University of Waterloo
ECE 682: Multivariable Control Systems
Fall 2023 (tentative)

Lectures: Wednesday, Friday 2:30 pm to 3:50 pm. EIT-3151.

Instructor: Prof. Christopher Nielsen.
Office hours: By appointment.
Contact: cnielsen@uwaterloo.ca.
Website: http://learn.uwaterloo.ca/

Calendar description: An introduction to control theory for linear time-invariant finite-dimensional systems from both the state-space and input-output viewpoints. State-space theory: the concepts of controllability, observability, stabilizability, and detectability; the pole-assignment theorem; observers and dynamic compensation; L.Q.R. regulators. Input-output theory: the ring of polynomials and the field of rational functions; the algebra of polynomial and rational matrices; coprime factorization of transfer matrices; Youla parametrization. Introduction to optimal control.

Recommended background: Undergraduate linear algebra; introductory course on feedback control (ECE380 or equivalent).

Text: Course notes are available on the course website. The optional suggested textbook is

Linear System Theory and Design, 3rd edition, C.T. Chen.

Additional references

- Linear System Theory, F.M. Callier and C.A. Desoer.
- Control Theory for Linear Systems, H.L. Trentelman, A.A. Stoorvogel, M. Hautus.
- Linear Systems Theory, J.P. Hespanha.

Evaluation:

55% Final exam: open book.

40% Assignments: Four (4) assignments spread over the term.

5% Student delivered tutorials (if sufficient enrolment). Held outside lecture time. Schedule to be determined.

Tentative Topics List:

1. **Introduction to linear multivariable systems**
   Motivation, examples.

2. **Linear state-space models**
   Deriving state models, Linearization, Solution of state equation, Realizations, Poles and zeros of a multivariable system.

3. **Linear algebra**
   Vector spaces, Linear transformations, Quotient spaces, Invariant subspaces.

4. **Controllability**
   Reachable states, Properties of controllability, PBH test, Equivalence of pole placement and controllability, Stabilizability.

5. **Observability**
   The Kalman decomposition, Detectability, Observers, Observer based controllers.

6. **Quadratic optimal control**
   Lyapunov equation, Riccati equation, The LQR problem and its solution.

7. **Stability of feedback systems**
   Well-posedness, Feedback stability, Output feedback stabilization.

8. **Regulation and tracking**
   Output regulation problem, Solution in the case of full information, Solution in the case of measurement feedback, Structurally stable synthesis.

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