AE/ME 5303-00X Classical Methods of Control Systems Analysis and Synthesis Spring 2018

01/25/2018 (rev a)

**Instructor:** Dr. Baxter R. (Bob) Mullins, Jr., P.E.

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**Faculty Profile:** https://mentis.uta.edu/explore/profile/baxter-mullins

**Office Hours:** MTWT 2:00 – 3:00 PM (other times by appointment)

**Section Information:** AE/ME 5303-00X

**Time and Place of Class Meetings: TT** 3:30PM – 4:50PM, LS (Life Sciences) Rm #124

**Description of Course Content:**
AE/ME 5303. CLASSICAL METHODS OF CONTROL SYSTEMS ANALYSIS AND SYNTHESIS. (3-0)
Equip the student with familiarity of significant tools of the control engineer. Topics covered include controllers and their effect on system performance and stability, block diagram algebra, stability and analysis, system performance definition, root locus, frequency techniques, and state variable methods. Digital simulation tools for design and simulation of control systems. Demonstration of controller design and performance in the laboratory. Also offered as AE 5303 and ME 5303. Credit will be granted only once.

**Student Learning Outcomes**
With the successful completion of this course, the student shall have a basic understanding of how to develop and model physical systems, analyze system behavior, and develop simplified control techniques, and the short falls of such models, including basic understanding of analysis techniques commonly used. As this is a professional-level course, the instructor shall be concerned with the student's response in meeting class requirements in a responsible, professional manner, considering both schedule and presentation. As such, industrial practices shall be included as part of the classroom, assignments, and project activities with standard nomenclature and processes introduced and practiced. This shall include standard industrial practices developed by national and international agencies including ISO, Six Sigma, government (e.g., FARS, MIL STD) and professional organizations (e.g. ASME, AIAA, SAE, AHS, etc.).

**Course Topics:**
- Problem Solving Methods and Processes
- Automatic Control and the Concept of Feedback
- Modeling
    - Frequency Domain
        - Laplace Transforms
        - Transfer Functions
    - Time Domain
        - State-Space Representation
        - Converting State-Space and Transfer Functions
    - Modeling Physical Systems
    - Nonlinear Systems and Linearization
    - Digital Computer (Software Controllers)

- Control System Specifications
  - Time Response
    - First Order Systems
    - Second Order Systems
    - Higher Order Systems (Addition of Poles and Zeros)
    - Nonlinear Systems
  - Stability
    - Routh-Hurwitz Criteria
    - Stability Analysis
  - Steady-State Errors
    - Unity Feedback and Steady-State Errors
    - Steady-State Error and System Type
    - Specifications
    - Sensitivity Requirements
- Analysis Methods
  - Reduction of Multiple Subsystems
    - Block Diagram
    - Block Diagram Reduction
    - Signal Flow Graphs (and Mason's Rule)
  - Root Locus Techniques
    - Root Locus Definition
    - Root Locus Rules
    - Sketching
    - Refining
  - Generalized Root Locus
  - Frequency Response Techniques
    - Bode Diagrams (and Asymptotic Approximation)
    - Nyquist Diagrams
    - Gain and Phase Margins
    - Stability Criteria
    - Closed Loop/Open Loop Responses
- Design
  - Design via Root Locus
    - Feedback Compensation
    - Improving Steady-State Error
    - Improving Transient Response
    - Improving Steady-State and Transient Response
  - Design via Frequency Response
    - Transient Response via Gain Adjustment
    - Lag Compensation
    - Lead Compensation
    - Lag-Lead Compensation
  - Design via State Space
    - Controller Design
    - Controllability
    - Observability
    - Alternative Designs
    - Steady-State Error via Integral Control
- Robust Control Systems

  - Define Robust Control Systems
  - Design using Robust Control System
  - Riccati equation
  - Quadratic Optimal Control Problem
  - Design Examples
- Digital Control Systems
  - Z-transform
  - Transfer Functions in the z-domain
  - Design via z-transforms
  - Digital Controller Implementation
- Control System Analysis and Design Software

Theory formulation, variable definition, analysis procedure and results presentation will follow industry standards. This shall include standard industrial practices developed by national and international agencies including ISO, Six Sigma, government (e.g., FARS, MIL STD) and professional organizations (e.g., ASME, AIAA, SAE, AHS, etc.).

