Introduction to Linear Systems

Fall Semester

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COURSE DESCRIPTION

Week 1: Classification of systems: linear/nonlinear, time invariant/time varying, causal/non-causal etc. Useful functions: impulse, unit step, ramp. Time-domain analysis of continuous linear time invariariant (LTI) systems. Description of the continuous LTI system by differential equations. Response to internal (initial) conditions. Response to the input excitation. Convolution. The impulse response.

Weeks 2 & 3: The (one-sided) Laplace transform (review). Solving the linear differential equations of a LTI system with the Laplace transform. Transfer functions, poles and zeros in the complex plane. Characterization of second order systems response. Stability of continuous LTI system. Feedback and its use control improve and stabilize a system.

Weeks 3 & 5: Electrical systems (review of KVL,KCL) and modeling of combinations of (translational and rotational) mechanical systems and electro-mechanical by electrical networks.

Weeks 6 & 7: State space presentation of continuous LTI systems. Some canonical presentations. Solution of the state equations in the time-domain. Solution of the state equations with Laplace transform. Transition between presentation of the system by differential equations, transfer function and canonical state space presentations. State variables feedback.

Week 7 & 8: Frequency response to sinusoidal excitation. Frequency domain analysis. By Bode frequency response plots.

Week 9: Discrete systems. Linear shift ("time") invariant (LSI) systems.. Time invariance causality in discrete systems. Discrete vs. digital. Sampled continuous LTI. Description of the LSI system by difference equations. Useful discrete functions. Solution of the difference equation in the "time-domain": Response to initial conditions. Response to excitation. Discrete impulse response. Discrete convolution.

Week 10-11: The one-sided Z transform and its properties. Its use to solve the discrete transfer function. Poles and zeros in the complex domain and stability conditions. Frequency response to sinusoidal excitation.

Week 12: State space presentation of LSI system in a state-space. Canonical presentations. Solution of the discrete state equations in the "time" domain and with the Z transform.

Week 13: Stability criteria for continuous and discrete time systems

ASSIGNMENTS

There will be weekly home assignments. The grade on them count for 10% percent of the final grade. The grade is determined by the 10 best evaluated assignments (out of 13 assignments).

A midterm exam will be scheduled in the beginning of the semester. During an examination. The midterm is elective but encouraged. It will weight 15% of the total course grade if the grade improves the the final grade.

FINAL GRADE POLICY

The final exam will cover the entire course material. The exam grade will be either (i) 90% of the total course grade in case the midterm grade is lower than the final exam grade (or is not available) or (ii) 75% final exam with 15% midterm grade in case the midterm grade is higher than the final exam grade and the remaining 10% will be determined by the grade for the weekly assignments. The duration of the exam will be 3 hours. During both the midterm and the final examination, student shall use only material (some pages with summary of formulas) provided by the instructor with the exam (but they will be exposed to them in advance). Students will have a Moed A exam and a Moed B exam. Students that took the Moed A exam may retake the Moed B exam too. The last exam taken determines the student's final grade.

READING

The students will get copy of the slides presented in class and a summary of the topics topics. The only way to have the complete material is to attend the lectures. Here is a list of recommended further reading with emphasis on texts with many solved problems. No single book matches exactly the taught material. The relevance of the list below will be evaluated in the first lecture.

[1] B. P. Lathi, *Linear Systems and Signals* Oxford University Press (2nd Edition) 2005.

[2] Di Stefano et al, *Feedback and Control Systems* (Schaum's Outline Series).

[3] D'Azzo, J. and C. Houpis. *Linear Control System Analysis & Design.* 4^{th} ed., McGraw Hill, 1995

[4] K. Ogata, *Modern Control Engineering*, Prentice Hall (5th edition 2005)
[5] K. Ogata, *Discrete-time control systems*, Prentice Hall (2nd Edition 1995)