

THE UNIVERSITY OF TEXAS AT AUSTIN
Department of Aerospace Engineering and Engineering Mechanics

ASE 330M Linear System Analysis
Spring 2023

SYLLABUS

Unique Number:	14315
Instructor:	David Fridovich-Keil ASE 3.232, dfk@utexas.edu Office hours: M 11-12:30 pm, Tu 2-3pm
Time:	MWF, 10-10:50 am
Location:	ASE 1.126
Teaching Assistant:	Antonio Lopez (alopez@utexas.edu , office hours: W 4-5pm, ASE 3.204) Anegi James (anegij@utexas.edu , office hours: F 3-4pm, ASE 3.204)
Web Page:	Canvas, http://canvas.utexas.edu

Catalog Description:

Explore the fundamentals of signals and systems; mathematical modeling of mechanical systems; transfer function; impulse response; Laplace transforms; response of linear, time-invariant systems; frequency response methods; time-domain analysis; introductory concepts for feedback control systems; multivariate linear dynamical systems; eigenvalues and eigenvectors; matrix exponentials. An introduction to fundamental elements of the theory of systems and signals and exposure to necessary concepts and tools required to perform modeling and analysis of linear dynamical systems. Demonstrate the theory through several simulation examples relevant to applications of modern aerospace engineering systems.

May be counted toward the quantitative reasoning flag requirement.

Course Objectives:

Introduce students to the fundamental elements of the theory of systems and signals and teach them the necessary concepts and tools required to perform modeling and analysis of linear dynamical systems. The theory will be demonstrated through several examples relevant to applications of modern aerospace engineering systems.

Prerequisites:

Engineering Mechanics 311M and Mathematics 427J or 427K with a grade of at least C- in each; and credit with a grade of at least C- or registration for Computational Engineering 311K (or Aerospace Engineering 211K or Computational Engineering 211K).

Knowledge, Skills, and Abilities Students Should Have Before Entering This Course:

Good familiarity with linear algebra, the theory of ordinary differential equations, and the dynamics of mechanical systems is required. Some basic knowledge of either MATLAB or similar software (e.g., Python) will be helpful for the homework assignments.

Knowledge, Skills, and Abilities Students Gain from this Course (Learning Outcomes):

Students will understand the fundamental theory of systems and signals and its application to problems of modeling and analysis of mechanical and aerospace engineering systems.

Impact on Subsequent Courses in Curriculum:

This class is a pre-requisite to the course ASE 370C (Feedback Control Systems).

Text:

This class will **not** use a textbook. However, for additional practice problems and background reading, the following texts are recommended (though not required):

- Åström, K. J. and Murray, R. M. *Feedback Systems: An Introduction for Scientists and Engineers*, Princeton University Press, 2008.
- Oppenheim, A. V. and Willsky, A. S. *Signals and Systems*, Second Edition, Prentice Hall, 1996.
- Close, C. M., Frederick, D. H., Newell, J. C., *Modeling and Analysis of Dynamic Systems*, John Wiley & Sons, Inc., 3rd Edition, 2002.

Other recommended resources:

For linear algebra:

- Linear Algebra: Foundations to Frontiers: <http://ulaff.net> - Essence of Linear Algebra: https://www.youtube.com/watch?v=fNk_zzaMoSs&list=PLZHQObOWTQDPD3MizzM2xVFItgF8hE_ab
- Introduction to Linear Algebra: <https://math.mit.edu/~gs/linearalgebra/> For differential equations:
- Differential equations and linear algebra course: <https://ocw.mit.edu/courses/res-18-009-learn-differentialequations-up-close-with-gilbert-strang-and-cleve-moler-fall-2015/pages/differential-equations-and-linearalgebra/>
- Differential equations course: <https://ocw.mit.edu/courses/18-03sc-differential-equations-fall-2011/>
- Khan Academy: <https://www.khanacademy.org/math/differential-equations>

Class Format:

Class will be held **in person** unless otherwise announced. Lectures will be recorded on Zoom and recordings will be made available to students who miss class with an excused absence.

Attendance:

Regular, in person attendance is expected. If you cannot attend, please notify the instructor by email **as soon as possible**. Excused lecture absences will be granted without documentation for, e.g., medical and religious reasons.

All exams will be held in person. Evidence for an excused absence from an exam day will be required (e.g., doctor's notice).

Final Exam: Thursday, April 27, 1-3:00 pm

Grading:

Grades will be assigned according to the following proportions:

- Homework: 10%
- Quizzes: 25%
- Midterm 1: 20%
- Midterm 2: 20%
- Final exam: 25% **

**If you score higher on the final exam than on either midterm, your final exam grade will replace your lowest midterm grade.