**Prerequisites:** Graduate Standing or Permission of the Instructor

**Required Textbooks and Other Course Materials**

- Ogata, K., ***Modern Control Engineering, 5th ed.***, Pearson, 2010.
- Student Copy of MATLAB®/SIMULNK® software is required.
- 12" ruler, protractor, and compass are required.
- Engineering Paper – Green Pad.

**References**

- Dorf, Richard C., and Bishop, Robert C., ***Modern Control Systems, 13th ed.***, Pearson, 2016.
- Nise, Norman S., ***Control Systems Engineering, 7th ed***., John Wiley & Sons, Inc., 2015.
- Distefano, J., et al., ***Schaum's Outline of Feedback and Control Systems, 2nd ed.*** (Schaum's Outline Series), McGraw-Hill, 2013.
- Frederick, D.K., and Chow, J., ***Feedback Control Using MATLAB and the Control System Toolbox*** (Bookware Companion Series), Cengage Learning, 1999.
- Zill, Dennis G., ***Advanced Engineering Mathemati***cs, Jones and Bartlett Publishing, MA 2009 (Chap 4 The Laplace Transform, Chap 10 Systems of Differential Equations, Chap17 Complex Numbers)
- Bretscher, Otto, ***Linear Algebra with Application, 5th ed***., Pearson, Boston, 2013.
- Blakelock, J.H., ***Automatic Control of Aircraft and Missiles, 1st ed***., John Wiley & Sons, 1965.

**Additional Information**

- Class lectures will be taped for review by off campus students and not available to on campus students.
- Exams for off campus students will be provided to designated administrator at your work location. The administrator will act as a monitor for the exam and will package and return exam to UTA in a timely manner. If an administrator/monitor is not available at the students work location, the student must take the exam on campus at the designated place and time.
- Off campus students shall take the Final Exam on campus at the designated place and time.

**Descriptions of major assignments and examinations**

***Exams***:

- Three (3) exams including a comprehensive final exam. (Thursday, May 10, 2018, 2:00 PM – 4:30 PM)

***Assignments:***

- Assignments will be made throughout the semester.
- Assignments must follow the format provided on Blackboard and include a (1) Problem Statement (Statement of Work) with appropriate sketches, (2) Problem "Knowns", (3) Problem Requirements, (4) Solution Approach, (5) Solution with equations, references and all necessary work to completely describe the solution, and (6) Answers will be Boxed. Computer programs, output, graphs, etc. will be attached to the solution. The top of each page of the assignment will have your Last Name, First Name, Class Information, and Date Due. Complete format requirements with examples can be found on Blackboard. When evaluated/graded, failure to follow the format will result in a "zero" grade for that assignment.
- Project format will be provided on Blackboard.
- Assignments shall be presented on engineering paper using the front-side of the paper only.
- Each assignment will be scanned as single pdf file and uploaded to Blackboard by the date and time as instructed by the instructor. Failure to follow the directions will result in a "zero" grade for that assignment.

  To pass the course, students shall successfully demonstrate the following proficiencies:
  - Use of Laplace Transforms
  - Convolution Integral
  - Time Responses of First and Second Order Equations
  - Error Analysis
  - Block Diagram Algebra/Signal Flow Diagrams
  - Frequency Response Method
  - Stability Criteria
  - Root Locus Method
  - State Space Method
  - Feedback System Design
  - Robust Systems
  - Digital Systems and the Z-Transform

  The proficiencies may be demonstrated with assignments, exam, and project completion.

***Assignments & Projects*** - Graphs/plots shall follow standard engineering formats. Chart Titles, Axis Titles, Legends, Scales and increment values, Grids and Tick marks, Descriptive textbox with pertinent information, etc. Failure to follow all the guidelines will result in a "zero" for item. An example of an engineering graph with annotations is provided on Blackboard.

**Attendance:**

At The University of Texas at Arlington, taking attendance is not required although attendance is a critical indicator of 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 requirement. However, the U.S. Department of Education requires Universities have a mechanism in place to report when Federal Student Aid recipients "begin attendance in a course." UT Arlington instructors are required to report when students begin attendance in a course. In addition, when a student is assigned a grade of F, the instructor is required to 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, that date is reported to the Department of Education for federal financial aid recipients.
Attendance will follow university policies. The policy for this class is that attendance will be taken.

