

California State Polytechnic University, Pomona

Department of Aerospace Engineering

ARO 322-02

Aerospace Feedback Control Systems

Fall 2009

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Office hours: 9:45AM-10:45AM MW, 1:00PM-2:30PM TTh
Class days/time: Tuesday and Thursday 10:45AM-12:00PM
Classroom: 17-1211
Prerequisites: ENG 104, C or better in MAT 216
Co-requisite: ARO 322L, MAT 318
Course units: 3 Units of Lecture
Department Office: 17-2132, Telephone: (909) 869-2470

Office Hours and E-Mail Inquiries

Students are encouraged to visit me for questions during my office hours or during any other time when I am in the office. I am available via e-mail and respond to most inquiries within 24 hours. Students are also encouraged to use Blackboard Discussion Board within **ARO 322 Discussion Forum** for questions.

Course Usage of Blackboard

Copies of the course syllabus and major assignments may be found on Blackboard. You are responsible for regularly checking the online resources, which is accessed through the portal at <https://bbpilot.csupomona.edu/>. Blackboard eHelp for students can be found at <http://www.csupomona.edu/~ehelp/blackboard/index.html>.

Course Description and Goals

This course is intended to provide, by means of discussion, theory, and experiment, a basic knowledge of Feedback Control Systems. The expected outcome of the course is a basic understanding of Mathematical Models of Physical Systems, Laplace Transformations, Feedback Control Systems (Characteristics, Performance, and Stability), Root Locus Method,

Frequency Response Methods, Stability in the Frequency Domain, Time Domain Analysis, , and Design and compensation of Aerospace Feedback Control Systems.

Student Learning Objectives

Upon completion of the course, the students will able to:

1. Develop transfer-function models of electrical, mechanical, and electro-mechanical systems
2. Describe the performance objectives of control systems.
3. Use root-locus methods to design feedback control systems
4. Use Bode plots to analyze frequency-response performance and to design feedback control systems
5. Learn on how to implement feedback control in real-life
6. Learn practical application of analysis and design techniques in a laboratory environment

Course Outline:

1. Historical Background
 - a. Definition of Control System
 - b. History of Control System
 - c. Examples of Control System
 - d. Open-Loop Control System
 - e. Closed-Loop Control System
 - f. Control System Design
2. Laplace Transforms
 - a. Complex Variable
 - b. Laplace Transformation
 - c. Laplace Transform of Some Time Functions
 - d. Laplace Transform Theorems
 - e. Inverse Laplace Transform
 - f. Partial Fraction Expansion
 - g. Solution of Differential Equation using Laplace Transform
3. Development of Mathematical Models of Physical Systems
 - a. Definition
 - b. Dynamic Models of Various Physical Systems
 - c. Transfer Function
 - d. State-Space Modeling
 - e. Nonlinear and Linearized Systems
 - f. Operational Amplifiers
4. Block Diagrams
 - a. Block Diagram Algebra
 - b. Open Loop Diagrams

- c. Closed Loop Block Diagrams
 - d. Finding Closed-Loop Transfer Function from Block Diagrams
5. Control-Systems Characteristics and Performance Objectives
 - a. Proportional Controller
 - b. Integral Controller
 - c. Derivative Controller
 - d. Proportional-Plus-Integral-Plus-Derivative Controller
 - e. System Error
 6. Transient and Steady-State Performance Analysis
 - a. First-Order Systems
 - b. Second-Order Systems
 - c. Higher-Order Systems
 - d. Transient Response Analysis
 - e. Steady-State Performance
 - f. Stability Analysis – Routh-Hurwitz Criterion
 7. Root Locus Analysis
 - a. Root Locus Plots
 - b. Rules of Plotting Root Locus Plots
 8. Root Locus Design Techniques
 - a. Preliminary Design Considerations
 - b. Lead Compensation
 - c. Lag Compensation
 - d. Lead-Lag Compensation
 9. Frequency-Response Analysis
 - a. Theory of Frequency Response
 - b. Bode Diagrams
 - c. Magnitude and Phase Plots
 - d. Stability Analysis
 - e. Relative Stability
 - f. Nyquist Plots
 - g. Nyquist Stability Criterion
 10. Frequency-Response Design Techniques
 - a. Lead Compensation
 - b. Lag Compensation
 - c. Lead-Lag Compensation

Required Texts/Readings

1. Ogata, Katsuhiko, **Modern Control Engineering**, 5th Ed., Prentice Hall, 2009.

General References:

1. Phillips, Chales L. and Harbor, Royce D. *Feedback Control Systems*, 4th Ed., Prentice Hall, New Jersey (1999).
2. Nise, Norman S., *Control Systems Engineering*, 5th Ed., John Wiley & Sons, Hoboken, New Jersey (2007).

