GEORGIA INSTITUTE OF TECHNOLOGY

ECE 6550 A,Q,QSZ Fall Semester 2016

Linear System Theory

Instructor: Professor Erik I. Verriest
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Put **"ECE6550"** in the subject line, or your mail disappears with SPAM.

Secretary: Sharon Pugh, E-492, (404) 894-3782
If you cannot reach me directly, please leave a message with her.

Grader: Muhammad Qureshi (umer.qureshi@gatech.edu). OH: TBA

Class Hours: MWF 13:05 - 13:55 pm, Weber SST III Room 1
Office Hours: MW 3:30 - 5:00 pm

Prerequisite: Graduate standing, and a *good* working knowledge of matrix algebra, elementary complex arithmetic and LTI-ODE's.
A little signal and systems introduction: including wiring diagrams, the Laplace transform, and the Routh-Hurwitz stability criterion.

Grading:

Homework:	10 %
Two tests:	25% each. Tentative dates: September 30 and Nov 11.
Final:	40%

Final: The final exam MUST be taken at the scheduled time:
Period 7, Monday December 12, 2:50–5:40 pm.

Make-ups: Permitted *only* if either you have a legitimate excuse and I am notified in advance, or you are physically incapable of being in class due to an emergency.
At the discretion of the instructor, make-up tests may either be oral or written, and may be given on the week before finals.

Honesty: In order to maintain academic honesty, all instances of academic misconduct will be reported to the Dean of Students.

Homework: There will be an assignment approximately every week (except on the test weeks), due a week later. Carefully prepared and detailed solutions will be posted on T-Square. Expect to work at least another 3 hours *outside* the class for each class hour. The test problems will be similar in nature, but not identical to homework problems. Late homework will not be accepted.

Course Objective:
To introduce the basic underlying principles in the study of linear systems with application to circuits, communication, computation, control and signal processing. Mathematical rigor will be strived for, therefore providing a good training ground for the prospective graduate student. It is this instructor's firm belief and experience that a good theoretical background provides a better mobility than training in a specific art or technique. *Nothing is more practical than a good theory!* However, let this not intimidate you. No prior knowledge of advanced or higher mathematics besides the cited prerequisites will be assumed. New concepts (mainly linear algebra) will be introduced as the course evolves, all that is required is a healthy dose of curiosity, a creative mind and a willingness to learn.

Emphasis: Will be on the *basic underlying methods* in the study of signals and systems. All derivations will start from "first principles".
This course is a prerequisite for all other graduate courses in the Systems and Controls area.

Computer Usage:
Individual computer experimentation (Matlab, Mathematica and/or Maple) is strongly recommended, but not required.

Text book: My own classnotes will be posted on T-Square.
Recommended: T. Kailath, *Linear Systems*, Prentice-Hall 1980.

Attention:
– The scheduled final exam date (Monday, December 12, 2:50–5:40 pm) is strict. No exceptions will be made for any reasons. If you need to schedule your flights home for the holidays, please do so accordingly.
– Caps, hats and other headdresses are **not allowed** during tests, *unless prior arrangements are made.*
– Bathroom runs are very disruptive for everyone, and are **not allowed** during tests - Take necessary precautions.

Research: For students who are contemplating research under my guidance: obtaining an "A" in this course is a prerequisite.
Students interested in my current research (mathematical system theory) may inspect my latest publications posted by my office. *Please do not remove these.*

Special needs: Qualified students with special needs who will require accommodations (e.g., religious observances, disabilities, or GT sanctioned activity such as athletes travel) shall inform the instructor as soon as possible (no later than the end of the second week of classes). Verification of eligibility from the ADAPTS-Disability Services Program is required prior to receiving disability accommodations. Disability information is confidential.

Grades
Over the years, my grade distribution for this course is roughly 1/3 A, 1/3 B and 1/3 C, but this does not preclude the appearance of an occasional D or F grade.
I grade using the full scale, which means that 50% indicates that you seem to know 50% of the material. Although this may not look pretty, for me this is a passing score. It is rare to get a score of 90%, but it happens. My A cut-off falls typically somewhere between 76% and 78%.

Distance Learning Students:

You have a **one week** delay for all tests, and **one lecture** for all homeworks. This means that after the 4-th lecture after the homework is assigned in class, solutions will appear on T-Square. If homework is received after the solutions are posted, it will not be graded (resulting in zero points). Homework should be mailed to the grader directly.
My previous experience with faxed handwritten solutions is very bad. Please use a **thick black pen** (not a pencil!), and make your handwritten characters at least 3 mm in diameter to beat the scanner/fax resolution. Also be careful not to write too close to the edge of the paper.
You may want to **test the limits** by mailing a test page to yourself first, and keep in mind that what cannot be read cannot be graded!

ECE 6550 Topical Outline - (tentative 2016)

1. Introductory Material
   (a) Overview
   (b) Motivating the State Space
2. Mathematical Structures
   (a) Groups, Rings and Fields
   (b) Vector Spaces and Modules
   (c) Linear Functionals and Dual Spaces
   (d) Operators, Matrices and Determinants
3. Linear Systems and Transforms
   (a) Linearity
   (b) Laplace Transform
   (c) Z Transform
4. State Variables and Realizations
   (a) State Space Realizations for Physical Systems
   (b) State Space Realizations from Transfer Functions
   (c) Similarity
5. Properties of Realizations
   (a) Observability Problems
   (b) Reachability Problems
   (c) Discrete Time Systems
6. Realization Theory
   (a) Minimality
   (b) PBH tests
7. Solutions of State Equations
   (a) Discrete Systems and Discretization
   (b) Continuous Systems: Matrix Exponential
   (c) Long Term Behavior: Stability
   (d) State Space Geometry

8. Quadratic Forms and Applications
    (a) Quadratic Forms
    (b) Lyapunov Theory
9. Gramians and Energy Principles
    (a) Gramians and Energy Principles
    (b) Balancing
    (c) Model Reduction
10. Linear State Variable Feedback
    (a) Modal Control Problem, Feedback
    (b) Formulas for the Gains
    (c) The Algebraic Riccati Equation
    (d) Legendre's Theory of Optimality
11. Linear State Observers
    (a) Modal Observer Problem
    (b) Combined Observer-Controller
    (c) Reduced Order Observers
    (d) Direct Transfer Function Design
12. Multivariable System Theory
    (a) State Observability and Reachability
    (b) Matrix Fraction Descriptions
    (c) Polynomial Modules and Polynomial Matrices
    (d) Rational Matrices and Smith-McMillan Form
    (e) Canonical MFD's and SS realizations