Note: This course will adopt the Plus/Minus Grading Policy. In particular, the passing grades will consist of the following ones: A, A-, B+, B, B-, C+, C, and C-. For more details, please refer to <http://registrar.utexas.edu/students/grades>.

Class outline and schedule:

A tentative schedule is given in the table below. The content of each lecture and assignment due dates are subject to change. Please watch for announcements in class and on Canvas.

Date	Category	Topics	Assignment
1/9	Introduction	Logistics, why system theory, examples	
1/11		Case study: 737 MAX	
1/13	Linear algebra review	Linearity, vector spaces, (in)dependence, inner products	
1/16		HOLIDAY	
1/18		Matrices, domain, rank, range, nullspace	
1/20		Proof techniques 1: rank-nullity theorem	HW 1
1/23		Eigenvectors/values, diagonalization	Quiz 1.1
1/25		Case study: rotation matrices and imaginary numbers	
1/27		Generalized eigenvalues, Jordan decomposition	
1/30		Proof techniques 2: Cayley-Hamilton theorem	Quiz 1.2
2/1	State space systems	Time-invariance, solving LTI ODEs, matrix exponential	
2/3		Modal decomposition	HW 2
2/6		State space stability	Quiz 2.1
2/8		Systems with outputs: observability	
2/10		CANCELLED	
2/13		Systems with inputs: controllability	Quiz 2.2
2/15		Solving LTI ODEs with inputs, convolution	
2/17		Modal decomposition with inputs	HW 3
2/20		Jacobian linearization	Quiz 3.1
2/22		Time discretization, discrete-time trajectories	
2/24		Discrete-time stability, controllability	
2/27	Review		
3/1	Midterm 1		
3/3	Frequency domain	SISO, delta functions, impulse response, convolution	
3/6		Convolutions	
3/8		Eigenfunctions of LTI systems	
3/10		Fourier transforms: a change of basis	HW 4, Quiz 4.1
3/13		HOLIDAY	
3/15		HOLIDAY	
3/17		HOLIDAY	
3/20		More on FTs, eigenfunctions, orthogonality	Quiz 4.2
3/22		Properties of FTs	
3/24		Frequency response	HW 5
3/27		Convolution theorem	Quiz 5.1
3/29		Laplace transforms, region of convergence	
3/31		BIBO stability, revisited	
4/3		LT properties	Quiz 5.2
4/5		LT properties	
4/7	Review		
4/10	Midterm 2		
4/12		Internal model principle	
4/14		PID control design	HW 6
4/17		PID control design	Quiz 6.1
4/19		Special topics	
4/21		Special topics	
4/24	Review		

Homework:

There will be six homework assignments during the semester. Each assignment *and its solution key* will be posted online. Homework assignments will be due approximately every two weeks, and *graded only for completion*. Students are encouraged to collaborate on homeworks; TAs will facilitate collaboration during problem sessions.

Quizzes:

There will be 10 short, in class quizzes. Each quiz will consist of a single question from the previous homework.

Examinations:

There will be two midterm, in class exams. The first examination is scheduled for **March 1**, and the second one for **April 10**. The final exam will be administered in accordance with the University scheduled time as posted in the registrar website. The default final exam time for this course can be found in <https://registrar.utexas.edu/schedules/232/finals> (at present, it shows “**Thursday, April 27, 1:00 pm - 3:00 pm**”). However, it is the student’s responsibility to verify the exact date, time, and location of the final exam. If you score higher on the final exam than on either midterm, we will replace that midterm grade with your final exam grade.

Office Hours:

The instructor will hold office hours in ASE 3.232, tentatively on Mondays from 11-12:30 pm. TAs will hold two weekly “problem sessions” in which students can collaborate with one another on homework and ask TAs for assistance as needed. Times and locations TBA.

To schedule other appointments, please reach out to the course staff by email. Put “ASE 330M” in the subject line, and suggest at least three time slots in which you could meet. **Reach out to the ENTIRE course staff so that everyone is in the loop and you receive a prompt response.**

Important Dates:

Please refer to <https://registrar.utexas.edu/calendars/22-23>.

Policy on Academic Integrity

Students who violate University rules on scholastic dishonesty are subject to disciplinary penalties, including the possibility of failure in the course and/or dismissal from the University. Since such dishonesty harms the individual, all students, and the integrity of the University, policies on academic dishonesty will be strictly enforced. For further information please visit the Student Judicial Services web site: <http://deanofstudents.utexas.edu/sjs/>.

A notice regarding accommodations for religious holidays

By UT Austin policy, a student must notify the instructor of any pending absence at least fourteen days prior to the date of observance of a religious holy day. If the student must miss a class, an examination, a work assignment, or a project in order to observe a religious holy day, the student will be given an opportunity to complete the missed work within a reasonable time after the absence.