Course Schedule/Assignments

Days	Topics	Reading	Assignments
09/24	Introduction, Laplace Transformation	Chapter 1, Appendix A	Extra Credit Assignment
09/29	Partial Fraction Expansion	Appendix B	Homework Assignment #1
10/01	Mathematical Modeling of Mechanical Systems	2.1-2.2, 3.1-3.2	-
10/06	Mathematical Modeling of Electrical Systems	3.3 (up to electronic controllers)	Homework Assignment #2
10/08	Modeling in State-Space, Block Diagrams	2.3, 2.4	-
10/13	Transient and Steady-State Response Analysis	5.1-5.3	Homework Assignment #3
10/15	Continuation of Transient and Steady-State Response Analysis	5.4-5.5	-
10/20	Routh-Hurwitz Criterion	5.6	Homework Assignment #4
10/22	Basic Control Actions and System Types	5.7-5.8	
10/27	Root Locus Analysis	6.1-6.2	Homework Assignment #5
10/29	Continuation of Root Locus Analysis	-	-
11/03	Midterm	-	Homework Assignment #6
11/05	Operational Amplifiers	3.3 (starting from electronic controllers)	-
11/10	Operational Amplifiers Continued	-	Homework Assignment #7
11/12	Control System Design using Root Locus Method	6.5-6.6	-
11/17	Control System Design using Root Locus Method	6.7-6.8	Homework Assignment #8
11/19	Frequency Response Analysis	7.1-7.2, 7.3	-
11/24	Continuation of Frequency	7.5, 7.6, 7.7	Homework Assignment #9

Days	Topics	Reading	Assignments
	Response Analysis		
11/26	Thanksgiving Holiday		-
12/01	Control System Design using Frequency Response	7.7	Homework Assignment #10
12/03	Continuation of Control System Design using Frequency Response	7.10-7.13	

Course Usage of Software

This class will make extensive use of MATLAB and Simulink. These are available on the school computers, but you may wish to buy your own copy of the Student Version. Depending upon the version, additional toolboxes may be required. They can be purchased and downloaded online from the Mathworks, www.mathworks.com. You may also be able to purchase the software at the CPP Bookstore.

Grading Policy

Grading will be based on a weighted average of the following items:

- Assignments 10%
- Quizzes (5) 20%
- Midterm exam 25%
- Final exam 25%
- Project report 10%
- Research paper 5%
- Class Participation (Attendance, Blackboard Discussion Board, etc.) 5%

Grading Scale:

A = 93 or higher	A- = 90 – 92.9%	
B+ = 87%-89.9%	B = 83 – 86.9%	B- = 80 – 82.9%
C+ = 77%-79.9%	C = 73 – 76.9%	C- = 70 – 72.9%
D+ = 67%-69.9%	D = 63 – 66.9%	D- = 60 – 62.9%
F = 59.9% or less		

I may curve the grades at the end.

Reading assignments given in the schedule *should be done before class session*. The lecture will make a lot more sense if you've done the reading beforehand.

Homework assignments will be given each Tuesday and *are due at the beginning of the class following Tuesday*. **No late work will be accepted** without prior arrangement. Partial credit will be given, so it is to your advantage to hand in a problem even if you haven't finished it. You will lose credit for the following flaws in your assignments:

- Failure to include all units or dimensions in all calculations
- Sloppy or unreadable writing, or writing on the back side of sheets
- Failure to follow the instructions at the back of this handout

You are encouraged to form “study groups” and work with your fellow classmates on the homework. However, **DO NOT COPY** someone else’s paper. Copying serves no purpose and will not help you prepare for the quizzes and final. You should be sure you understand what you have put down on the paper if you wish to do well on quizzes and the final; consider it “practicing” for these events. *You are responsible for all the assigned material whether you turn in the homework or not.*

Quizzes will be closed-book, closed-notes, emphasizing basic concepts.

Project Report

Project report should consist of:

1. A cover page containing the course number and title, the title of the project, student’s name, group number and the date of submission.
2. A summary containing the objectives, important results, and conclusions.
3. Table of Contents
4. A discussion of the results, tables, and figures.
5. An appendix with sample calculations.

Research Paper

Research paper should be posted online as a blog and should consist of:

1. An abstract
2. Literature survey
3. Current research
4. Future directions

Extra Credit

There may be some opportunities to earn extra credit in this class. Extra credit problems will be given in the class.

Online Discussion Evaluation Criteria

CATEGORY	4	3	2	1
Mechanics of Posting	Complete sentences, well organized, grammatically correct and free of spelling errors	Complete sentences, well organized, but some (2 or less per paragraph) grammar and/or spelling errors	Complete sentences, comprehensible, organization could be improved to present a more coherent argument or statement, has three or more grammar and/or spelling errors per paragraph	Poor sentence structure inadequate organization, several grammar and/or spelling errors
Participation in Discussion	Provides comments and new information in a regular and equitable manner. Interacts with a variety of participants	Provides comments and some new information in a fairly regular manner. Interacts with a few selected participants	Sporadically provides comments and some new information. Interacts with only one or two participants	Provides minimal comments and information to other participants
Content of Posting	Revealed a solid understanding of the topic as evidenced by thoughtful responses and questions	Revealed an adequate understanding of the topic as evidenced by posts indicating superficial knowledge	Revealed a restricted understanding of the topic limited to information that could be derived from prior posts	Message was unrelated to discussion
Critical Thinking Evidenced by Posting	Offered a critical analysis of an existing posted idea or introduced a different interpretation to an existing idea	Agreed or disagreed with existing discussion and provided limited justification/explanation	Agreed or disagreed with existing discussion but provided no justification/explanation	Provided no evidence of agreement or disagreement with existing discussion

