### EE 5307: LINEAR SYSTEMS ENGINEERING Fall 2016

Instructor: Bahare Kiumarsi Khomartash

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**Office Hours:** before or after class

Section Information: EE5307

Time and Place of Class Meetings: MW 4-520pm, NH 106 Nedderman Hall

**Course objectives:** To provide students with basic knowledge of design and analysis of linear dynamical systems. To lay the foundations of state space design, including stability, controllability, observability, minimality, and duality. To provide design and computer simulation techniques for design of control systems, observers, and regulators. To study system structure in terms of block diagram realizations and Jordan normal form.

### **Course outline:**

### I. SYSTEM ANALYSIS

- Review of Matrix Algebra
- State Variable Systems
  - Linear state equation
  - Nonlinear state equation
- Computer Simulation of Nonlinear Dynamical Systems
  - MATLAB Review
- Review for Continuous-time Systems
  - Laplace transform review
  - Second-order systems
- Continuous-time State Variable Analysis
  - Frequency response and transfer function
  - Time response
  - Relative degree and system zeros
- Stability I
  - Stability of input/output systems and Routh test
  - Stability of SV systems
- Lagrange's Equation and SV Models of Some Representative Systems
- Multivariable Zeros and Minimality
  - Popov-Belevitch-Hautus (PBH) Tests
- System Input/Output Structure Analysis
  - Reachability

- Observability
- Duality
- Review for Discrete-time Systems
  - Z transform review
- Discrete-time State Variable Analysis
  - Frequency response and transfer function
  - Time response
- Expanded State Equation (ESE)
  - Iterative solution of discrete-time systems and DT ESE
  - ESE for discrete-time and continuous-time systems
- Stability of Discrete-time Systems
- Lyapunov Stability Analysis, Open-loop
- Discretization of Continuous-time Systems
  - Sampling the state equation
  - Euler's approximation sampling
  - Effect of sampling on the poles
  - Sampling the transfer function
  - Effect of sampling on the zeros
- Realization and Canonical Forms
  - Reachable and observable canonical forms
  - Parallel canonical form
  - Duality
  - Minimality
- State-Space Transformations and JNF
  - State-space transformations
  - SST and reachability / observability
  - Jordan normal form
  - Kalman decomposition

# **II. SYSTEM DESIAGN**

- State-variable Feedback
  - Reachability
  - Ackermann's formula
  - Multivariable system eigenstructure assignment
  - Linear quadratic regulator
- Digital Control
  - Control for Discrete-time Systems
    - Deadbeat control
    - DT linear quadratic regulator

- Discretization of continuous-time controllers
- Output Injection
  - Observability and duality
  - State observers
- Dynamic Regulator Design
  - Separation principle
- Diophantine Equation Polynomial Design
- Lyapunov Stability and Analysis, Closed-loop
- Output Feedback Control
  - Output feedback design
  - Output feedback design for inverted pendulum
  - Digital output feedback design for inverted pendulum

### Text:

• Chi-Tsong Chen, Linear System Theory and Design

## Grading:

Homework	25%
Exam 1 (1 sheet of notes both sides)	25%
Exam 2 (2 sheets of notes both sides)	25%
Final Exam	25%

The instructor reserves the right to make appropriate changes to the grading policy.

### Submission of Homeworks and Posting of Solutions:

Homeworks and exams should be submitted to the GTA through Blackboard online. Solutions will also be posted on Blackboard.

Attendance is not mandatory. If you skip classes, you will find the homework and exams more difficult. Due to the pace of the lectures, copying someone else's notes may be an unreliable way of making up an absence. You are responsible for all material covered in class regardless of absences.

You will need to use MATLAB including Simulink and the Control Systems Toolbox. MATLAB is available in some of the OIT computer labs and you can also purchase the student edition of MATLAB for your personal computer.

Check the grading of the exams thoroughly. You will have one week after the exam to see me for regrading. After this period, the grade is final

#### **Student Learning Outcomes:**

- 1. Acquire the mathematical tools needed to analyze feedback control systems by state space methods **Assessment** homework design projects and examinations.
- 2. Learn the relation of state space systems to classical forms including transfer functions.

Assessment- design and simulation projects in homeworks, exams.

3. Acquire the mathematical tools needed to study system stability, performance, controllability, observability.

Assessment- homework design projects and examinations.

4. Ability to perform feedback control system design using state variable methods including pole placement and LQR.

Assessment- design and simulation projects in homeworks, exams.

5. Ability to perform designs with various control tools using MATLAB computer simulation toolboxes.

Assessment- computer design and simulation projects assigned in homeworks.

6. Ability to design dynamic feedback systems using state variable form including observers, output feedback and regulators.

Assessment- design and simulation projects in homeworks, exams.

**Drop Policy:** Students may drop or swap (adding and dropping a class concurrently) classes through self-service in MyMav from the beginning of the registration period through the late registration period. After the late registration period, students must see their academic advisor to drop a class or withdraw. Undeclared students must see an advisor in the University Advising Center. Drops can continue through a point two-thirds of the way through the term or session. It is the student's responsibility to officially withdraw if they do not plan to attend after registering. **Students will not be automatically dropped for non-attendance**. Repayment of certain types of financial aid administered through the University may be required as the result of dropping classes or withdrawing. For more information, contact the Office of Financial Aid and Scholarships (http://wweb.uta.edu/aao/fao/).

