Introduction to Automatic Control – ME/AE 4310 – Summer 2020
Department of Mechanical and Aerospace Engineering
The University Of Texas at Arlington

Instructor: Prof. P. S. Shiakolas

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Office Hours: Request an appointment through email

Course Assistant: TBA **Office:** Virtual **Office Hours:** TBA and by appointment

Prerequisites: MAE 3319 or MAE 3405

Text: *Control Systems Engineering* by Norman S. Nise, 7th Edition (Hardcopy/Loose Leaf/E-book) preferred

Description of Course Content: Introduction to block diagram algebra, transfer functions and stability criteria. Use of transient response, root locus and frequency techniques in the performance, analysis, design, and evaluation of dynamic control systems. Introduction to state space techniques and experimental demonstrations – time permitting.

Note: *As the instructor for this course, I reserve the right to adjust this syllabus in any way that serves the educational needs of the students enrolled in this course.*

Grading Policy – Expectations – Course Logistics

Assume no collaboration is allowed unless expressed permission is obtained from the instructor.
Anyone collaborating on PQ or HWs will be assigned a grade of zero on the assignment and reported for plagiarism.
Anyone collaborating on an exam will be assigned a failing grade in the course and reported for plagiarism.

Due to COVID-19 and the requirement for online teaching a few changes to the traditional syllabus will be implemented.

Lecture: The lectures will take place using UTA provided resources, mainly through *Microsoft Teams (MST) and/or Canvas*. You will be emailed information on the modality to be used and how to join the lectures. The lectures will start promptly at the university assigned time of 8:00 am on Monday and Wednesday. The lecture "meeting room" will be opened before the lecture starting time to provide time for you to "join and be seated". It is your responsibility to be seated and ready on MST by 8:00 am. Courtesy rules for online teaching are shown below. These rules could be modified and amended as needed for improving the learning environment for all students. You will be promptly notified of any changes.

Before joining: Make sure you have your cameras and microphone OFF to avoid any surprises. You might join in a waiting room and then admitted be the GTA.

After joining and during the lecture:

Your camera must be ON (camera of the respective electronic device you will be using to participate in the lectures).

Your microphone must be OFF during the lecture unless you need to ask a question.

I usually ask students to answer questions, by directing questions either to the whole class or by nam5ing an individual student, and as such you should be ready to participate in this instructional modality. I strongly believe the bi-directional modality to be beneficial and positively contribute to better understanding of the material.

Asking Questions: If you need to ask a question, you must raise your 'electronic hand' in MST and send a note through Chat to the GTA who will inform me of your request, and then wait for me to call on you. Whenever you ask a question, make sure you speak clearly so everyone can understand you. After you answer your question, make sure you turn your microphone OFF.

Disruptive behavior: If anyone displays inappropriate backgrounds or information or is disruptive during the lecture, they will be kicked out of the lecture. If this behavior continues, in the interest of providing a learning environment, the disruptive student will not be allowed to participate in the lectures and I reserve the right to take further actions including but not limited to administratively dropping the student from the course.

You must take responsibility for your own learning!

Electronic Devices and Internet Access: Make sure you have access to electronic devices and internet to participate in the lectures in a synchronous mode and other activities for the course.

If anyone does not have access to needed tools please email me and let me know so I can work with you to help you out.

Attendance and Preparation: It has been undeniably proven that students who come prepare to the lecture by studying the covered material and actively participate in the discussions and complete the assigned work on their own, in general, tend to have better understanding and demonstrate better knowledge of the subject matter. It is your responsibility to come prepare and participate in the discussion and do your own work.

Mini-Assessments: I used to have pop-quiz. In an online format, at any time during the lecture, I will pose questions to the class as a form of mini-assessments. The purpose is to get *feedback;* for me to evaluate your understanding of the concepts and for you to think about the concepts and assess your own understanding. I will ask individual students to answer these mini-assessment during the lecture and present their answers to the whole class.

