AE 3531-A: Control Systems Analysis and Design

Course Syllabus

Instructor: Prof. Kyriakos G. Vamvoudakis

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Time & Location: WF, 2:00pm - 3:15pm, Mason 1133

Office Hours: WF, 12:00pm - 1:45pm, Montgomery Knight Building, Office 415-B

TA and Office Hours: Mr. Corbin Klett (corbin@gatech.edu) TTh, 10:00am – 12:00pm TSRB 434

These are the "formal" office hours. However, you are more than welcome to stop by my office any time, should you have any questions regarding the course material. Additionally, appointments can be arranged to discuss any questions regarding the course material. The easiest way to reach me is, however, via e-mail.

Course Web Page: All relevant information on the class will be disseminated electronically at canvas.

Textbooks: Modern Control Engineering, by K. Ogata, Prentice-Hall, New Jersey, 2002, (5th edition).

References:

There exist many excellent books on the subject. Below is a partial list. Please feel free to consult these and any other books you may want that will assist you in comprehending the class material. These books have been placed on reserve at the Engineering Library and should be available during the semester.

Control Systems Engineering, by N. S. Nise, John Wiley, New York, 2008, (5th edition).

Modern Control Systems, by R. Dorf and R. Bishop, Addison-Wesley, 2000, (9th edition).

Feedback Control of Dynamic Systems , by G. F. Franklin, J. D. Powell, and A. Emami-Naeini, Prentice-Hall, 2002, (4th edition).

Feedback Systems: An Introduction for Scientists and Engineers, by K. J. Astrom and R. Murray, Princeton University Press, 2008.

Prerequisites: System Dynamics and Vibrations (AE 3530), Differential Equations (MATH 2403).

Required Software: Student Edition of Matlab

Course Description and Topics: Control system performance analysis and specifications, classical methods of control system analysis and design, introduction to modern control methods.

Course Topics and Schedule:

I. Introduction to Control Systems (6 hours)	Section
1. Examples of Control Systems	1-2
2. Open-Loop versus Closed-Loop Control	1-3
3. Feedback Block Diagrams and their Simplification	2-3
4. Mason's Gain Formula	Notes
5. Mathematical Modeling of Dynamical Systems	2-4
6. Modeling in the State Space	2-4
7. Transfer Functions and Impulse Response Functions	2-3

II. Transient and Steady-State Response Analysis (6 hours)	Section
1. First- and Second-Order Systems	5-2, 5-3
2. Higher-Order Systems	5-4
3. Transient Response Analysis	5-5
4. Time Domain Performance Specifications	5-3
5. Delay Time, Rise Time, Peak Time, Maximum Overshoot, Settling Time	5-3
6. Stability Analysis and Routh's Stability Criterion	5-6
7. Proportional, Derivative, and Integral Control Actions	5-7
8. Steady-State Error Analysis in Feedback Systems	5-8

III. Root Locus Analysis (5 hours)	Section
1. Root Locus Plots	6-2
2. General Rules for Constructing the Root Locus	6-3
3. Positive feedback Systems	6-4, 6-5
4. Parameter Variation	6-5, 6-6

IV. Frequency-Response Analysis (8 hours)	Section
1. Bode Diagrams	7-2
2. Nyquist Plots	7-3, 7-5
3. Stability and Relative Stability Analysis	7-6, 7-7
4. Systems with Transport Lags	7-2
5. Gain and Phase Margins	7-8
6. Closed-Loop Frequency Response	7-8
7. Frequency Domain Performance Specifications	7-10
8. Peak Resonance, Resonant Frequency, and Bandwidth	7-3

V. Time and Frequency Domain Design of Control Systems (8 hours)	Section
1. PID Design	8-2, 8-3, 8-4
2. Lead-Lag Compensation	7-1, 8-7
3. Sensitivity and Complimentary Sensitivity Transfer Functions	Notes
4. Disturbance Rejection and Loop Shaping	8-5

VI. Analysis and Control Design in the State Space (9 hours)	Section
1. Lyapunov Stability, BIBO Stability	Notes
2. State Transition Matrix	9-4
3. Controllability and Observability	9-6, 9-7
4. The Lyapunov Equation	Notes
5. Full-State Feedback Control Design and Pole Placement	10-2, 10-3
6. Optimal State Space Control System Design	10-8

7. Linear-Quadratic Regulator 10-8, 10-9

Tentative Grading Policy
The grades will be determined based on class participation, homework assignments, two mid-terms, and a final exam according to the rule:
Total = CP x 5 % + Hmwk x 20% + Mid-Terms x 40% + Final x 35%.
Class attendance and participation will be considered in borderline cases.
A 90 – 100
B 80 – 90
C 65 – 80
D 50 – 65

Homework Assignments:

- Due at the beginning of the class on the due date. Solutions to the homework will be posted on the web at the time that they are due. Therefore, NO LATE HOMEWORK will be accepted.
- Electronic submissions will be accepted before the class starts.
- Late homework will not be accepted without formal documentation of extenuating circumstances (e.g. a note from a Dean, a physician, etc.).