***Students are expected to attend every class, to arrive on time, and to stay in class <u>until they are dismissed</u>.*** Students who fail to adhere to the attendance policy can expect an impact on their grade. Attendance will be considered in the assignment of the final letter grade. Students will not be penalized in the case of an emergency or an incident beyond the student's control.

Attendance of off campus students will be based on a review of the video tape viewings.

**Grading**

- Final Grade Weighting:
  - First Trimester Exam: 25%
  - Second Trimester Exam: 25%
  - Final Exam: 30%
  - Assignments: 20%

- Grade Allocation:
  - Letter grades will be assigned by the following ranges
    A (85-100), B (75-84), C (65-74), D (55-64), F (less than 55)

  Grades will be posted in Blackboard in a timely manner. Students are expected to keep track of their performance throughout the semester and seek guidance from available sources (including the instructor) if their performance drops below satisfactory levels.

**Assignment Grading Policy:** Assignments will be reviewed weekly and randomly chosen assignment(s) will be graded based on the assignment format previously described.

**Assignment Policy:**

- Assignments are due on the date and time specified.
- All assignments shall follow the process as shown by the examples provided on Blackboard. Failure to follow the process will result in a zero grade for the assignment.
- Each assignment will be kept in a three-ring notebook with a divider between each assignment.
- One assignment will be requested to be turned in with each exam as part of the exam.
- As requested by the instructor assignments demonstrating area proficiencies will be submitted online via PDF no later than the beginning of class on the date due.
- **Late assignments will not be accepted**.
- **The notebooks may be reviewed by the instructor at any time during the semester for completeness and the results included in the final grade assessment**.

**Exam Policy:**

- All problems stated in the exams will be weighted equally unless otherwise specified.
- Offsite personnel exams will be proctored by selected personnel at the facility and assigned online. The student must provide a designated proctor with facility name, proctor name, address and telephone number one week prior to the exam. This is not available to full time students in general attendance at the main campus.
- **All exams unless otherwise directed by the instructor are "closed-book, one-page of notes, 8.5"x11", one-side only."** No internet capable devices (i.e., laptops, tablet devices or "smart" calculators) can be used during exams. Only simple, hand calculators are permitted during class exams (see **Use of Electronic Devices** section of the syllabus).

- Students will be allowed a single-sided, 8.5"x11" piece of paper (i.e., no writing on the back of the paper) with their personal exam notes, formulas, etc. Failure to follow these instructions will result in confiscation of the formula sheet. The formula sheet will be turned in with its corresponding exam as part of the exam. **Failure to turn in the formula sheet will result in a grade of zero for the exam.**
- There will be **NO** make-up exams for unexcused absences. **Missed exams will receive a grade of zero**.
- A student having an **UNEXCUSED** absence from the final exam will receive the course grade earned.
- A student having an **EXCUSED** absence from the final exam has two options:
  - The student may elect to receive the course grade earned with the final exam grade equal to zero, or
  - The student may elect to receive the grade of ***"I"*** (incomplete) and arrange with the instructor to complete the course by taking the final examination at the end of the next semester.
    - If the student chooses the second option, it is the student's responsibility to consult with the instructor regarding completion of the course requirements.
    - NOTE: Excuses for absences from the final exam must be in writing with appropriate verification; e.g., note from your manager, doctor, etc.

**Special Needs:**

The instructor must be notified at the beginning of the semester, **within the first week of class**, by any student requiring **'Special Needs'** exam testing. The student must be registered and approved for special testing allowances. If so, the student is responsible for obtaining and presenting the necessary confirmation forms to the instructor in that first week. Additionally, **the student is responsible for coordinating all "special needs testing" with the test center two weeks before each exam**. **This includes coordinating with the instructor the date and time of the alternate test.** Per the university procedures, the testing center will contact the instructor and arrange the necessary private test schedule after the student has coordinated with the test center and the instructor. **Failure to meet these requirements will negate any "special needs testing" for that exam.**

## Course Schedule:

Spring session begin on January 16, 2018, and ending on May 4, 2018, with final exams held from May 5th through May 11th of 2018. Spring break is schedule for March 12 – 17, 2018. A class schedule will be provided on Blackboard. Exam dates and reading assignments are provided. Homework, assignments and project assignments will be updated on a continuous basis. As directed by the instructor, homework, assignments and projects shall be scanned as a pdf and uploaded to Blackboard otherwise the will be handed in at the beginning of class. Homework not handed in before the beginning of class will be considered late and given a grade of zero.

