

LINEAR SYSTEMS I

ECE230A — FALL 2002



Abstract

The purpose of this course is to provide the students with the basic tools of modern linear systems theory: stability, controllability, observability, realization theory, state feedback, state estimation, separation theorem, etc. For time-invariant systems both state-space and polynomial methods are studied. The students will also be introduced to the computational tools for linear systems theory available in MATLAB.

The intended audience for this course includes, but is not restricted to, students in circuits, communications, control, signal processing, physics, and mechanical and chemical engineering.

[Recommended readings](#) and [homework](#) are available on the web.

Instructor

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Office hours: Please email me or phone in advance to schedule for an appointment.
Preferred times are Tue, Thu 2:30-4:00pm

Course's Web Page

The [syllabus](#), [homework](#), solutions to homework, and all other information relevant to the course will be continuously posted at the course's web page. The URL is

<http://www.ece.ucsb.edu/~hespanha/ece230a/>

Assessment format

Homework – 30%

Mid-term exam – 30%

Final exam – 40%

Textbook

The main textbook is:

[1] C.-T. Chen. *Linear Systems Theory and Design*. Oxford Univ. Press, 3rd ed., 1999. (ISBN 0-19-511777-8)

Other recommended textbooks are:

[2] P. Antsaklis, A. Michel. *Linear Systems*. McGraw Hill, 1997.

[3] W. Rugh. *Linear System Theory*, 1996.

[4] E. Sontag. *Mathematical Control Theory*, 1990.

The classes will follow Chen's book [1] closely. Antsaklis' book [2] will be used for topics not covered by [1] (see [syllabus](#) below).

Detailed Syllabus

The following is a tentative schedule for the course. If revisions are needed they will be posted on the course's web page. The rightmost column of the schedule contains the recommended reading for the topics covered on each class. *Students are strongly encouraged to read these materials prior to the class.*

Class	Content	Reference
9/26	Introduction and course overview Key concepts: system, causality, state, linearity, time-invariance Examples: electrical network, spring-mass system, etc.	Secs 2.1 and 2.5 of [1]
10/1	Examples (discrete-time systems) Input-output vs. state-space models for causal, linear systems	Secs 2.1-2.2 of [1]
10/3	Transfer matrix of linear time-invariant (LTI) systems Introduction to linearization	Secs 2.3-2.4 of [1] Clarification notes here .
10/8	Linearization Example: inverted pendulum	Sec 2.4 of [1]
10/10	Solutions of homogeneous linear ODEs—Peano-Baker series	Sec 4.5 of [1] Sec 1.13 of [2]
10/15	Properties of the fundamental and state transition matrices Solutions of nonhomogeneous linear ODEs—variations of constants formula Solutions of continuous-time state-space models	Sec 4.5 of [1] Sec 1.13 of [2]
10/17	Elements of matrix algebra: matrix polynomials, Cayley-Hamilton Theorem Jordan normal form	Secs 3.5-3.6 of [1]
10/22	State transition matrix for LTI systems—matrix exponential Properties of e^{At} Computation of e^{At} : Cayley-Hamilton Theorem, Laplace transform, Jordan normal form	Sec 3.6 [1] MATLAB script and notes
10/24	Input-output stability of continuous-time LTI systems	Secs 5.1-5.2 of [1]
10/29	Internal stability of continuous-time LTI systems Continuous-time Lyapunov Theorem	Secs 3.9, 5.3-5.4 of [1]
10/31	(continuation from previous class)	
11/5	<i>Midterm exam on the material covered up to the 10/24 class</i>	Practice mid-term exam and solutions
11/7	Elementary realization theory for LTI systems—canonical forms Equivalent state-space models for linear systems	Secs 4.3-4.4 [1]
11/12	Linear Quadratic Regulation (LQG): Algebraic Riccati Equation, Optimal state-feedback	Sec 4.2C of [2]

Class	Content	Reference
11/14	Controllability: definitions, gramians, time-invariant case	Sec 6.1-6.2 of [1]
11/19	Observability: definitions, grammians, time-invariant case Duality	Sec 6.3 of [1]
11/21	Canonical decomposition	Sec 6.4 of [1]
11/26	Minimal realizations: definition, connection with controllability/observability, and equivalence of minimal realizations	Secs 7.1-7.2 of [1]
11/28	<i>Thanksgiving</i>	
12/3	State estimation Stabilization through output feedback—separation theorem	Secs 8.4-8.5 and 8.7-8.8 of [1] Sec 4.3C of [2]
12/5	<i>Final exam on all the material covered up to the 11/26 class. The exam will take place on GIRV 2129 from 12:30-2:30PM.. NEW</i>	Practice final exam and solutions

