ME 540/ECE 515: Control System Theory & Design (Spring 2025)

Section AL2 MWF 11:00 am – 12:20 pm, Room 2055 Sidney Lu Mech Engr Bldg

Instructor Prof. Srinivasa Salapaka (salapaka@illinois.edu)

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Course website https://canvas.illinois.edu
ME 540 / ECE515 should already be listed in your "Courses" list.

Prerequisite: ECE 486 or Equivalent
You should already be familiar with complex numbers, Laplace transformation, Transfer functions, Poles and zeroes, Frequency domain analysis, Bode plots, using Matlab.

Office hours The instructor and TAs will hold office hours throughout the semester. Here are the timings and locations.

Monday	TBD	TBD	TBD	TBD
Tuesday	4:30-5:30 PM	Srinivasa Salapaka	CSL 367	salapaka@illinois.edu
Wednesday	TBD	TBD	TBD	TBD

Homework assignments – Assignments will be put up on Canvas course site on Wednesdays and submissions will be due the following Wednesday. You are encouraged to collaborate with others in the course, but you should hand in only your own work. No late homework will be accepted. The lowest homework grades will not be counted. The assignments will be submitted and graded via Gradescope (https://www.gradescope.com). An instruction-guide on how to submit solutions onto Gradescope is provided on the canvas site in the module *Course Information*.

Textbook: I will provide you with class notes for the week at the beginning of each week. The following books can be used as reference books.

- **Main Reference:** Tamer Basar, Sean Meyn, and William R. Perkins, Lecture Notes on Control System Theory and Design . (Available at https://arxiv.org/pdf/2007.01367.pdf)
- Other References: These notes provide only a survey of the course material. More depth can be found in the reference textbooks, which can be found in the Engineering Library (More references are given at the end of this sheet).
  - C-T Chen, Linear System Theory and Design, Holt, Rinehart and Winston, Inc., 1984.
  - Wilson J. Rugh, Linear System Theory, Prentice Hall, 1995.
  - Alan J. Laub. Matrix Analysis for Scientists and Engineers. Society for Industrial and Applied Mathematics, Philadelphia, PA, 2005.
  - B.D.O. Anderson and Moore, J.B., Linear Optimal Control, Prentice Hall, 1990

Assessment: Homework: 50%; Midterm: 25%; Final Exam:25%
Grading: The grades will be decided based on the relative performance. The average performance will get a B grade or better.

Academic integrity:

- **Guiding principle:** The work that you submit must represent your understanding of the course materials.
- **Integrity violations:**
  - This course has a zero-tolerance policy with regards to academic integrity violations. This includes cheating, plagiarism, fabrication, and facilitating infractions by others.
  - You are expected to adhere to all of the rules pertaining to academic integrity outlined in the UIUC Student Code. Use the following links to familiarize yourself with what constitutes an integrity violation and the campus policies.
    - http://www.admin.uiuc.edu/policy/code
    - http://studentcode.illinois.edu/article1_part4_1-401.html
  - Integrity violations will be prosecuted to the maximum possible extent. Depending on severity, recommended sanctions can range from zero on the assignment, to failure of the course, and even dismissal from the university.
- **Acceptable sources for assistance**
  - We will have adequate office contact hours distributed throughout the week, with the professor and with the TAs. You are free to make use of this time for assistance on the homework assignments.
  - You are also free to work in partnership with other students, as long as you adhere to the guiding principle (above). Your work must be your own and must represent your understanding.
  - Feel free to use other textbooks as aids.
- **Unacceptable sources of assistance**
  - Example 1 - A student performs an online search to seek help on a homework problem and found that someone had posted previous years' solutions to a website. Thinking that this is public domain information, the student copies the solution. This is considered cheating under the Student Code 1-402(a) (i.e. use of unauthorized materials) and potentially plagiarism under Student Code 1-402(b) (i.e. representing the work of others as your own).
  - Example 2 - A different student decided not to copy since that would obviously be cheating. However, this person read through this solution and then paraphrased the answer. This is still a violation under Student Code 1-402(b) as it amounts to plagiarism. Crediting the source material will not absolve the student in this case since it is unauthorized material.