**Use of Electronic Devices:**

- Cellphone use in class is prohibited. They must be turned off and stored during class.
- No internet capable devices (i.e. laptops, tablet devices or calculators) can be used during exams.
- Only simple, hand calculators (non-smart devices) are permitted during class exams.
- Laptops, tablet devices, etc. (but no cellphones) may be used during lectures for taking personal notes with written permission of the instructor. Any other use of electronic devices will nullify any agreement allowing personal note taking on such devices.
- **No audio and/or video recordings by the students are permitted.**
- All audio devices such as headphones, earbuds, etc., must be turned off and stored during class time.

**Expectations for Out-of-Class Study:**
Beyond the time required to attend each class meeting, students enrolled AE/ME 5303-00X, a 3-credit hour course, should expect to spend at least an additional **9 hours per week** of their own time in course-related activities, including reading required materials, completing assignments, preparing for exams, etc. (The general rule of thumb is for every credit hour earned, a student should expect to spend at minimum 3 hours per week working outside of class.)

**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. For undergraduate courses, see http://catalog.uta.edu/academicregulations/grades/#undergraduatetext; for graduate courses, see http://catalog.uta.edu/academicregulations/grades/#graduatetext. For student complaints, see http://www.uta.edu/deanofstudents/student-complaints/index.php.

**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/ses/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:
**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.

**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 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, §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.

**Lab Safety Training:**
No lab training is required for this course.

**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 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 http://www.uta.edu/sfs.

**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.

**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.

The IDEAS Center (2nd Floor of Central Library) offers free tutoring to all students with a focus on transfer students, sophomores, veterans and others undergoing a transition to UT Arlington. To schedule an appointment with a peer tutor or mentor email IDEAS@uta.edu or call (817) 272-6593.

The English Writing Center (411LIBR): The Writing Center Offers free tutoring in 20-, 40-, or 60-minute face-to-face and online sessions to all UTA students on any phase of their UTA coursework. Our hours are 9 am to 8 pm Mon.-Thurs., 9 am-3 pm Fri. and Noon-6 pm Sat. and Sun. Register and make appointments online at http://uta.mywconline.com. Classroom Visits, workshops, and specialized services for graduate students are also available. Please see www.uta.edu/owl for detailed information on all our programs and services.

The Library's 2nd floor Academic Plaza offers students a central hub of support services, including IDEAS Center, University Advising Services, Transfer UTA and various college/school advising hours. Services are available during the library's hours of operation. http://library.uta.edu/academic-plaza

**Library Home Page library.uta.edu**

**Resources for Students**

**Academic Help**

- Academic Plaza Consultation Services library.uta.edu/academic-plaza
- Ask Us ask.uta.edu/
- Library Tutorials library.uta.edu/how-to
- Subject and Course Research Guides libguides.uta.edu
- Subject Librarians library.uta.edu/subject-librarians

**Resources**

- A to Z List of Library Databases libguides.uta.edu/az.php

- Course Reserves pulse.uta.edu/vwebv/enterCourseReserve.do
- FabLab fablab.uta.edu
- Special Collections library.uta.edu/special-collections
- Study Room Reservations openroom.uta.edu

**Notice:**

***The instructors reserve the right to make changes to the course syllabus as necessary. It is the student's responsibility to keep up with changes to the syllabus as posted on the class website.***

*AE/ME 5303-00X Classical Methods of Control Systems Analysis and Synthesis*
Spring Semester 2018
Baxter R. Mullins, Jr. • Room 302WH • Tel: 817-272-2896 • E-Mail: *mullins@uta.edu*

**Introduction to Automatic Controls**

**AE/ME 5303-00X**
**3 HOURS CREDIT**

**SPRING 2018**

***SYLLABUS***

By signing this document, the student acknowledges that he/she has read and understood the syllabus for AE/ME 5303-00X.

Print Name: _____

Signature: _____ Date: _____

Prepared by: Baxter R. Mullins, Jr.
Date: 25 January 2018