Cleveland State University

Department of Mechanical Engineering

MCE 441 Introduction to Linear Control Systems
MCE 541: Linear Control Systems

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Office Hours: Tuesday and Thursday, 3:00-5:00 PM. Other times by appointment.

Text : *Modern Control Systems* by Dorf and Bishop, any edition≥9th.

Objectives The course objective is to enable the student to design linear control systems using classical methods. Matlab and Maple will be used throughout the course.
Course Outcomes Students should be able to:

1. Have a basic understanding of the history of the discipline of automatic control and the motivations for its development. Be aware of the applications of control to current and future engineering problems.
2. Construct simple linear dynamic models of mechanical, electrical, electromagnetic and mixed systems. Perform model conversions between transfer function, state-state space and ordinary differential equation. Manipulate and reduce transfer function block diagrams.
3. Be able to obtain the linearization of a nonlinear system of ordinary differential equations about an equilibrium point.
4. Predict and sketch the response of simple systems to step inputs by transfer function analysis. Understand the effects of pole and zero locations in system response. Compute the response of more complex systems numerically using Matlab. Design system parameters to meet open-loop transient response specifications.
5. Understand the benefits and limitations of feedback. Understand the effects of proportional, integral and derivative actions. Evaluate the open-loop and closed-loop stability of systems using the Routh criterion. Predict closed-loop transient response characteristics and steady state errors.
6. Use the Root Locus technique for closed-loop response prediction and parameter selection. Design basic compensators using time-domain techniques. Tune PID controllers by the Ziegler-Nichols technique.
7. Predict system response using frequency domain techniques. Sketch Bode plots of simple transfer functions. Approximate a transfer function from a Bode plot. Evaluate the stability of closed-loop systems using the Nyquist criterion.
8. Translate time based specifications such as steady state error, disturbance rejection, noise attenuation and transient behavior into the frequency domain. Design compensators using frequency domain techniques: lead-lag and loop shaping. Understand and use the Nichols diagram. Write design routines in Matlab. Design compensators targeting specific phase and gain margins.
9. Understand practical limitations of theoretical control laws: discrete-time implementation, finite-precision arithmetic, computational delay, complexity and hardware constraints.
10. For MCE541: Deploy a control system to real-time hardware after completing the modeling-validation-simulation-control design and simulation cycle.

Grading and Attendance Policies Class attendance will have an influence on the grade. There will be 4 quizzes, 6 homework assignments, two midterm exams and one final exam. A project option will be given as an alternative to the final in-class exam. The project is mandatory for MCE541 students in addition to the final exam. The grade will be computed as follows:

$$GR = 0.15Q_4 + 0.25H + 0.3E_m + 0.3E_f$$

where Q_4 is the quizzes average, H is the average of collected homework assignments, E_m is the average of the midterms and E_f is the average of final exam and project. Cutoff numerical grades for conversion to letter grades will be as follows:

Range	Letter
85 – 100	A
75 – 84	B
65 – 74	C
50 – 64	D
0 – 49	F

Subranges for grades (A-, B+ etc) will be determined and announced toward the end of the semester. Make-up quizzes will not be administered. Make-up examinations will be arranged only due to extenuating circumstances, after proper justification is submitted.

Evaluation Policies for MCE541 MCE541 students will find additional and/or substitute problems and questions in all quizzes, homeworks and exams. In addition, MCE541 students will have a separate final exam and a mandatory final project involving laboratory deployment of a feedback controller. Otherwise, grade calculations are the same as for MCE441.

Tentative Schedule

Session	Date	Topic/Activity
1	08-30	Overview of course objectives. History and motivations of Automatic Control. Examples.
2	09-01	Open-loop vs. closed-loop. Feedback architectures and block diagram sketching.
3-4	09-06,08	QUIZ 1 (15'). Physical system models.
5-6	09-13,15	Laplace transforms and transfer function models.
7-9	09-20, 22, 27	Quiz 2. Poles, zeros and time response. Midterm revision.
10	09-29	MIDTERM 1.
11-12	10-4,6	Block Diagram manipulations. Stability definitions and the Routh-Hurwitz criterion.
13-14	10-11,13	QUIZ 3 (20') Closed-loop performance: Stability, system type and SS error.
15-17	10-18,20,25	Root-Locus techniques. Midterm revision.
18	10-27	MIDTERM 2.
19	11-1	Basic PID compensator design. Ziegler-Nichols PID tuning.
20-22	11-3,8,10	QUIZ 3 (20') Frequency domain analysis. Bode plots.
23-24	11-15,17	Phase and gain margins, Nyquist criterion.
25-26	11-22,29	Introduction to frequency domain design: specifications, compensator design.
27	12-1	Case study in control design.
28	12-6	State-space representations and conversions with transfer functions.
29	12-8	QUIZ 4 (20') Practice problems for final exam.
*	12-6th to 9th	Laboratory sessions for final projects (MCE541)
*	12-13	Final Exam. 1-3 PM

Course website
`http://academic.csuohio.edu/richter_h/courses/mce441`
Class notes, announcements, homework and exam solutions will be posted. The site also contains interesting links and Matlab program downloads.

Academic Integrity Academic dishonesty will not be tolerated and will be handled according to University policy: `http://www.csuohio.edu/studentlife/StudentCodeOfConduct.pdf`

Prepared by Dr. Richter, Fall 2011.