- **Copyrights:** **All materials that the instructors provide during the course are copyrighted** (even if not explicitly stated on the materials). This copyright will apply to all course notes, homework problem sets, exams, Matlab code, solutions of any kind, etc.
  - You are not permitted to share the materials outside of the course (e.g. homework sharing websites). That is a copyright violation and may be prosecuted under the "facilitating infractions" clause of the academic integrity code.
  - Please remember that the course materials are the intellectual property of the instructors and TAs. We hope that you will act respectfully in this regard.
  - Do inform the instructor if you become aware of unauthorized materials on any website.

Tentative Course Syllabus

This is a fundamental graduate-level course on the modern theory of dynamical systems and control. It builds on an introductory undergraduate course in control (such as ECE 486), and emphasizes state space techniques for the analysis of dynamical systems and the synthesis of control laws meeting given design specifications. To follow the course, some familiarity with linear algebra as well as ordinary differential equations is strongly recommended, although the necessary material will be reviewed at appropriate junctions throughout the semester.

(I) System Modeling and Analysis

- System Modeling: system models, linearization, transformation between models, state-space realizations
- Review of Linear Algebra: vector space, subspace, linear independence, span, sums and intersections of subspaces, linear transformations, dimensions, norms, inner product spaces, Cauchy-Schwarz inequality, orthogonality, orthonormality, linear operators and representations, similarity, range space, null space, rank, eigenvalues and eigenvectors, adjoint transformations
- Solution of State Equations: state-space solution, transfer function form, change of state variables, Cayley-Hamilton theorem, LTV systems

(II) System Structural Properties

- Stability: Lyapunov, stability subspaces, input-output stability
- Controllability, Observability, Duality, and Minimality

(III) Feedback Control

- Pole Placement: state feedback, observers, observer feedback, Luenberger observer stability: Lyapunov, stability subspaces, linearization, input-output stability
- Tracking and Disturbance Rejection: Internal model principle, transfer function approach
- Control Design: performance, measurements, robustness and sensitivity, zeros and sensitivity

(IV) Optimal Control

- Dynamic Programming: problem formulation, Hamilton-Jacobi-Bellman equations, LQR problem
- Minimum Principle: Minimum Principle and HJB equations, Lagrange multipliers, examples

Reference Textbooks

Several textbooks related to the course material are on reserve in the Grainger Engineering Library, with a selected few listed below. Others may be added to the list in due course.

- Joao P. Hespanha, Linear Systems Theory, Princeton University Press, 2009
- C-T. Chen, Linear System Theory and Design, 3rd edition, Oxford University Press, 1999.
- W.L. Brogan, Modern Control Theory, Prentice Hall, 3rd ed., 1991.
- P.J. Antsaklis and A.N. Michel, Linear Systems, McGraw Hill, 1997.
- T. Kailath, Linear Systems, Prentice Hall, 1980.
- R.W. Brockett, Finite Dimensional Linear Systems, Wiley, 1970.
- W.J. Rugh, Linear Systems Theory, Prentice Hall, 1993 (2nd edition, 1996).
- H. Kwakernaak and R. Sivan, Linear Optimal Control Systems, Wiley, 1972.
- J.B. Cruz, Jr., Feedback Systems, McGraw Hill, 1972.
- J.B. Cruz, Jr., System Sensitivity Analysis, Dowden, Hutchinson & Ross, 1973.
- S. Skogestad and I. Postlethwaite, Multivariable Feedback Control, Wiley, 1996.
- R.E. Bellman, Introduction to Matrix Analysis, 2nd ed., McGraw Hill, 1970.
- V.I. Arnold, Ordinary Differential Equations, 3rd edition, Springer, 1992.
- F.R. Gantmacher, Theory of Matrices, vols. I, II, Chelsea, 1959.
- B.D.O. Anderson and J.B. Moore, Optimal Control: Linear Quadratic Methods, Prentice Hall, 1990.