Homework (0.25 point each and not all assigned problems will be graded): The purpose of the homework (HW) is to provide practice exercises that apply the theory and concepts presented in class in order to identify and inform on any deficiencies a student might have and allow the student the opportunity to seek assistance for improving the understanding. You are *strongly encouraged to discuss* the assigned HW with your classmates, however, *to receive credit you must write, solve and submit the HW on your own and by doing so you will evaluate your understanding, identify areas where you might have questions and deficiencies and try to get help*. If you need assistance, it is your responsibility to reach out to the GTA and the instructor for help.

HW will be analytical and/or computational. It is important that you do not just mechanically apply the theory and just perform the algebra *but try to understand the concepts employed and discuss the results obtained. Take advantage of computer tools to experiment by modifying system parameters and observe the effects on system performance/response characteristics. In this course, generating plots of system responses and critically evaluating and analyzing the plots will improve your understanding of the material.* You must always turn in the software code used to solve the HW and all plots must be briefly discussed. HW will be due on Canvas at the specified day and time. Late HW will not be accepted nor will you be able to make it up except in extreme emergency circumstances. Attempt the homework on your own for your own benefit. ***I reserve the right to ask you to demonstrate any work turned in for credit.***

If any part of a HW set is copied from the solution manual or classmates, the whole HW set will get a grade of zero and the student reported for plagiarism.

HW submission will be in electronic format on Canvas in a single PDF formatted file. *It is your responsibility to submit the HW in the correct format. You can scan your HW using your mobile phones with various utilities such as CamScanner, Notes Writer, Adobe Scan or any other utility you would like to use. You can combine the photos, plots and discussion in a word processing software and then export to PDF. Make sure you use appropriate resolution to avoid generating large size files.* ***Again, every HW set must be a single PDF.***

Mid-Semester Exam: There is no plan for a mid-semester online exam. If plans change, you will be promptly notified.

Final Exam (50 points): The final exam will be *comprehensive* (including all material emailed to you) and may consist of two parts; an analytical and/or a computational. If there will be a computational part, it will be assigned according to university regulations. The exam will be given at the university scheduled time and following university regulations for online exams.

You will be notified of the procedures for the final exam and we might have a testing run as well.

Makeup Exam: There will be no makeup exam except in extreme emergency circumstances and with prior approval.

Exam Rules: There is no formula sheet and you are allowed to use a simple non-programmable engineering calculator.

Key Assignment(s): Students must submit all key assignments. The key assignments will be announced as part of the assigned work.

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Recordings: Recorded lectures will ***not*** be made available on Canvas. *See note on copyright of course materials.*

Expectations for Out-of-Class Study: Beyond the time required to attend each class meeting, you are expected to spend at least 10 additional hours per week for course-related activities, including but not limited to preparing for class, reading required material, completing assignments, preparing for exams, etc.

Guaranteed Grading Scale: The guaranteed grading scale based upon the minimum percentage number of points you earned is **A >= 90%, 90% >B >= 80%, 80% > C >= 70%, 70% > D >=60%, 60% > F**
Note that no incomplete grade will be assigned unless prior arrangements are made and only in extreme circumstances.

Communication: Email communication will be through *your official UTA email account.* It is your responsibility to check your email often for information and/or announcements.

Student Initiated Email: Email must be from your UTA issued email account and must have the subject MAE 4310 – SM 20: Descriptive Title i.e. MAE 4310 – SM 20: HW 2 Exercise 4.3.
Note: Emails not following the correct guidelines will be deleted and no further action will be taken reference to their content. I usually reply to emails within one business day (do not expect an immediate response) towards the end of the day and during normal work hours. The same requirements apply to communication with the GTA as well. You must follow proper decorum in all email communication.

Software: Popular general purpose software tools for simulation and controls include: SCILAB http://www.scilab.org, MATLAB http://www.mathworks.com, Mathematica http://wolfram.com, and LabVIEW http://www.ni.com. You can use any software you like but make sure that you are proficient in it for the purposes of this class and that you will have access to it as needed. *I encourage the use of computers tools as a means to improve understanding of concepts.* However, be careful **do not** just learn how to exercise the software commands but rather try to understand the underlying theory and concepts addressed through the assigned work.

