AUTOMATIC CONTROL, BASIC COURSE (FRT010)

Course Syllabus, Fall 2016

Higher education credits: 7.5 ECTS (one eighth of a year of full-time studies). **Grading scale:** Fail, 3, 4, 5. **Level:** G2 (Secondary basic level). **Language of instruction:** English. **Course coordinator:** Kristian Soltesz, Department of Automatic Control, Lund University, Sweden. **Recommended prerequisites:** Calculus in One Variable, Calculus in Several Variables, Linear Algebra, Linear Systems or Systems and Transforms. **Assessment:** Written exam, three laboratory exercises. **Further information:** The course is given at Zhejiang University in Hangzhou, China. **Home page:**

`http://www.control.lth.se/Education/EngineeringProgram/FRT010_China.html`

Aim

The aim of the course is to give knowledge about the basic principles of feedback control. The course will give insight into what can be achieved with control—the possibilities and limitations. The course mainly covers linear continuous-time systems.

Knowledge and understanding

For a passing grade the student must

- be able to define the fundamental concepts of control.
- be able to linearize nonlinear dynamical models.
- be able to compute the relations between dynamical models in the form of transient responses, transfer functions, differential equations on state-space form, and frequency responses described with Bode or Nyquist diagrams.
- be able to analyze dynamical systems with respect to stability, robustness, stationary characteristics, controllability, and observability.
- be able to implement controllers using discretization of analog controllers.

Skills and abilities

For a passing grade the student must

- be able to design controllers from given specifications on robustness and performance based on models on state-space form, transfer function form, Bode diagrams or Nyquist diagrams.
- be able to design controllers based on cascade connections, feedforward, and delay compensation.
- be able to evaluate controllers by analysing transient and frequency responses, and via laboratory experiments on real processes.

Judgement and approach

For a passing grade the student must

- understand relationships and limitations when simplified models are used to describe complex dynamical systems.
- show ability for teamwork and collaboration at laboratory exercises.

Lectures and Problem Solving Sessions

Lectures and exercise sessions are given by Gustav Nilsson (Nov 15 - Nov 25), Olof Troeng (Nov 23 - Dec 9) and Fredrik Bagge Carlson (Dec 1 - Dec 20). Each person is at ZJU during the dates in parenthesis. The room codes are to be read "building:room".

Nr	Date	Time	Room	Topics
L1	Nov 15 (Tue)	15:55-17:30	7:302	Introduction. The PID Controller. State-space Models.
L2	Nov 15 (Tue)	18:30-20:55	7:302	Linearization. Transfer Function. Block diagram representation. Transient Response.
E1	Nov 17 (Thurs)	15:55-17:30	7:302	Process models. Linearization.
L3	Nov 17 (Thurs)	18:30-20:55	7:302	Step response analysis. Frequency Response. Relation between Model Descriptions.
E2	Nov 22 (Tue)	15:55-17:30	7:302	System representations. Block diagrams. Step response. Linearization.
E3	Nov 22 (Tue)	18:30-20:55	7:302	Frequency response. Bode & Nyquist diagrams. Step response.
L4	Nov 24 (Thurs)	15:55-17:30	7:302	Feedback–An Example. Stability. Stationary errors.
E4	Nov 24 (Thurs)	18:30-20:55	7:302	Lab 2 preparations. Stability. Root locus.
L5	Nov 29 (Tue)	15:55-17:30	7:302	The Nyquist Criterion. Stability Margins. Sensitivity.
E5	Nov 29 (Tue)	18:30-20:55	7:302	The Nyquist criterion. Stability margins.
L6	Dec 1 (Thurs)	15:55-17:30	7:302	State Feedback. Controllability. Integral Action.
E6	Dec 1 (Thurs)	18:30-20:55	7:302	Sensitivity. Stationary errors. Controllability.
L7	Dec 6 (Tue)	15:55-17:30	7:302	Observability. Kalman Filtering. Output Feedback. Pole/Zero cancellation.
E7	Dec 6 (Tue)	18:30-20:55	7:302	State feedback. Observability.
L8	Dec 8 (Thurs)	15:55-17:30	7:302	Lead-lag Compensation. Frequency Analysis of PID.
L9	Dec 8 (Thurs)	18:30-20:55	7:302	More on PID. Controller structures.
E8	Dec 13 (Tue)	15:55-17:30	7:302	Kalman filtering. Lead-lag filtering.
L10	Dec 13 (Tue)	18:30-20:55	7:302	Sampling and Discretization. A Control Example.
E9	Dec 15 (Thurs)	15:55-17:30	7:302	PID analysis and tuning.
E10	Dec 15 (Thurs)	18:30-20:55	7:302	Controller structures. Synthesis.
L11	Dec 19 (Mon)	15:55-17:30	7:204	Course review.
E11	Dec 19 (Mon)	18:30-20:55	7:204	Old exam.