Course Policies: 1. NO CELL PHONES are allowed during lecture. 2. Be on time to class. Tardy is discouraged. 3. No make-up exams/quizzes. If you miss the exam, a zero score will be assigned to the missed exam/quiz. 4. If you miss a class due to personal emergency or medical reasons, please be sure to inform the instructor by e-mail. 5. Homework assignments are to be submitted by the due date. You may discuss homework problems with your classmates, but you are responsible for your own works. 6. After an assignment grade has been posted online, students must see the instructor within one week if they wish to discuss the assignment and their work.

Principles of Community: Students are expected to be polite and professional when interacting with one another and with the instructor. Abusive or insensitive behavior will not be tolerated.

Academic Support: The instructor will provide assistance through normal protocols, such as office hours, but cannot serve as a private tutor.

Special Accommodations: Special accommodations can be made for students with disabilities. Please bring any such issues to the instructor's attention *no later than the second week of class*.

Health and Well-Being: Georgia Tech and the School of Aerospace Engineering understand that many students experience stress through a variety of academic, financial and personal experiences. We value you and want to make you aware of resources available to you should you need them. Your well-being and mental health are important, and we are here for you.

Center for Assessment, Referral and Education (CARE)		https://care.gatech.edu/
Campus Police (any emergency):	404-894-2500	http://www.police.gatech.edu/
Counseling Center:	404-894-2575	https://counseling.gatech.edu/

Dean of Students Office: 404- 894-6367 https://studentlife.gatech.edu/

Georgia Crisis and Access Line: 800-715-4225

National Suicide Prevention Lifeline: 800-273-TALK (8255) https://suicidepreventionlifeline.org/

Crisis Text Line: Text HOME to 741741

VOICE: Victims Survivor Support: (404) 385-4464 (or 4451) http://healthinitiatives.gatech.edu/well-being/voice

Stamps Health Services https://health.gatech.edu/contact

Tentative Roadmap			Fall 2021 (AE 3531-A)	
Number of Lecture	**date**	**day**	**Topic**	**Reading Assignments**
1	25-Aug	wed	Introduction to Control Systems	1.2, 1.3
2	27-Aug	fri	Feedback Block Diagrams and their Simplification	3.3, 3.9
3	1-Sep	wed	Mathematical Modeling of State Space	3.4, 3.5
4	3-Sep	fri	Transfer Functions and Impulse Response	3.1, 3.2
5	8-Sep	wed	Transfer Functions and Impulse Response	3.1, 3.2
6	10-Sep	fri	First and Second Order Systems	5.2, 5.3
7	15-Sep	wed	Higher Order Systems	5.4, 5.5
8	17-Sep	fri	Time Domain Performance Specifications	5.3
9	22-Sep	wed	Delay Time, Rise Time, Peak Time etc.	5.3
10	24-Sep	fri	Delay Time, Rise Time, Peak Time etc.	5.3
11	29-Sep	wed	Stability Analysis and Routh	5.6
12	1-Oct	fri	Stability Analysis and Routh	5.7
13	6-Oct	wed	PID and Steady State Error Analysis	5.8, 5.9
14	8-Oct	fri	PID and Steady State Error Analysis	5.8, 5.9
15	13-Oct	wed	Root Locus	6.2, 6.3
16	15-Oct	fri	Root Locus	6.2, 6.3
17	20-Oct	wed	Parameter Variation	6.5, 6.6
18	22-Oct	fri	Parameter Variation	6.5, 6.6
19	27-Oct	wed	Lead-Lag	6.7, 6.8
20	29-Oct	fri	Lead-Lag	6.7, 6.8
21	3-Nov	wed	Postitive feedback systems (as a problem in homework)	6.4
22	5-Nov	fri	Bode Plots	7.2
23	10-Nov	wed	Bode Plots	7.2
24	12-Nov	fri	Gain and Phase Margins	7.8
25	17-Nov	wed	Nyquist Plots	7.3, 7.5
26	19-Nov	fri	PID Design	8.2, 8.3, 8.4
27	24-Nov	wed	Lyapunov Equation, Full State Feedback, Ackerman	Notes
28	26-Nov	fri	Thanksgiving	Notes
29	1-Dec	wed	Optimal Control	Notes
30	3-Dec	fri	Optimal Control and Recap	Notes
30	10-Dec	fri	Final Exam	-

These descriptions and timelines are subject to change at the discretion of the Instructor.