Additional Reference Material: There are plenty of resources on the Internet especially on how to use software tools.

Miscellaneous: If you have a disability, any religious holidays that you need to observe or anything else that might interfere with this class and you would like for me to know about it, you must inform me in writing and through an email no later than the second-class meeting.

Graduate Teaching Assistants' Duties: The GTAs will be available to help with your homework, answer questions and provide guidance for you to have the best learning experience in this course. **Note** that the GTAs have expressed instructions not to solve the homework for you. It is your responsibility to attempt the homework and if you need help, you must bring with you your current attempts, explain your procedure and thought process and ask specific and not general open-ended questions. The GTAs will hold both regular office hours, recitation and software help sessions as needed. Should you need software help, make sure you have an electronic copy of your code and associated errors if any.

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Tentative Topics (not in order of coverage)

A tentative schedule will be provided to you. The tentative topics to be covered this summer include the following.

System Representation

- Differential Equations
- Transfer Functions
- Block Diagrams
- State Space

System Transient Response Analysis

- Time Domain Response
- Frequency Domain Response
- Laplace Transform
- Stability

Feedback Control Systems

- Effects of Feedback Control
- Classical Control Actions
  - Proportional (P), Integral (I), Derivative (D) and Combinations PI, PD, PID
  - Analog implementation
- Steady State Error Analysis – Controller Design
  - Initial and Final Value Theorems
  - Static & Dynamic Error
  - Performance Indices & Controller Tuning
- Sensitivity Analysis

Controller Design (Pole-Zero locations)

- Root Locus Analysis
- Frequency Response Analysis - Bode Plot
- Compensation Analysis: Lead, Lag

State Variable Feedback Systems – Modern Control (time permitting)

- Controllability and Observability
- Pole Placement Design
- Observer Design - Optimal Control

Hardware Demonstrations (possibly through the Internet and time permitting)

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GENERAL INFORMATION COMMON TO ALL COURSES

Academic Integrity: Students enrolled in this course 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 as they see fit in their courses, including (but not limited to) 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, section 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 https://www.uta.edu/conduct/.

Attendance: At The University of Texas at Arlington, taking attendance is not required but attendance is a critical indicator in student success. Each faculty member is free to develop his or her own methods of evaluating students' academic performance, which includes establishing course-specific policies on attendance.

However, while UT Arlington does not require instructors to take attendance in their courses, the U.S. Department of Education requires that the University have a mechanism in place to mark when Federal Student Aid recipients "begin attendance in a course". UT Arlington instructors will report when students begin attendance in a course as part of the final grading process. Specifically, when assigning a student a grade of F, faculty report the last date a student attended their class based on evidence such as a test, participation in a class project or presentation, or an engagement online via Blackboard. This date is reported to the Department of Education for federal financial aid recipients.

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/).

Grade Grievances: Any appeal of a grade in this course must follow the procedures and deadlines for grade-related grievances as published in the current undergraduate catalog. See
http://catalog.uta.edu/academicregulations/grades/#undergraduatetext
See http://www.uta.edu/deanofstudents/student-complaints/index.php.

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:

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

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 tutoring, major-based learning centers, developmental education, advising and mentoring, personal counseling, and federally funded programs. For individualized referrals, students may visit the reception desk at University College (Ransom Hall), call the Maverick Resource Hotline at 817-272-6107, send a message to resources@uta.edu, or view the information at http://www.uta.edu/universitycollege/resources/index.php.

