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Mechanical Engineering
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ENG ME/SE/EC 501: **Dynamic Systems Theory — State-space linear systems**

Course Outline: (Fall 2023)

1. Mathematical preliminaries: linear algebra
 - (i) Finite dimensional linear spaces
 - (ii) Linear transformations and matrices
 - (iii) Jordan normal form
2. State-space representation of linear control systems
3. Mathematical foundations of state-space representations
 - (i) Existence and uniqueness results for linear ordinary differential equations
 - (ii) Peano-Baker series and matrix exponentials
 - (iii) Properties of the state-transition matrix
4. Points of contact with frequency-domain analysis
 - (i) The resolvent; Newton's algorithm
 - (ii) Stability analysis in the frequency domain
5. Controllability and observability
 - (i) The controllability Gramian; the observability Gramian
 - (ii) Algebraic tests for controllability and observability
6. Shaping the dynamic response — Where do we put the closed-loop poles?
 - (i) Analysis of second-order systems; dc-motor control example
 - (ii) Design of regulators
7. Digital control theory
 - (i) Modeling discrete-time and sampled-data systems
 - (ii) Analysis of sampled data systems
8. Linear observers
9. Compensator design by separation of variables principle
10. Linear quadratic optimal control theory
 - (i) The Pontryagin maximum principle
 - (ii) Least squares theory and the matrix Riccati equation
11. Introduction to stochastic processes and stochastic control processes
 - (i) Wiener processes
 - (ii) The Ito calculus and the theory of stochastic differential equations
 - (iii) Recursive estimation

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12. Nonlinear/geometric control theory
- (i) Introduction to the theory of differentiable manifolds
 - (ii) Accessibility, controllability, and system Lie algebras
 - (iii) Geometric mechanics and control of mechanical systems

Suggested Reading

Text:

Roger W. Brockett, *Finite Dimensional Linear Systems*, SIAM, 2015 / xvi + 244 pages / Softcover / ISBN 978-1-611973-87-7. For student discount prices, order according to the instructions given on the course web site: <http://people.bu.edu/johnb/ME501.html>.

For a convenient guide to online shopping for the text, visit the course website:

<http://people.bu.edu/johnb/ME501.html>

Other books:

Panos J. Antsaklis & Anthony N. Michel, *Linear Systems*, ISBN: 0-07-041433-5, Electrical and Computer Engineering Series, McGraw-Hill, 1997, 696 pages.

Chi-Tsong Chen, *Linear System Theory and Design*, Oxford University Press, 3-rd Edition, ISBN 0-19-511777-8, 1999, 334 pages.

Karl Johan Åström and Richard M. Murray, *Feedback Systems: An Introduction for Scientists and Engineers*, Princeton University Press, ISBN-13: 978-0-691-13576-2, ISBN-10: 0-691-13576-2, 2008, 396 pages.

João P. Hespanha, *Linear Systems Theory*, Princeton University Press, ISBN: 978-0-691-14021-6, 2009, 278 pages.

Roger W. Brockett, *Finite Dimensional Linear Systems*, John Wiley and Sons, SBN 471 10585 6, 256 pages. (Out of print. See <http://www.amazon.com/> or download from course web site <http://people.bu.edu/johnb/ME501.html>. Alternatively, use the identical SIAM reissue listed above.)

Grading

Grades will be given for homework assignments (one every week or so), class participation, and a mix of quizzes and exams.

For up-to-date information about the class, visit: <http://people.bu.edu/johnb/ME501.html>.

(August 22, 2023)