheduled exam time, I may not generate a makeup.

Grading

Midterm 1 & 2: 20% each

Final exam: 30%

Quizzes: 15%

Homework: 15%

A= 90% - 100%

B= 80% - 89%

C= 70% - 79%

D= 60% - 69%

F= <60%

Neatness and clarity are important for all assignments.

Academic integrity/dishonesty policy

Check WVU web page: <http://www.arc.wvu.edu/admissions/integrity.html>

WVU Social Justice Statement

West Virginia University is committed to social justice. The instructor of this course expects to maintain a positive learning environment based upon open communication, mutual respect, and non-discrimination. Our University does not discriminate on the basis of race, sex, age, disability, veteran status, religion, sexual orientation, color, or national origin. Any suggestion as to how to further such a positive and open environment in this class will be appreciated and given serious consideration.

If you are a person with a disability and anticipate needing any type of accommodation in order to participate in this class, please advise me and make appropriate arrangements with Disability Services (293-6700).

Tentative Course Schedule

Week #1: Mathematical modeling of physical systems (classical). Mechanical translational and rotational systems, levers and linkages, DC motors, solenoids, electromechanical sensors and components.

Week #2: Mathematical modeling, continued. Pneumatic and hydraulic systems, thermal systems, linearization, coupling.

Week #3: Finish modeling and block diagrams. Review/finalize pneumatics. Diaphragms, bellows, feedback linkages. Thermal systems example. Introduction to Root Locus. System response vs. S-plane pole locations. Quiz 1.

Week #4: Root Locus analysis of system dynamics. System design using Root Locus. Manual construction of root locus plots. Practice & examples. Primer on using Matlab for RL Plots. Quiz 2.

Week 5: Review, Exam 1.

Week 6: Compensator design on the S-plane. P+ D controllers. Lead filters - design and effect on performance. P+I Controllers. Lag filters - design and effect on performance.

Week #7: Bode Plots, steady state error and stability analysis, design of control systems in Frequency Domain. Quiz 3.

Week #8: System design in classical control. Integration and practice.

Week #9: Introduction to State Space modeling. Stability analysis in the State Space. Pole placement controller design. Pole placement criteria. Quiz 4.

Week #10: Observability and Controllability. Full state observer design. Reduced order observer design. Pole placement with observer feedback.

Week #11: Review, Exam 2.

Week #12: State Space Controller Design. Reference inputs.

Week #13: Introduction to optimal control, linear quadratic regulator, internal model control. Practice. Quiz 5.

Week #14: Thanksgiving break.

Week #15: Introduction to Robust Control.

Week #16: Review and wrap-up.

Final Exam.