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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

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 http://www.uta.edu/eos

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 https://www.uta.edu/eos-title-ix/title-ix or contact the Vice President and Title IX Coordinator at 817-272-4585

~~**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 http://www.uta.edu/news/info/campus-carry/~~

Student Feedback Survey: At the end of each term, students enrolled in classes categorized as "lecture", "seminar," or "laboratory" shall be 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 enters the SFS database anonymously and is aggregated with that of other students enrolled in the course. UT Arlington's effort to solicit, gather, tabulate, and publish student feedback is required by state law; students are strongly urged to participate. For more information, visit https://www.uta.edu/ier/Student_Feedback_Survey/students.php

Final Review Week: 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. 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.~~

General Introductory Definitions and Control Design Approach

A. Definitions

System: collection of matter contained within a real or an imaginary boundary

Inputs: variables prescribed by the environment or another system to the system of interest

Outputs: variables of interests produced by the system

State Variables: the minimum set of independent variables required to define the state of the system (order of system = number of state variables, state variables non-unique: i.e. v and p=mv)

Plant: system to be controlled

Controller: system that generates control action on the plant

Disturbance: an unwanted - unexpected input/signal

B. General system model

Nonlinear:

$$\dot{x} = f(x,u) \; and \; y = g(x,u)$$

Linear:

$$\dot{x} = Ax + Bu \; and \; y = Cx + Du$$

C. Open loop/Closed loop control systems

Open loop: control action not influenced by system outputs

Closed loop: control action is a direct function of the system output(s)

Features of Closed Loop compared to Open Loop Control

- Reduces sensitivity to disturbances
- Reduces sensitivity to changes in plant parameters
- Alters dynamic behavior of the closed loop system
- Affects overall gain of the closed loop system
- Affects stability

D. Control task – Controller Design Process

1. Formulate plant model (non-linear or linear)

2. Linearize if needed about operating point and represent system

- State equations
- Transfer functions
- Block diagrams

3. Specify steady state and transient performance measures or requirements

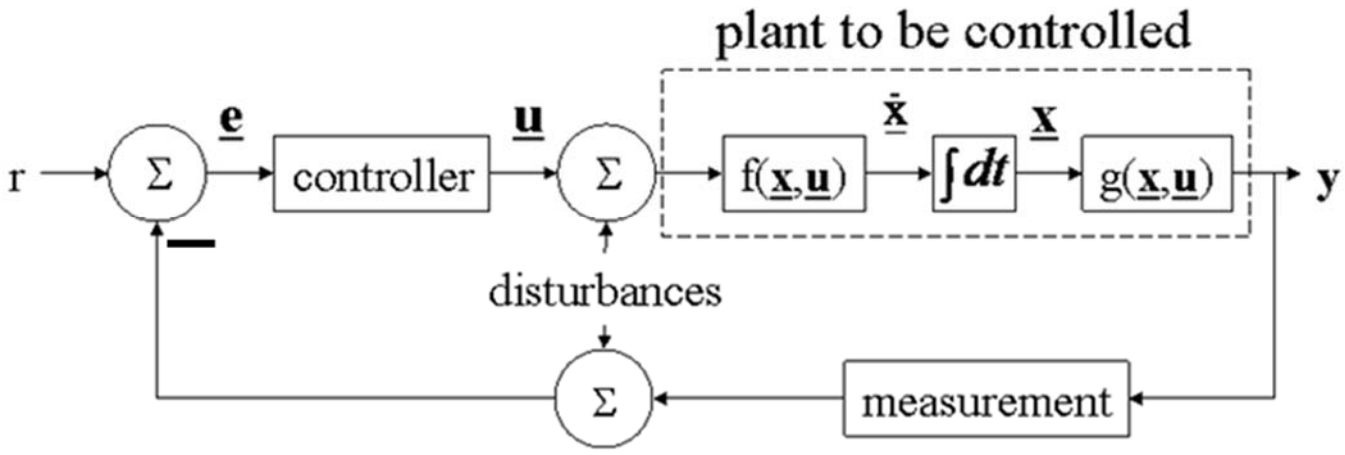
- Time domain
- Frequency domain

4. Synthesize a controller design to satisfy the performance measures or requirements

5. Verify system performance

E. Types of feedback control systems

1. Linear versus nonlinear
2. Time invariant versus time varying
3. Continuous versus discrete time



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