Special Notes:

The University of Texas at Austin provides upon request appropriate academic adjustments for qualified students with disabilities. For more information, contact the Office of the Dean of Students at 471-6259, 471-4641 TDD or the Cockrell School of Engineering Director of Students with Disabilities at 471-4321. As in the case of excused absences, lecture notes and recordings will be made available to qualified students with disabilities upon request.

Evaluation:

Note that the Measurement and Evaluation Center forms for the Cockrell School of Engineering will be used during the last week of class to evaluate the course and the instructor. They will be conducted in an electronic format for Spring 2023.

COVID-19 Updates: Spring 2023 Semester

Our best protections against spreading COVID-19 on campus are masks (defined as cloth face coverings) and staying home if you are showing symptoms. Therefore, for the benefit of everyone:

- **Adhere to university mask guidance** (<https://tinyurl.com/UTMaskGuidance>). Masks are strongly recommended indoors regardless of vaccination status.
- **Vaccinations are widely available**, free and not billed to health insurance. For more information, visit <https://uthealthaustin.org/patient-resources/covid-19-updates/covid-19-vaccination>.
- Information regarding safety protocols with and without symptoms can be [found here](#).
- Visit <https://protect.utexas.edu> for updated information and announcements from the university.

To help keep everyone at UT and in our community safe, it is critical that students report COVID-19 symptoms and testing, regardless of test results, to [University Health Services](#), and faculty and staff report to the [HealthPoint Occupational Health Program](#) (OHP) as soon as possible. Please see this [link](#) to understand what needs to be reported. In addition, to help understand what to do if a fellow student in the class (or the instructor or TA) tests positive for COVID, see this [University Health Services link](#).

Sharing of Course Materials is Prohibited: No materials used in this class, including, but not limited to, lecture hand-outs, videos, assessments (quizzes, exams, papers, projects, homework assignments), in-class materials, review sheets, and additional problem sets, may be shared online or with anyone outside of the class unless you have my explicit, written permission. Unauthorized sharing of materials promotes cheating. It is a violation of the University's Student Honor Code and an act of academic dishonesty. I am well aware of the sites used for sharing materials, and any materials found online that are associated with you, or any suspected unauthorized sharing of materials, will be reported to Student Conduct and Academic Integrity in the Office of the Dean of Students. These reports can result in sanctions, including failure in the course.

Class Recordings:

Class recordings are reserved only for students in this class for educational purposes and are protected under FERPA. The recordings should not be shared outside the class in any form. Violation of this restriction by a student could lead to Student Misconduct proceedings. Guidance on public access to class recordings can be found [here](#).

Relationship of Course to Program Outcomes:

This course contributes to the ABET Criterion 3 student outcomes that took effect with the Fall 2019 semester. For more information, see *Criteria for Accrediting Engineering Programs, 2020-2021* at <https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2020-2021/>

STUDENT OUTCOME	
1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	√
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	
3. an ability to communicate effectively with a range of audiences	
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies	

ABET Program Criteria Achieved:

Program criteria are unique to each degree program and are to be compiled from the program criteria given for each degree program and listed in table format below. The faculty should check which of the program criteria are achieved in the course.

Criterion	√	Criterion	√	Criterion	√
A. Aerodynamics		G. Orbital Mechanics		M. Preliminary/Conceptual Design	
B. Aerospace Materials		H. Space Environment		N. Other Design Content	
C. Structures		I. Attitude Determination and Control		O. Professionalism	
D. Propulsion		J. Telecommunications		P. Computer Usage	X
E. Flight Mechanics		K. Space Structures			
F. Stability and Control	X	L. Rocket Propulsion			

Topics:

List the major topics in the course and in parentheses the number of classes in which the topic is covered; assume 42 classes as in a MWF class on a long-session semester for this purpose. Give also in separate parentheses the Program Outcomes and Program Criteria addressed by each topic referenced by letter.

- Introduction to signals and systems, block diagrams (3), (F)
- Mathematical modeling of mechanical systems using ordinary differential equations, stability (16), (F, P)
- Linear approximation of systems (1), (F)
- Laplace transform, Fourier transform, impulse response, convolution (16) (F)
- Transfer function and input-output description of linear systems (6), (F)
- State-variable system models and relationships to input-output system models (5), (F)
- Computer-based analysis of linear systems (1), (P)

Professionalism Topics: Discussion of ethics and teamwork based on instructor's professional experience will be given periodically throughout the semester.

Design Assignments:

There will be no design assignments.

Laboratory Assignments:

There will be no laboratory assignments.

Computer:

Students are strongly encouraged to use computers in order to become familiar with the computer-based techniques for modeling and analysis of linear systems using MATLAB or other similar software. Several homework assignments will require the use of such software for simulation and other analysis.