ECE4510/ECE5510
FEEDBACK CONTROL SYSTEMS

*Linear analysis and analog simulation of electrical, chemical, hydraulic, and mechanical systems using block diagrams and signal-flow graphs. Comparison of open- and closed-loop configurations. Feedback control system design using Nyquist, Bode, and root-locus methods. Effects of simple networks on system response. Introduction of state-variable techniques and digital computer solutions. **Prer., ECE2205 or equiv**.*

Instructor: Dr. Gregory L. Plett   **Office:** EN-290   **Phone:** 255–3468   **email:** gplett@uccs.edu
Course web-page: `http://mocha-java.uccs.edu/`

Text: K. Ogata, *Modern Control Engineering*, 5th Edition, Prentice Hall, 2009.

Optional Software: The Matlab® Student Version (full windows version is running in the EAS computer lab). Simulink® will also be used, and is available in the computer lab.

ECE4510 Evaluation:	1) Graded homework assignments; 30% total.
	2) One midterm exam; 30% total.
	3) Final exam, 40%.
ECE5510 Evaluation:	1) Graded homework assignments; 25% total.
	2) One midterm exam; 25% total.
	3) Final exam, 25%.
	4) Final lab-based project, 25%.
Grading:	90–100=A^- to A; 80–89=B^- to B^+; 70–79=C^- to C^+;
	60–69=D^- to D^+; 0–59=F.

Topics	Text	Est. Weeks
1. Introduction to feedback control.	1.1–1.5	0.5
2. System modeling in the time domain.	2.1–2.3, 2.7, 3.1–3.3	1.0
3. Dynamic response.	5.1–5.5	2.0
4. Basic properties of feedback.	5.3, 5.7, 5.8	2.0
5. Stability analysis.	5.6	1.0
6. Root-locus analysis.	6.1–6.2	2.0...(Exam)
7. Root-locus controller design.	6.5–6.8	1.0
8. Frequency-response analysis.	7.1–7.3, 7.5–7.7	2.0
9. Frequency-response design.	7.10–7.13 (10.9)	1.0
10. Digital controller implementation.	—	0.5

Work Load: This is an aggressive course requiring weekly homework assignments. Expect to spend six to nine hours per week outside of class reading the textbook and completing homework assignments. This is in accord with UCCS policy relating credit hours for a lecture course to student workload. Some students will find that more time is required, while others will find that less time is required.

Homework Policy #1: Homework will be collected at the beginning of class on the assigned date. Homework turned in after the class period will be penalized 10%. Homework turned in after the due date will be penalized an additional 25% per day unless previous arrangements have been made with the instructor. Examinations will be based on the homework problems and the material covered in class. It is to your advantage to understand the fundamental concepts that are demonstrated in the homework problems. It will be difficult to earn higher than a "C" without performing well on the homework assignments.

Homework Policy #2: Your homework is expected to be a bona-fide individual effort. Copying homework from another student or other source is CHEATING and will not be tolerated. You may (and are encouraged to) discuss homework problems with other students, but only to the extent that you would discuss them with the instructor. Don't ask another student a question that you would not expect the instructor to answer. Most of us know when we are compromising our integrity. If you are in doubt, ask first.

Homework Policy #3: Part of your engineering education involves learning how to communicate technical information to others. Basic standards of neatness and clarity are essential to this process of communication. Your process of solving a problem must be presented in a logical sequence. Consider your assignments to represent your performance as an engineer. Do not submit scrap paper, and do not submit paper containing scratched out notes. Graphs are to be titled and axes are to be labeled (with correct units). The above standards of clarity and neatness also apply to your work on exams.

Attendance: Attendance is your responsibility. Class lectures will cover a significant amount of material. Some will not be in the text or may be explained differently. It is to your advantage to take notes, ask questions, and to fully participate in the classroom experience.

Missed Exams: Missed exams will count as ZERO without a physician's documentation of an illness, or other appropriate documentation of an emergency beyond your control and requiring your absence.

Drop Date: This course complies with the UCCS campus rules for drop date.

Homework Format Rules: Points will be deducted for failure to comply with the following rules:

1. Use 8 1/2 by 11 paper (engineering paper is good).
2. Write on one side of the paper only.
3. Enclose your final answer to each problem in a box so that it may be clearly identified.
4. Write name and date and homework set number in the right corner.
5. Staple in the upper left corner. Use only one staple!
6. Be sure to write in pencil. Do not use ink to complete your homework assignments.

The Course Reader: These notes have been entered (with thanks to Jonathan Plett for his help) using LyX, and typeset with LATEX2$_\varepsilon$. All diagrams (with the exception of a few scanned photos) have been created using either xfig or MATLAB.

Most of these notes are original to Drs. Plett and Trimboli, but several sections have been adapted from lectures given by Dr. Jonathan How at Stanford University.

Course Objectives

The following are objectives for each unit of the course reader. The student should be able to:

Unit 2: System modeling in the time domain.

- Make differential-equation models for electrical circuits and mechanical-translational, mechanical-rotational and electro-mechanical systems.

- Linearize a nonlinear system around a specific "operating point".

Unit 3: Dynamic response.

- Compute Laplace transforms and inverse Laplace transforms (via partial-fraction expansion).

- Compute system transfer functions.

- Find system pole locations to meet rise-time, settling-time and peak-overshoot specifications.

- Reduce block diagram to rational-polynomial transfer function using *either* diagram manipulation or Mason's rule.

Unit 4: Basic properties of feedback.

- Use Ziegler-Nichols' methods I and II to find PID tuning parameters.

- Find steady-state system error with respect to reference input.

- Find steady-state system error with respect to disturbance input.