**Disability Accommodations:** UT Arlington is on record as being committed to both the spirit and letter of all federal equal opportunity legislation, including *The Americans with Disabilities Act (ADA), The Americans with Disabilities Amendments Act (ADAAA),* and *Section 504 of the Rehabilitation Act.* All instructors at UT Arlington are required by law to provide "reasonable accommodations" to students with disabilities, so as not to discriminate on the basis of disability. Students are responsible for providing the instructor with official notification in the form of a letter certified by the Office for Students with Disabilities (OSD).\_ Only those students who have officially documented a need for an accommodation will have their request honored. Students experiencing a range of conditions (Physical, Learning, Chronic Health, Mental Health, and Sensory) that may cause diminished academic performance or other barriers to learning may seek services and/or accommodations by contacting:

<u>The Office for Students with Disabilities, (OSD)</u> <u>www.uta.edu/disability</u> or calling 817-272-3364. Information regarding diagnostic criteria and policies for obtaining disability-based academic accommodations can be found at <u>www.uta.edu/disability</u>.

<u>Counseling and Psychological Services, (CAPS)</u> <u>www.uta.edu/caps/</u> or calling 817-272-3671 is also available to all students to help increase their understanding of personal issues, address mental and behavioral health problems and make positive changes in their lives.

**Non-Discrimination Policy:** The University of Texas at Arlington does not discriminate on the basis of race, color, national origin, religion, age, gender, sexual orientation, disabilities, genetic information, and/or veteran status in its educational programs or activities it operates. For more information, visit <u>uta.edu/eos</u>.

**Title IX Policy:** The University of Texas at Arlington ("University") is committed to maintaining a learning and working environment that is free from discrimination based on sex in accordance with Title IX of the Higher Education Amendments of 1972 (Title IX), which prohibits discrimination on the basis of sex in educational programs or activities; Title VII of the Civil Rights Act of 1964 (Title VII), which prohibits sex discrimination in employment; and the Campus Sexual Violence Elimination Act (SaVE Act). Sexual misconduct is a form of sex discrimination and will not be tolerated. *For information regarding Title IX, visit* www.uta.edu/titleIX or contact Ms. Jean Hood, Vice President and Title IX Coordinator at (817) 272-7091 or jmhood@uta.edu.

Academic Integrity: Students enrolled all UT Arlington courses are expected to adhere to the UT Arlington Honor Code:

I pledge, on my honor, to uphold UT Arlington's tradition of academic integrity, a tradition that values hard work and honest effort in the pursuit of academic excellence.

I promise that I will submit only work that I personally create or contribute to group collaborations, and I will appropriately reference any work from other sources. I will follow the highest standards of integrity and uphold the spirit of the Honor Code.

UT Arlington faculty members may employ the Honor Code in their courses by having students acknowledge the honor code as part of an examination or requiring students to incorporate the honor code into any work submitted. Per UT System *Regents' Rule* 50101, §2.2, suspected violations of university's standards for academic integrity (including the Honor Code) will be referred to the Office of Student Conduct. Violators will be disciplined in accordance with University policy, which may result in the student's suspension or expulsion from the University. Additional information is available at <a href="https://www.uta.edu/conduct/">https://www.uta.edu/conduct/</a>.

**Electronic Communication:** UT Arlington has adopted MavMail as its official means to communicate with students about important deadlines and events, as well as to transact university-related business regarding financial aid, tuition, grades, graduation, etc. All students are assigned a MavMail account and are responsible for checking the inbox regularly. There is no additional charge to students for using this account, which remains active even after graduation. Information about activating and using MavMail is available at http://www.uta.edu/oit/cs/email/mavmail.php.

**Campus Carry:** Effective August 1, 2016, the Campus Carry law (Senate Bill 11) allows those licensed individuals to carry a concealed handgun in buildings on public university campuses, except in locations the University establishes as prohibited. Under the new law, openly carrying handguns is not allowed on college campuses. For more information, visit <u>http://www.uta.edu/news/info/campus-carry/</u>

**Student Feedback Survey:** At the end of each term, students enrolled in face-to-face and online classes categorized as "lecture," "seminar," or "laboratory" are directed to complete an online Student Feedback Survey (SFS). Instructions on how to access the SFS for this course will be sent directly to each student through MavMail approximately 10 days before the end of the term. Each student's feedback via the SFS database is aggregated with that of other students enrolled in the course. Students' anonymity will be protected to the extent that the law allows. UT Arlington's effort to solicit, gather, tabulate, and publish student feedback is required by state law and aggregate results are posted online. Data from SFS is also used for faculty and program evaluations. For more information, visit <u>http://www.uta.edu/sfs</u>.

**Final Review Week:** for semester-long courses, a period of five class days prior to the first day of final examinations in the long sessions shall be designated as Final Review Week. The purpose of this week is to allow students sufficient time to prepare for final examinations. During this week, there shall be no scheduled activities such as required field trips or performances; and no instructor shall assign any themes, research problems or exercises of similar scope that have a completion date during or following this week *unless specified* 

*in the class syllabus*. During Final Review Week, an instructor shall not give any examinations constituting 10% or more of the final grade, except makeup tests and laboratory examinations. In addition, no instructor shall give any portion of the final examination during Final Review Week. During this week, classes are held as scheduled. In addition, instructors are not required to limit content to topics that have been previously covered; they may introduce new concepts as appropriate.

**Emergency Exit Procedures:** Should we experience an emergency event that requires us to vacate the building, students should exit the room and move toward the nearest exit, which is located at either and of the Nedderman Hall Atrium. When exiting the building during an emergency, one should never take an elevator but should use the stairwells. Faculty members and instructional staff will assist students in selecting the safest route for evacuation and will make arrangements to assist handicapped individuals.

Student Support Services: UT Arlington provides a variety of resources and programs designed to help students develop academic skills, deal with personal situations, and better understand concepts and information related to their courses. Resources include developmental education, personal counseling. For individualized referrals, students may visit the reception desk at University College (Ransom Hall), call the Maverick Resource Hotline 817-272-6107, send message resources@uta.edu, or view the information at a to at http://www.uta.edu/universitycollege/resources/index.php.