Midterm Exam

Midterm exam will be given tentatively on Thursday, November 5 from 10:45 am-12:00 pm. Midterm exam will be open-book, open-notes, emphasizing quantitative- and derivation-type problems.

Final Exam

Final exam will be given on Thursday, December 10 from 9:10 am-11:10 am. Final exam will be open-book, open-notes, emphasizing quantitative- and derivation-type problems.

Dropping and Adding

You are responsible for understanding the policies and procedures about add/drops, academic renewal, etc. found at <http://www.dsa.csupomona.edu/registrar/Registration.asp>. You should be aware of the new deadlines and penalties for adding and dropping classes.

Disability Services

Any student who feels s/he may need an accommodation based on the impact of a disability should contact me privately to discuss your specific needs. Please also contact the Disability Resource Center (Building 9, Room 103, Phone: 909-869-3333) to coordinate reasonable accommodations. For more information, visit Disability Resource Center website: <http://dsa.csupomona.edu/drc/>.

Learning Resource Center

Learning Resource Center (LRC) is a comprehensive academic support service that assists students in achieving scholastic excellence. The Center's programs improve self-confidence and create independent and more effective learners. The LRC is located in the University Library. For more information, visit the website: <http://www.csupomona.edu/~lrc>

University Writing Center

University Writing Center is located in the Building 15, room 2919. The Center offers One-on-one tutoring session for any writing assignment, writing workshops for particular English courses and assistance with Graduate Writing Test (GWT) preparation. For more information, visit <http://www.csupomona.edu/~uwc/> or call 909-869-5343.

Library Resources

Students are encouraged to take advantage of the resources available at the University Library, building 15. For more information, visit <http://www.csupomona.edu/~library/>. For Engineering resources, visit <http://www.csupomona.edu/~library/blackboard/disciplines/engineering.html>. The Library can

deliver documents that are not available in the library. You can request delivery of the documents by logging onto Document Delivery at <http://illiad.library.csupomona.edu/illiad/logon.html>.

Help Desk

For information technology (IT) related issues including Blackboard, Broncodirect, E-mail, etc., please contact Help Desk (Building 1, Suite 100, and Phone: (909) 869-6776). Help Desk website: <http://www.csupomona.edu/~ehelp/>.

Academic Integrity

Students are expected to be familiar with the University's Academic Integrity Policy. Your own commitment to learning, as evidenced by your enrollment at California State Polytechnic University, Pomona, and the University's Academic Integrity Policy requires you to be honest in all your academic course work. The cases of academic dishonesty and plagiarism will be dealt with as per the university policy and as outlined on page 54 of the current university catalog (2007-2009).

The policy on academic integrity and other resources related to student conduct can be found at: <http://dsa.csupomona.edu/judicialaffairs/academicintegrity.asp> and <http://dsa.csupomona.edu/judicialaffairs>.

Copyright and Fair Use Policy

Information about Copyright and Fair Use Policy can be found at the following website: <http://www.csupomona.edu/~copyright/>.

Electronic Mail (E-Mail):

The Cal Poly Pomona (CPP) e-mail system is the official method of communication between faculty and students. All students are required to use their CPP assigned e-mail address for communication with the instructor.

Classroom Protocol

Students are expected to

- Be on time for the class and to stay once class starts.
- Turn off cell phones in class.
- Be respectful of other students and instructor.
- Use proper format for all homework.
- Not talk in class.

Netiquette

Just as you follow the rules of etiquette in our face-to-face relations with others, when you communicate online, you should follow the rules of online etiquette, often known as "netiquette." The following are some general guidelines for participants in electronic class discussion lists:

- Respect the fact that the class list is a closed discussion; do not forward mail from your classmate to others without their permission.
- Debate is welcome, but be tactful in responding to others. Remember that there is a person (or a whole class) at the receiving end of your post.
- If you want to get in touch with only one person in the class, send a message to that individual's E-mail address, not to the entire discussion list.
- If you are responding to a message from someone else, briefly summarize his or her post.
- Make your paragraphs a bit shorter than usual - perhaps three sentences or so. This makes your message easier to read on the screen.
- When speaking to someone, we use a variety of signals (such as body language and tone of voice) to let them know how to interpret our words. In E-mail we lack such signals and tone can be hard to judge. If you think your tone might be misinterpreted, let your readers know what it is. For instance, if you are making a joke, tell people "Joke" - or consider including a "smiley" :).