

University of Waterloo  
Department of Electrical & Computer Engineering  
SE 380: Introduction to Feedback Control

Term and year of offering: Fall 2016.

Course number and title: SE 380, Introduction to Feedback Control.

Lecture times, building and room number: M, W, F 10:30 am to 11:20 am; EV3 1408.

Tutorial times, building and room number: Thursday 11:30 am to 12:20 pm; MC 1085.

Laboratory location: E2-3341.

Instructor: Christopher Nielsen.

Office: CEIT 4106.

Office hours: Wednesday 2:00pm to 4:00pm.

Contact: [cnielsen@uwaterloo.ca](mailto:cnielsen@uwaterloo.ca); ext. 32241.

Website: <http://learn.uwaterloo.ca/>

Lab website: <https://ece.uwaterloo.ca/~se380/>

Lab instructor: Carmen Caradima, E2 3337, ext. 33003 ([cmcaradima@uwaterloo.ca](mailto:cmcaradima@uwaterloo.ca)).

Teaching assistants:

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**Calendar description:** Introduction to control systems. Advantages of closed-loop feedback systems. The role of the system mathematical model. Block diagrams. The basic control system design problem, stability in control systems. Frequency response analysis techniques. Root-locus analysis. Elementary lead-lag compensation.

**Course prerequisites:** MATH 213; software engineering students only.

**Course objectives:** At the end of the course it is hoped that you have learned:

- The value of block diagrams.
- What feedback is and why it's important.
- How to model a system using differential equations.
- What it means for a system to be linear.

- The value of graphical simulation tools like Simulink.
- Why we use transfer functions and the frequency domain.
- What stability means.
- How to determine if a feedback system is stable.
- The Nyquist stability criterion and the meaning of stability margin.
- How to design a simple feedback loop using frequency-domain methods.
- What makes a system easy or hard to control.

**Required text:** Course notes are available for purchase at the Davis Centre Media.doc (DC 1820B). The optional suggested textbook is

Introduction to Feedback Control, L. Qiu and K. Zhou.

Additional references

- Modern Control Systems, 12th edition, R.C. Dorf, R.H. Bishop.
- Feedback Systems: An Introduction for Scientists and Engineers, K.J. Åström, R.M. Murray  
<http://www.cds.caltech.edu/~murray/amwiki>
- Feedback Control of Dynamical Systems, 7th edition, G.F. Franklin, J.D. Powell, A. Emami-Naeini.

**Evaluation:** If you fail the final exam ( $< 50\%$ ) then your course mark is 100% final. Else

20% Laboratory ( $\{1, 2, 3, 4, 5\} = \{2\%, 4\%, 4\%, 5\%, 5\%\}$ ).

5% Quizzes (held during tutorial, 10 total, each worth 1 point).

75% Exams.

The quizzes mark is calculated as

$$\text{Quizzes} = \min \{ \text{sum of your 10 quiz marks}, 5 \}.$$

The exams mark is calculated as

$$\text{Exams} = \max \{ 25\% \text{ midterm} + 50\% \text{ final}, 75\% \text{ final} \}.$$

The midterm is on Friday October 28, 6:30pm to 8:00pm, M3 1006. If you miss the midterm for any reason, then your midterm mark is zero.

## Tentative Topics List:

### 1. Introduction to feedback

Examples, open-loop versus closed-loop.

### 2. Mathematical models of systems

Building models, linearization, transfer functions, block diagram manipulations.

### 3. Linear system theory

Initial-state response, input-response, total response, asymptotic stability, bounded input bounded output stability, frequency response, graphical representations of the frequency response.

### 4. First and second order systems

First order systems, second order systems, time domain effect of pole locations, characteristics of step responses, settling time, overshoot, time to peak, rise time, effects of adding poles and zeros, reduced order models.

### 5. Feedback control theory

Stability of feedback systems, Routh-Hurwitz criterion, steady-state performance.

### 6. Root-locus method

Basic root locus, non-standard problems.

### 7. PID control

Classical PID controller, pole placement.

### 8. Frequency domain methods for stability analysis

Nyquist stability criterion, stability margins.

### 9. Introduction to control design in the frequency domain

Loop shaping, performance specifications, lag compensation, lead compensation, performance limitations.

## Laboratory:

Table 1: Important laboratory dates.

Lab	Name	Prelab due	Lab dates	Report due
1	Instrumentation	Sept. 28	Sept. 29, Oct. 4, 5	Oct. 14
2	2nd order systems	Oct. 17	Oct. 18, 19, 20	Oct. 31
3	Motor Control	No prelab	Nov. 1, 2, 3	Nov. 11
4	PID analysis	No prelab	Nov. 15, 16, 17	Nov. 24
5	Lead and Lag design	Nov. 28	Nov. 29, 30, Dec. 1	Dec. 5

- Prelabs and lab reports are due at 10:00pm on the date specified on the table above and the lab webpage. Please verify that you have uploaded your submission on time, the document is complete, and it is under the group account of the correct course number.
- All submissions are to be done electronically, through the course website (LEARN). All submissions must be in pdf format.

- Revised submissions prior to the deadline are accepted; in such cases, the most recent file of will be marked.
- Both lab partners are responsible for verifying that the group submission was uploaded to LEARN; the file submitted will show on the list of files in the group account.
- Prelabs will be graded, and the grades make up a part of the overall grade for each lab module. Late prelabs will incur a penalty of 10% in the first 24 hours, and 100% thereafter, unless prior arrangements are made or a valid reason presented. With a valid reason, prelabs can be handed in late, but no later than the date on which the actual lab sessions start (since prelab answers are made available at that point).
- Late lab reports will incur a penalty of 20% in the first 24 hours, and 100% thereafter, unless prior arrangements are made or a valid reason presented within a week from the missed deadline. In no case will a lab report be accepted more than a week past the deadline; if a valid reason exists for being unable to hand in the lab within the week following the deadline, then the lab will be assigned a weight of zero and the remaining labs will be re-weighted accordingly.
- Lab attendance is mandatory for each student. Missing a significant portion of a lab session without a valid reason will result in a reduction in the lab report grade (for that student only). The grade reduction will be proportional to the fraction of the lab session missed, where missing an entire lab session (without a valid reason) results in a 100% reduction in the lab report grade. In cases where a student misses part of a lab session, the lab instructor is the one who determines the mark reduction.

#### Rules for group work in lab assignment:

- Students work in groups of two. Both partners must do all of the lab work, and attend all lab sessions (see above). Each group submits one prelab per lab, and one report per lab. See the lab web page for more details about report formats, deadlines, etc.
- The instructor or lab instructor has the authority to split up or re-arrange groups for academic reasons, including the possibility or requiring certain students to work alone.
- Under no circumstances are students allowed to access, in any form, SE/ECE380 lab reports or answers or results from previous terms. Such access will be treated as an academic offence under Policy 71.
- You are allowed to talk with other students currently enrolled in the course about the lab content, but each group must write up their lab reports completely independently. Of course, students can also talk to the lab TAs, the lab instructor, or the course professor for help.

**Academic integrity, grievance, discipline, appeals and note for students with disabilities:** see [www.uwaterloo.ca/accountability/documents/courseoutlinestmts.pdf](http://www.uwaterloo.ca/accountability/documents/courseoutlinestmts.pdf). The text for this 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/](http://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](http://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/](http://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](http://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](http://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](http://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.