University of Waterloo
Department of Electrical & Computer Engineering
ECE 682: Multivariable Control Systems

Fall 2018 (tentative outline subject to change)

Lecture times, building and room number: Tuesday 2:30pm to 5:20pm; EIT 3151.

Instructor: Prof. Christopher Nielsen.
Office: CEIT 4106.
Office hours: Friday 2:30pm to 4:30pm or, by appointment.
Contact: cnielsen@uwaterloo.ca; ext. 32241.
Website: http://learn.uwaterloo.ca/

Course 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.

Course prerequisites: ECE 380 (or equivalent) and familiarity with basic linear algebra.

Textbook

There is no required text for this course. Instructor will write notes on the board. A good optional text is: Linear System Theory and Design, 3rd edition, C.T. Chen.

Additional references:

- Finite-Dimensional Vector Spaces, P.R. Halmos.
- Linear Systems, T. Kailath.

Evaluation

25% Assignments.

5% Tutorials (schedule to be determined).

20% Midterm.

50% Final exam.

Tentative Topics List

1. **Introduction to linear multivariable systems**
   Examples.

2. **Linear state 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, Properties of the optimal LQR feedback.

Academic integrity, grievance, discipline, appeals and note for students with disabilities: see www.uwaterloo.ca/accountability/documents/courseoutlinestmts.pdf. The text on that web site is listed below.

Academic integrity: In order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility. [Check www.uwaterloo.ca/academicintegrity/ for more information.]

Grievance: A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70, Student Petitions and Grievances, Section 4, www.adm.uwaterloo.ca/infosec/Policies/policy70.htm. When in doubt please be certain to contact the department's administrative assistant who will provide further assistance.

Discipline: A student is expected to know what constitutes academic integrity [check www.uwaterloo.ca/academicintegrity/] to avoid committing an academic offence, and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offence, or who needs help in learning how to avoid offences (e.g., plagiarism, cheating) or about "rules" for group work/collaboration should seek guidance from the course instructor, academic advisor, or the undergraduate Associate Dean.

For information on categories of offences and types of penalties, students should refer to Policy 71, Student Discipline, www.adm.uwaterloo.ca/infosec/Policies/policy71.htm. For typical penalties check Guidelines for the Assessment of Penalties, www.adm.uwaterloo.ca/infosec/guidelines/penaltyguidelines.htm.

Appeals: A decision made or penalty imposed under Policy 70 (Student Petitions and Grievances) (other than a petition) or Policy 71 (Student Discipline) may be appealed if there is a ground. A student who believes he/she has a ground for an appeal should refer to Policy 72 (Student Appeals) www.adm.uwaterloo.ca/infosec/Policies/policy72.htm.

Note for students with disabilities: The Office for persons with Disabilities (OPD), located in Needles Hall, Room 1132, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with the OPD at the beginning of each academic term.