Each lecture has a separate chapter in the lecture notes by Tore Hägglund, see 'Literature'.

Laboratory exercises

The course contains three mandatory laboratory exercises (4 hours each). Each exercise will be given at two occasions. It is mandatory to sign up for one occasion per exercise through the course homepage. The room codes are to be read "building:room".

Nr	Date	Time	Room	Topics	Responsible
Lab 1	Nov 21 (Mon)	16:00-20:00	10:3101	Empirical PID control.	Gustav
	Nov 23 (Wed)	16:00-20:00	10:3101		
Lab 2	Nov 28 (Mon)	16:00-20:00	10:3101	Model construction and	Olof
	Dec 2 (Fri)	16:00-20:00	10:3101	calculation of PID controller.	
Lab 3	Dec 14 (Wed)	16:00-20:00	10:3101	State feedback	Fredrik
	Dec 16 (Fri)	16:00-20:00	10:3101	and Kalman filtering.	

You will work in groups of two or three students. You should ideally work in mixed Swedish/Chinese groups.

The manuals for Labs 2 and 3 contain preparatory exercises that must be solved before the laboratory exercise. At the start of Lab 2, a quiz with two review questions are given. You must give correct answers to both questions in order to proceed with the laboratory exercise. Sign-up lists for the laboratory exercises will be available on the course web page.

Literature

The course is based on the following compendiums:

- Tore Hägglund: *Automatic Control, Basic Course – Lecture Notes.* Department of Automatic Control, Lund University, 2014.
- *Automatic Control, Basic Course – Collection of Exercises.* Department of Automatic Control, Lund University, 2014.
- *Automatic Control, Basic Course – Laboratory Manuals.* Department of Automatic Control, Lund University, 2012.
- *Automatic Control, Basic Course – Collection of Formulae.* Department of Automatic Control, Lund University, 2012.

As reference textbook, we recommend

- Karl Johan Åström & Richard Murray: *Feedback Systems: An Introduction to Scientists and Engineers.* Princeton University Press, 2008. The newest version of the book can be downloaded for free at

  `http://www.cds.caltech.edu/~murray/amwiki`

Examination

The mandatory parts of the course are

- the three laboratory exercises,
- the written exam.

The final grade is based only on the result from the written exam.

You may bring the collection of formulae and a pocket calculator (without any control software) to the exam.

In case of absence or failure it is possible for LTH students to write any of the FRT010 re-exams at LTH. For non-LTH students, there will be no re-take exam. LTH students are primarily referred to the ordinary exam occasion in Lund: January 10, 08:00-13:00, Vic:1 and Vic:2. Remember to sign up for the exam according to the standard procedure at LTH.

For ZJU students, and those LTH students who have reported that they cannot make it to the exam in Lund, an exam will be given at ZJU December 20 13:00-18:00 in 7:502.

The corrected exams will be available for inspection at the Department of Automatic Control in Lund. Inspection date will be announced online.

Recommended Exercise Problems

S = Solved at exercise session. H = Recommended to be solved at home.

E1	S:	1.1, 1.2, 1.7
	H:	1.5a-c, 1.6, 1.9
E2	S:	2.1, 2.14ab, 2.15,
	H:	2.2ab, 2.16ab
E3	S:	2.5, 2.9, 2.11, 2.13, 3.1, 3.2, 3.4bd, 3.5b, 3.7
	H:	2.6, 3.4ac, 3.5a, 3.6
E4	S:	4.1, Preparatory exercises 3.1 and 3.5 in Lab 2, 4.9, 4.11, 4.2, 4.6, 4.4
	H:	6.3, 6.4, 4.3, 4.5
E5	S:	4.13, 4.15, 4.17, 4.18, 4.7
	H:	4.12, 4.14, 4.19
E6	S:	5.5, 5.8, 5.10, 5.11
	H:	5.2, 5.6
E7	S:	5.3, 5.12, 5.9
	H:	5.13
E8	S:	6.11, 6.12, 6.13, 6.14, 6.5, 6.2
	H:	6.15
E9	S:	6.7, 6.8, 7.1, 7.6, 7.8, 7.9
	H:	6.6, 6.9, 7.2, 7.5
E10	S:	8.1
	H:	8.2

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