

ECE 516: System Control Engineering

This course focuses on the analysis and design of systems control. This course will introduce time-domain systems dynamic control fundamentals and their design issues for electrical engineering applications. Emphasis will be on linear, time-invariant, multi-input multi-output continuous time systems. Topics include open and closed-loop state-space representations, analytical solutions, computer simulations, stability, controllability, observability, pole-placement controller/observer design, and introduction to optimal control. [ECE 301 \(Linear Systems\)](#) or equivalent is the *pre-requisite* for this course. A strong background in linear algebra and differential equations is not required but is highly recommended. The [MATLAB/SIMULINK](#) computer software package will be used extensively to assist in the understanding of concepts and fundamentals of system dynamics and control, and also to analyze and design control systems.

ECE 516 System Control Engineering

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BACKGROUND MATERIAL

Prerequisite Courses

[ECE 301](#) **Linear Systems**

Recommended Background Courses

[ECE 435](#) **Elements Control**

[ECE 436](#) **Digital Control System**

Recommended Co-Requisite Courses

[ECE 513](#) **Digital Signal Processing**

[ECE 514](#) **Random Processes**

[ECE 556/456](#) **Mechatronics**

GRADING SCHEME

Exams and homework will be based mainly on the basic material. Recommended materials will be presented once a while for your entertainment, and optional materials will be presented once a long while for your imaginations.

- A. Homework (approximately 6 – 9 assignments): 30%
- B. Mid-term Exam: 30%
- C. Final Exam: 40%

The problems of exams will be based mainly on lecture materials and the textbook.

Your Class Grade = MAX {Relative standing, Absolute standing}, where

(a) Relative standing

The whole class grade will be “curved” and your grade will be based on your relative standing in the class.

(b) Absolute standing (AS – average score)

A+: AS \geq 98%	A: 98% > AS \geq 92%	A-: 92% > AS \geq 90%
B+: 90% > AS \geq 88%	B: 88% > AS \geq 82%	B-: 82% > AS \geq 80%
C+: 80% > AS \geq 78%	C: 78% > AS \geq 72%	C-: 72% > AS \geq 70%
D+: 70% > AS \geq 68%	D: 68% > AS \geq 62%	D: 62% > AS \geq 60%
F: 60% > AS		

TEXT BOOKS:

William L. Brogan, Modern Control Theory, 3rd Ed., Prentice Hall, ISBN: 0-13-589763-7. (Required)

REFERENCES (Optional):

- A. The Wikibook of Automatic Control Systems And Control Systems Engineering with Classical and Modern Techniques And Advanced Concepts.
- B. Chi-Tsong Chen, Linear System Theory and Design, HRW.
- C. Thomas Kailath, Linear Systems, Prentice Hall.
- D. Katsuhiko Ogata, Modern Control Engineering, Prentice Hall.
- E. Donald Kirk, Optimal Control Theory - An Introduction, Prentice Hall, ISBN 13-638098-0.
- F. Frank L. Lewis, Vassilis L. Syrmos, Optimal Control, 2nd ed., John Wiley & Sonc, Inc., ISBN: 0-471-03378-2.
- G. Bryson & Ho, Applied Optimal Control, Hemisphere Publishing Corporation.

ECE 516 System Control Engineering Course Outline

T01. General description of Systems and System Dynamics

1. The Concepts of Systems, System Dynamics and Classifications
2. Control Theory
3. Systems Performance

Goal: After these lectures and studies, students should have a general concept and meaning of “dynamic” systems. Hopefully, you will be fascinated with “systems and control” and are interested to find *more*.

T02. State Variables and State Space Description of Dynamic Systems

1. The Concept of State
2. State Space Representation of Dynamic Systems
3. State Equation for Dynamic Systems
4. Obtaining State Equations from Input-Output Differential Equations

Goal: After these lectures, students should know how use state-space description to model simple linear electric circuits, dc motor dynamics, transfer functions, and high-order differential equations.

T03. Analysis of the Equation of (Linear Time Invariant) Dynamical Systems – Mathematical

Tools Review

1. Linearity and Time Invariance
2. Exponential Functions
3. State Transition Matrix
4. Linear Independence, Rank, Determinant, Gaussian Elimination, Basis
5. Eigenvalues and Eigenvectors

Goal: After these lectures, students should have reviewed and are confident on using the linear algebra concepts learned before to solve engineering problems.

T04. Analysis of the Equation of (Linear Time Invariant) Dynamical Systems – Analytical

Solutions

1. Solution of State Equations — Time domain solutions
2. Modal Decomposition
3. Jordan Form
4. Discretization

Goal: After these lectures, students should know how to apply some basic linear algebra such as matrix operations and eigenvalues to solve linear system and control problems directly in time domain – Yes! We do not need to go to frequency domain to find the solutions.

T05. Linearization of Nonlinear Equations and Perturbation Theory

1. Taylor Series
2. Nominal Points and Operating Points

3. Linearization of Nonlinear Equations

Goal: After these lectures, students should know that most systems in the real-world are nonlinear, yet in most cases, we can linearize the nonlinear system and apply the linear control system design techniques learned in the class to a system to obtain good performance.

T06. Stability for Linear and Nonlinear Systems

1. Equilibrium Points
2. Stability Definitions
3. Linear Time-Invariant Stability
4. Nonlinear Time-Invariant Stability

Goal: After these lectures, students should feel comfortable and confident in using the word *stability* for control applications. They should also be able to use the techniques to test if the system is stable.

T07. Controllability and Observability

1. Concepts and Definitions
2. Rank Test
3. Controllability Index
4. Observability Index

Goal: After these lectures, students should understand the meaning of controllability and observability, and under what circumstances that system can be controlled and observed .

T08. Design of Linear Feedback Systems

1. Controller Design
2. Disturbance Rejection
3. Observer Design
4. Noise Filtering

Goal: After these lectures, students should be able to synthesize all the concepts and techniques learned in previous lectures to design controllers to improve system transient responses, disturbance rejections, virtual sensing and sensor noise filtering.

T09. Introduction to Optimal Control (when time permits)

Goal: The session will provide the class with basic concept of optimal control, which often used along with state-space description.