Reglerteknik ERE091 and SSY310 - Course program

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Göteborg, study period 4, online course in 2020/21

Welcome!

Department of Electrical Engineering (E2), Hörsalsv. 9, E-building, floor 5.
This course is mandatory for choosing MPSYS at Chalmers.
Course is decomposed into a series of lectures, problem solving, tutoring, and lab sessions. In 2020/21 LP4 all sessions will be given online via ZOOM. Therefore room/lecture hall numbers published at TimeEdit are not valid!

- **Lecturer**(in English): Balazs Kulcsar, `kulcsar@chalmers.se`
- **Course assistant**:
  Albin Dahlin, `albin.dahlin@chalmers.se`
- **Exercises**:
  SSY 310: Albin Dahlin, `albin.dahlin@chalmers.se`
  ERE 091: Viktor Andersson, `vikta@chalmers.se`
- **Lab**:
  Albin, Viktor
- **Project work SSY310**: Albin
- Course homepage at Canvas

Course materials

1. Black board lectures (in English).
2. E-quizzing (anonymous, *socrative.com*): weekly (Mondays), course wrap-up (last Wednesday, 45 min)
3. Problem solving manual (Canvas, `https://www.youtube.com/channel/UCY6DFWOhNHPjE_D5nO9FGmw`)
4. Balanduino project syllabus (Canvas),
5. Project description for SSY310 (Canvas)
6. Course book available at Cremona

   Reglerteknik - Grundläggande teori
   T. Glad and L. Ljung
   ISBN-9789144022758, Studentlitteratur AB

7. Optional

   Reglerteknikens grunder
   B Lennartson
   ISBN-9789144024165, Studentlitteratur AB

Lectures

Week	Monday 13-15, (chapter)	Wednesday 13-15/Tuesday 15-17
1(w12)	L1 Intro, models (1, 2.1-2.3) (1, 2.1-2.3, 2.5)	L2 Stability (2.4-2.6) (2.6, 6.1-6.3)
2(w13)	L3 Interconnect (2.7-2.8, 2.9) (2.7)	L4 State space I (8.1-8.6) (3.1-3.5)
3 (w14)	Easter break	
4(w15)		L5 State space II (8.7-8.9) (3.6, 11.1)
5(w16)	L6 Closed-loop (3.1-3.6) (7.1-7.6)	L7 Nyquist (3.8, 4.1-4.2) (6.5-6.6)
6(w17)	L8 Bode I (4.3, 5.1-5.2) (5.5-5.6))	
7(w18)	L9 Bode II (5.3-5.6, 7) (5.8-5.10, 10.1-10.3)	L10 Sensitivity (6) (9.1-9.4, 9.6)
8(w19)	L11 State feedback I (9.1-9.2) (11.2)	L12 State feedback II (9.3) (11.2)
9((w20)	L13 State observer (9.6, 9.4) (11.3)	L14 Output feedback (9.5) (11.4), overview
10(w21)		

Table: Scheduled lectures in ZOOM (Chapter numbers refer to Reglerteknik - Grundläggande teori and to Reglerteknikens grunder)

- ”Black board” using online streaming via ZOOM. All lectures recorded and uploaded to Canvas.
- Interactive quizzes, lecture notes with gaps, transparent structure (ILO)

Responsible: Balazs

Exercises

Exercise sessions (both SSY310/ERE091) given in Zoom in the time slots published at TimeEdit

	Topics	Exercises solved (Ex. #)	Optional HW
1	Dynamics 1	1.3,1.6,1.7,1.10,1.12	1.1,1.2,1.4,1.5,1.8,1.9
2	Dynamics 2	1.15,1.17,1.16,1.28	1.11,1.14,1.19,1.18,1.22
3	Modeling	3.4,3.13,3.16, 3.34	3.2, 3.3, 3.5, 3.11, 3.20
4	State space 1	2.3 2.7 2.9,2.11,2.15	2.1,2.2,2.4,2.8,2.10,2.12
5	State space 2	3.18,3.22, 3.26, 3.29	3.19, 3.27, 3.28, 3.31
6	Closed-loop	4.2a, 4.5, 4.9, 4.11, 4.21	4.3, 4.8, 4.22, 4.25
7	Nyquist	5.13, 5.14 ,5.19	5.12, 5.17, 5.23
8	Bode	5.2a, 5.2 f, 5.5	5.2 d, 5.2 e, 5.6
9	Controller 1	6.1, 6.3, 6.8, 6.36b	6.6, 6.23, 6.26, 6.27
10	Robustness	6.16, 6.21a, 6.35	6.18, 6.31, 6.33, 6.34, 6.36a, c
11	Controller 2	7.1, 7.5, 7.14, 7.16	7.2, 7.7, 7.11, 7.15
12	State feedback 1	8.1 8.3	8.8
13	State feedback 2	8.5, 8.6a,	8.10
14	State observer	8.9 Q7(Exam20171006)	

Table: Problem solving manual numbered topics.

Responsible: Albin, Viktor

Lab sessions both for SSY310 and ERE091

Students create groups up to 3 persons (Canvas, groups are open). Difficulty to group up? Contact course assistant on week 1! Deadline to group up end of study week 1.