Unit 5: Stability analysis.

- Use all cases of the Routh test to determine system stability, or to determine ranges of some controller parameter for system stability.

Unit 6: Root-locus analysis.

- Accurately sketch $180°$ and $0°$ root-locus plots. Must be able to perform all steps, including: real-axis, asymptotes and centroid, arrival and departure angles, crossing of the stability boundary and multiple roots.

- Determine the gain K that places roots at a certain point on the root locus plot.

Unit 7: Root-locus design.

- Design phase-lead and PID controllers using root-locus methods.

Unit 8: Frequency-response analysis.

- Sketch Bode magnitude and phase plots (by hand).

- Determine steady-state errors of a unity feedback system from the open-loop Bode plot.

- Sketch Nyquist plot given a table of frequency-response data or a transfer function.

- Determine system stability and stability margins using Bode plot.

- Determine system stability and stability margins using Nyquist plot.

Unit 9: Frequency-response design.

- Design lead controller or lag controller using frequency-response methods.
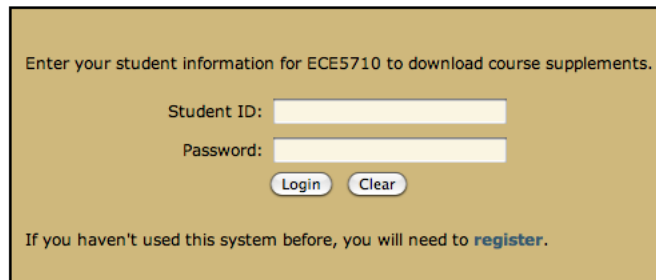
- Design for robustness considerations.

Unit 10: Digital controller implementation.

- Given $G(s)$ (first or second order), find difference equations to emulate using forward-rectangular, backward-rectangular and bilinear rules.

The EduFile Course Supplement Management System (*EduFile*):

The class homepage is accessed via `http://mocha-java.uccs.edu/`. Click on the [+] sign next to the course name, and then click on the link to access course supplements.

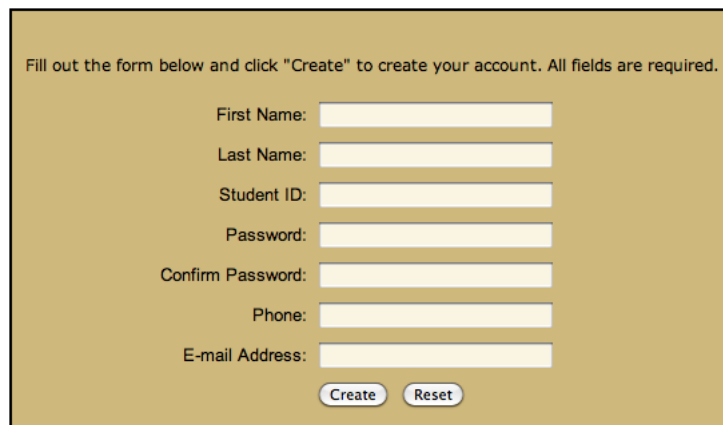Follow this link, and you will be directed to the log-on screen (for 4510/5510):

Enter your student information for ECE5710 to download course supplements.

Student ID: _____

Password: _____

[Login] [Clear]

If you haven't used this system before, you will need to **register**.

The first time you use the system, click on the word "register". You will be directed to the screen:

Fill out the form below and click "Create" to create your account. All fields are required.

First Name: _____

Last Name: _____

Student ID: _____

Password: _____

Confirm Password: _____

Phone: _____

E-mail Address: _____

[Create] [Reset]

Enter the requested information and press "Create". You should see the screen (for 4510/5510):

User Added To Course

The user 111223333 has been added to course ECE5710. You are currently registered in another course with this system. Your student ID has been added to the course you have requested. However, you will not be able to use the system until your account has been enabled by your instructor.

Note that passwords are case-sensitive!

You will not immediately gain access to course supplements. You will receive email notification when your account is enabled for this course. Only then may you log on using your student ID and password. You will see a screen like this (tailored to ECE4710/ECE5710, of course):

Welcome to EduFile

Course Info	
Instructor Name:	Dr. Gregory Plett (glp@eas.uccs.edu)
Course Name:	Modeling, Simulation, and Identification of Battery Dynamics
Course Description:	Derives mathematical models of the electrochemical dynamics of battery cells, including thermodynamic and kinematic properties, at multiple scales. Modern, lithium-ion chemistries are emphasized. Students will use simulation software and will use lab-test data to create and validate parameterized models. Prer., ECE2205, MATH2350, MATH3400 or equiv.

Click on the Filename to download the file you need.

Update Since Last Download?	Downloaded	Filename	File Description
LECTURE NOTES			
No	Yes	CH01-BootCamp.pdf	Lecture notes chapter 1

Edit Personal Info

At the top of the page, the course name, course description and instructor are listed. By clicking on the instructor email address, you may send an email message directly from your web browser to the instructor. Below the course description is a listing of supplements that you may download. These are divided into categories (*e.g.*, ANNOUNCEMENTS, CHAPTER 1…) as assigned by the instructor.

In the figure, we see that this student has downloaded the syllabus and the first chapter of the lecture notes. Furthermore, she is assured that she has the most recent copy of the lecture notes since the flag "Update Since Last Download" says "No". However, the syllabus has been updated since the last time she downloaded it, so she should retrieve the newer version. This student has not downloaded the tutoring schedule or the example Matlab simulation files, which she might want for extra help and understanding of the material. Not shown, because it falls at the bottom of the page, is a button allowing the student to modify her personal information (name, password, and so forth).