EE585
LINEAR SYSTEMS THEORY
SPRING 2012

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Abstract

The purpose of this course is to provide the student with the basic tools of modern linear systems theory. The emphasis is on *state-space* methods; however, we will attempt to establish a balance between the application-oriented state-space methods, including controller design and numerical linear algebra, and the more algebraically-oriented polynomial methods, like the Smith-McMillan form and matrix fraction descriptions. This course is presented in such a way as to make it of interest to students in controls, communications, signal processing, robotics, power, and financial engineering.

Schedule

Mo. & Wd. 5:00-6:20 p.m. OHE 100D

Instructor

Dr. E. Jonckheere
EEB 306
(213) 740-4457
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Office hours: Mo. & Wd., 2:00 p.m. - 4:00 p.m.

Teaching Assistant

TBA

Discussion sessions

TBA

Grader

TBA

Prerequisites

- EE301 (required): a good working knowledge of Fourier and Laplace transforms, transfer functions, poles/zeros, and partial fraction decompositions is required.
- EE441 (required): a good working knowledge of linear algebra (vector spaces, matrices, eigenvectors, eigenvalues, quadratic forms) is required.
- EE482 (optional): the students are supposed to have the *very basic* knowledge of linear feedback systems; however, all of the details of EE482 (rise time, settling time, compensator design specifications, Nyquist plots, root locis, ...) are not necessary.

Formal textbook

- Joao P. Hespanaha, *Linear System Theory.* Princeton University Press, 2009. (ISBN 978-0-691-14021-6). The major advantage of this text over the previously used one (Chi-Tsong Chen) is that the flow of ideas appears much smoother in this new text than in the former one. The text is, however, written in a way that might challenge the students. In class, we will present things in a lighter way; but for this process to work, attendance and participation in the classroom discussions is of utmost importance.

Other recommended books

1. Chi-Tsong Chen, *Linear System Theory and Design*, Third Edition, Oxford, 1999. This is the formal text that has been used over the past few years. It is reasonably concise, with many (too many?) electrical circuits applications. But it remains an excellent additional reading.

2. P. Antsaklis and A. Michel, *Linear Systems Theory*, McGraw Hill, 1997. Very good book, pretty much in line with the state-space versus polynomial methods balance that EE585 tries to achieve, but a little too "fat." This book contains a good introduction to polynomial methods.

3. Wilson J. Rugh, *Linear System Theory*, Prentice Hall, 1996. Comprehensive exposition of linear system theory, but it is a bit hard to see the train of thoughts. The text wanders through too many details. Its major advantage is that it contains some good introduction to the geometric approach to linear system theory.

4. Chi-Tsong Chen, *Linear System Theory and Design*, Holt, Rinehart and Winston, 1970. Older book, a little outdated, but very pragmatic.

5. T. Kailath, *Linear Systems*, Prentice Hall, 1980. This is an advanced, very comprehensive exposition of linear systems theory. Its major advantage is that it provides thought-provoking discussions on some subtle issues in linear systems. Probably too wordy as the official EE585 textbook, not quite in line with the way EE585 is taught, but recommended for students who want to do some advanced, personal reading.

6. F.M. Callier and C.A. Desoer, *Linear System Theory*, Springer-Verlag, 1991. This is a book by two outstanding experts in the field, probably a bit too much control-oriented, but covers the main points EE585 will cover.

7. P. A. Fuhrmann *A Polynomial Approach to Linear Algebra*, Springer, 1996. This book provides a high-power algebraic approach to linear systems. Definitely too algebraic an approach for EE585 students, but a useful book for those who want to do some advanced reading.

Format

- one homework every other week (assigned Mo., due Mo.) (10%)

- one midterm (Wed., March 07, 2012) (40%)

- one final (Wed., May 02, 2012) (50%); the final exam is comprehensive, but will emphasize the material covered *after* the midterm.

Regarding the final, the class schedule specifies the following:

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4 or starting after 4 but before 6 p.m. 4:30-6:30 p.m.
first scheduled class period, May 2-9
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which places the final on Wednesday, May 02, 4:30-6:30 p.m. By school policy, we are obliged to strictly abide by the published schedule.

General course description

Essentially, we will cover Parts I-IV of the text by Hespanha (except that we will probably skip Part II, Chapter 10). In addition, we will go over Part V (advanced topics), Sections 18.2 and 18.3 (polynomial methods and Smith form).

Remark: Numerals correspond to chapters of the formal textbook.

Chap. 1-5. Introduction to state-space versus transform methods in linear systems; internal versus input/output formulation; discrete-time and continuous-time systems; Laplace $\mathcal{L}_{-}$transform, z-transform. Fundamental concepts of linearity, causality, time-invariance, system inversion. Simple network theory examples; simple mechanical system examples; simple communication (decoding) examples; simple image processing examples (Fornasini-Marchesini model). Basic realization theory via elementary companion canonical forms.

Chap. 6-7/Sections 18.2-18.3. The convolution theorem, $\exp(At)$, Cayley-Hamilton theorem, characteristic versus minimal polynomials, diagonalization of matrices, Jordan form. Various methods to compute $\exp(At)$, including numerical aspects. Introduction to polynomial matrix theory via the Smith form (Section 18.2-18.3); more systematic approach to Jordan form; the Belevitch-Rosenbrock matrix, and the multivariable zeros of a transfer matrix.

Chap. 8-9. Stability, from the the internal and the external points of view.

Chap. 11-14. Controllability, reachability, including polynomial criteria, controllable space, controllability decomposition, pole placement.

Chap. 15-16. Observability and reconstructibility in linear systems both from the state-space and the polynomial points of view. Synthesis of observers. Control by output feedback and separation theorem

Chap. 17. Canonical structure theorem. Geometric insight. Minimality of realization. Balanced realizations. Introduction to identification problems

Schedule

Chapters	*Timing*
Chap. 1-5	January 2012
Chap. 6-7/Sections 18.2-18.3	02/01-02/21, 2012
Chap. 8-9	02/21-03/07, 2012
Chap. 11-14	03/07-03/15 + 03/21-03/31, 2012
Chap. 15-16	04/01-04/15, 2012
Chap. 17	04/15-04/30, 2012