- *Simulation based* balanduiono project. 2 assignments. Distribution of tasks from study w1 via Canvas.
- Optional drop-in consultation/labtutorial hours
- Mandatory, oral assessment via ZOOM
- Assessments (**April 16 and May 24**), 15 min each/group, scheduled at Canvas

Responsible: Viktor, Albin

Lab sessions both for SSY310 and ERE091

lab	date and time	room
Consult/Lab tutorial,	w12	Zoom (drop in)
Consult/Lab tutorial	w15	Zoom (drop in)
Lab assessment 1	w15	Zoom (scheduled!)
Consult/Lab tutorial	w16	Zoom (drop in)
Consult/Lab tutorial	w17	Zoom(drop in)
Consult/Lab tutorial	w18	Zoom(drop in)
Consult/Lab tutorial	w20	Zoom(drop in)
Consult/Lab tutorial	w20	Zoom(drop in)
Lab assessment 2	w21	Zoom (scheduled!)

Table: Timeline: labs

- Mandatory assessment takes 15 min/group, scheduled via Canvas. Lab tutorials are optional drop-ins, online sessions.
- Groups may swap time-slots if mutually agreed (assessment).

Project for SSY310

Students create groups up to 3 persons (Canvas, groups are open). Difficulty to group up? Contact course assistant on week 1! Deadline to group up end of study week 1. Labgroups may be different from projectgroups.

1. Project work
    - Extensive project. Distributed (w 1) and solution is collected via Canvas.
    - Report deadline 1, study week 4 (**April 23, Thursday 6:00 pm**) via Canvas answer questions 1-3.
    - Report deadline 2, study week 7 (**May 21, Friday, 6:00 pm**) via Canvas answer questions 4-end.
    - Upload to Canvas, 1 solution report per group.
    - Notifications on acceptance, 1 study week after the submission deadlines.
    - Wrong/missing solutions have to be corrected/uploaded within 1 study week.

Tutorial sessions only are meant to help but are insufficient to carry out the complete solutions. Tutorials are run online in Zoom.

Responsible: Albin

Requirements

1. Necessary condition: approved labs (for ERE091/SSY310), approved project work (only for SSY310).
2. Sufficient condition is to pass written examination (Grading TH, 3,4,5, 4.5c). **Exam: 2021 June 4, pm**
3. You have to **register** to the exam! Check registration deadline!
4. Exam is planned to be **remotely** done, standard 4h .
5. In the exam question list; some theoretical questions (10-20%),one a bit challenging numerical question (10-20 %), majority are standard numerical questions (similar to the exercise session ones).

What do I learn here?

Scheduled Intended Learning Outcomes (ILO)

w1 **Intro, Modeling for control**(Course PM, system definition, control goals, LTI system's properties, models for dynamical systems, transfer function)
Stability(BIBO stability definitions, impulse and step and their responses,final value theorem, Routh stability criterion)

- Understand and explain the function of a linear control system, and be able to define basic control terminology.
- Describe and explain the most important properties of linear dynamical systems.
- Formulate models for dynamical systems, frequently encountered in a technical context. The models take the form of transfer functions as well as state equations.

w2 **Block diagrams** (First, second order and delayed models, block diagrams, closed-loop system stability.)
State-space models I (State-space models, canonical forms, change of coordinate frame, state-space vs transfer functions)

w3 **State space models II** (Solution to the state equation, stability, controllability, observability)

- Transform in both directions between linear state equations and transfer functions, especially for single-input single-output systems. Linearize nonlinear state equations.
- Analyse feedback dynamical systems, emphasizing stability assessment based on the Nyquist criterion. Formulating solutions to state equations, using transition matrices.

- w3 **Closed-loop design** (Closed-loop system analysis, time and Laplace domain, PID regulation, Zieglers-Nichols)
- w4 **Nyquist criterion** (Nyquist polar plots, Nyquist stability criteria)
  Bode I (Frequency function, closed-loop Bode stability criteria, Bode-diagram)
- w5 **Bode II** (Compensator design by phase and gain margins, Bode compensation, PID)
- w6 **Cascade**(Cascade PID and controller design, feedforward and Pade approximation)
  Sensitivity (Robustness and Bode sensitivity integral, basic limitations of closed-loop design)
  - Describe and explain the principle of P-, I-, PI-, PD- and PID-controllers in a control loop, as well as being able to carry out design for such controllers, in particular by use of Bode plot techniques.
  - Analyse feedback systems, using sensitivity functions, particularly to estimate how large modelling errors a control system can handle without risking instability.
  - Describe and explain the principle of feedforward, cascade control and dead time compensation.

w7 **LQR** (State-space controller design, state feedback, pole placement, linear quadratic compensation)

w8-9 **LQG** (Observer design and Kalman filters, output feedback control)

- Explain and apply the concepts of controllability and observability, and to carry out design of state feedback controllers and observers, using the pole placement method.

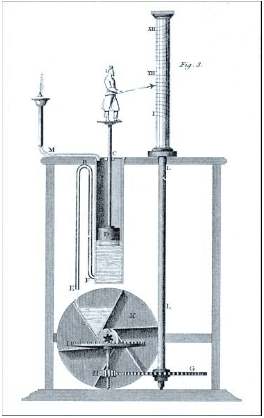
Introduction

- Objective: influence a ”system” to reach autonomous mechanism
- How? With control system design, control theory: tools and concepts to reach it
- https://www.youtube.com/watch?v=3CR5y8qZf0Y

Is that a modern subject?

Is it more than 300/500/1000 years old do you think?

Is it a modern subject?



Wikipedia, waterclock BC 300, Greek. Control along the daylight length, split into 12 hours from sunrise to sunset.

Is that a modern subject?

Wikipedia, NASA flight X29 Grummen fly-by-wire, 1984

Is that a modern subject?

- Consist of 3 parts:
  1. plant (process, system) to control
  2. signals interconnection (e.g. sensing, actuation, feedback)
  3. decision logic (controller)