ELEC4410
Control System Design and Management (10cp)
Course Outline

School of Electrical Engineering and Computer Science
Faculty of Engineering and Built Environment
The University of Newcastle
School Office EAG08, Callaghan.

Course Coordinators - James Welsh / Julio Braslavsky

Semester 2, 2008

Contents

1 Brief Course Description

ELEC4410 examines advanced analysis and design issues in linear feedback control systems. The course provides an in-depth introduction to the fundamental concepts of linear system theory using both transfer function and state equation system descriptions. Emphasis is placed on the design of feedback controllers and state estimators for pole-placement, robust regulation, tracking and disturbance rejection, in the context of real world industrial process applications.

2 Course Objectives

This course offers a more advanced discussion of control systems, introducing many modern control techniques, and implementation issues. In particular, students who successfully complete this course should have:

- an exposure to modern control tools (e.g., observers, state variable feedback, internal model control)
- a basic understanding of various factors which limit the achievable control system performance (e.g., time delays, non minimum phase zeros)
- experience in several lab implementations of control systems
- initial exposure to various control implementation issues (e.g. Sampled data systems, Actuator saturation, Anti-windup schemes)
- an initial exposure to more advanced topics (e.g., multivariable systems, pole assignment, Kalman filters)
- some knowledge of various case studies of successful modern control implementations
- introduction to empirical modelling and system identification

3 Course Content

1. Review of Classical Control and Modelling
2. Internal Model Control design procedure for SISO systems; (Q parametrisation, relationship to state feedback) with implications for PID, Smith predictors; and extensions to unstable plants.
3. Saturation and anti-integral windup schemes
4. State Space models, and systems theory (controllability, observability, state variable feedback, observers)
5. Design constraints in feedback control systems
6. Elements of System Identification
7. Introduction to Multivariable control (decoupling, interaction, analysis & design)
8. Introduction to optimal control and estimation.
9. Case studies

4 Assumed Knowledge

All topics covered in ELEC4400. It is also assumed that students have an active knowledge of linear algebra and Laplace transforms as well as an elemental knowledge of complex variables and linear ordinary differential equations.

5 Contact Hours

Lecture: for 4 Hours per Week for the Full Term
Tutorial: for 2 Hours per Week for the Full Term
Laboratory: for 4 Hours per Term for the Full Term

Note: Students are required to spend on average 120–140 hours of effort or total load (contact and non-contact including assessment) per 10 unit course.

6 Course Content Details

1. **Introduction and motivation to ELEC4410**
2. **Mathematical description of systems**
   - 2.1 A taxonomy of systems
   - 2.2 Linear time invariant systems
   - 2.3 Discrete-time systems
3. **Control design via affine parametrisation**
   - 3.1 Affine parametrisation for stable systems
   - 3.2 PID synthesis via the affine parametrisation
   - 3.3 Affine parametrisation for systems with time delays
   - 3.4 Undesirable closed-loop poles
   - 3.5 Saturation and anti-windup
   - 3.6 Affine parametrisation for unstable systems
   - 3.7 Affine parametrisation for MIMO systems
4. **Fundamental limitations in control design**
   - 4.1 Sensors, actuators, perturbations and model errors
   - 4.2 Structural limitations
     - i. Delays
     - ii. Unstable poles
     - iii. Non-minimum phase zeros
   - 4.3 Design tradeoffs in the step response
     - i. Interpolations constraints
     - ii. Design specifications
     - iii. Design limitations
5. **Elements of system identification**
   - 5.1 Introduction
   - 5.2 Least squares model fitting
6. **Introduction to state space system theory**
   - 6.1 Solution of LTI state equations
     - i. Discretisation
     - ii. Discrete-time state equations
   - 6.2 Realisations
   - 6.3 Equivalent state space equations
   - 6.4 Stability
     - i. External and internal stability
     - ii. Lyapunov Theorem
   - 6.5 Controllability
   - 6.6 Observability
   - 6.7 Canonical forms
   - 6.8 Discrete-time state equations
     - i. Controllability after sampling
7. **Control design via state space methods**
   - 7.1 State feedback
   - 7.2 Regulation and tracking
     - i. Robust tracking: integral action
   - 7.3 State estimation
   - 7.4 Feedback from estimated states
     - i. The Separation Principle
     - ii. Design considerations
   - 7.5 MIMO state feedback
   - 7.6 MIMO state estimation
   - 7.7 MIMO feedback from estimated states
8. **Introduction to optimal control**
   - 8.1 The basic optimal control problem
   - 8.2 The Kalman Filter

7 Contact Details

7.1 Lecturers

Lecturer	Email	Room	Phone	Availability
Greg Adams	Gregory.Adams@newcastle.edu.au	EAG03d	4921 6033	Wed 10:00–12:00
Julio Braslavsky	Julio.Braslavsky@newcastle.edu.au	EAG02	4921 5740	Thu, 15:00–17:00
Alejandro Rojas	Alejandro.Rojas@newcastle.edu.au	EF07e	4921 6023	Mon, 15:00–17:00
James Welsh	James.Welsh@newcastle.edu.au	EAG15	4921 6087	Mon 15:00–17:00

7.2 Other Contacts

School Information

School of Electrical Engineering and Computer Science

Office: EAG08
Telephone: 4921 6026

Faculty Information

The Student Hubs are a one-stop shop for the delivery of student related services and are the first point of contact for students on campus. The four Student Hubs are located at:

- Callaghan campus
- Shortland Hub: Level 3, Shortland Union Building
- Hunter Hub: Student Services Centre, Hunter side of campus City Precinct
- City Hub & Information Common: University House, ground floor in combination with an Information Common for the City Precinct Ourimbah campus

- Ourimbah Hub: Administration Building

Faculty Website: Faculty of Engineering and Built Environment
http://www.newcastle.edu.au/faculty/engineering/

Further Contact Details

Callaghan, City and Port Macquarie: Phone: 02 4921 5000 Email:
EnquiryCentre@newcastle.edu.au
Ourimbah: Phone: 02 4348 4030 Email:
EnquiryCentre@newcastle.edu.au
The Dean of Students: Resolution Precinct Phone: 02 4921 5806 Fax: 02 4921 7151 Email:
resolutionprecinct@newcastle.edu.au
Deputy Dean of Students (Ourimbah): Phone: 02 4348 4123 Fax: 02 4348 4145 Email:
resolutionprecinct@newcastle.edu.au

Various services are offered by the University Student Support Unit:
http://www.newcastle.edu.au/study/studentsupport/index.html

8 Teaching Modes

The material is presented based on a lecture format, including case studies, and is supplemented with Tutorials, Computer Simulations and Laboratories to reinforce student learning.

9 Lecture Times

Activity	Day	Time	Room
Lecture	Monday	10:00–12:00	EAG01
Tutorial	Wednesday	08:00–10:00	EF14/ES204
Lecture	Thursday	13:00–15:00	EAG01

First lecture: July 21th. Last lecture: November 6st.

10 Grading Policies

The composition of the final mark is as follows:

Assignments	15%	Quiz	15%
Labs	10%	Exam	60%

The Quiz will be held on Wednesday, 17th September 2008, 08:00–10:00, in EF14. It will be open book—you are welcome to bring lecture notes and/or reference books. It will cover the material of the first eight weeks (up to and including Wednesday, 10th September 2008), with emphasis on lecture and tutorial material.

Students are required to obtain a minimum of 40% in the final exam to pass the course.

Quizzes and final exams are not returned; everything else is.

11 Assignments

There will be ten weekly assignments and one paper review presentation. They contribute to the final mark in the following proportion:

Weekly assignments	10%
Paper review presentation	5%

Weekly assignments: Homework problems will be given each week during the tutorial sessions as a way for students to master the course topics. The assignments may be solved and presented individually or in groups of two students (the mark obtained will be the same for both students in the group). Each week, one problem in the set will be chosen and marked as an assignment, which will be due at the beginning of the tutorial session in the following week. Marked problems will be returned at the tutorial sessions. Solutions to all the problems in the set will be posted after the due date.

Paper review presentation: Students, working in groups of 2, will be required to review a technical article based on a specified topic or theme within the context of control systems, subject to the approval of the lecturer. Students are to write an executive summary ($>$ 750 words) and make a 10 minute presentation based on the article they review.

Presentation: All assignment solutions must be clear and neat, with the pages stapled together. Illegible or messy solutions will not be marked.

Coversheet: All assignments need to be submitted with an **assignment cover sheet**, which can be obtained from the School's website, or from the School's Discipline Offices in Buildings EA and ES.

Assignment schedule:

Weekly assignments

No.	Assigned	Due
1	July 23	July 30
2	July 30	August 6
3	August 6	August 13
4	August 13	August 20
5	August 20	August 27
6	August 27	August 29
7	September 3	September 10
	September 10	No assignment (upcoming Quiz)
	September 17	Quiz
8	September 24	October 15
9	October 15	October 22
10	October 22	October 29

Paper review presentation

Part	Assigned	Due
Summary	July 21	September 24
Presentation	July 21	October 15, 22

12 Laboratory Projects)

Students are required to complete at least 10 points of laboratory projects. The table below summarises the projects and their weighting in points. Laboratory Project 1, Simple Servomechanism Control, is compulsory i.e. all students must complete this project. Students may choose to do any of the other projects to meet the 10 point requirement. Students are permitted to work in groups of 3. Note that exceeding the 10 points will not result in extra marks towards the final assessment.

Laboratory Exercises

No.	Title	Weighting	Due Date
1	Simple Servomechanism Control	2	October 24
2	Resonant Servomechanism Control	8	October 24
3	Deadbeat Servomechanism Control	4	October 24
4	State Feedback and Observer Servomechanism Control	4	October 24
5	Air Heater Control	4	October 24
6	Magnetic Levitation System (subject to equipment availability)	8	October 24

For more information regarding the laboratory projects please see the separate document titled 'Laboratory Guide for ELEC4410'.

13 Lecture and Tutorial Timetable

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
Jul 21 **Class 1** *§1 Introduction to ELEC4410. §2 Math. description of systems*	*22*	*23* **Tut 1** ***Revision:** Transfer functions, PID control, inversion by feedback*	*24* **Class 2** *§3 Introduction to IMC. Affine parametrisation for PID synthesis*	*25*
28 **Class 3** *§3 IMC for systems with time delay. Undesirable closed-loop poles*	*29*	*30* **Tut 2** §3 Affine parametrisation, PID synthesis	*31* **Class 4** *§3 Undesirable closed-loop poles (continuation)*	*Aug 1*
4 **Class 5** *§3 Saturation and IMC with anti-windup. IMC for unstable systems*	*5*	*6* **Tut 3** §3 IMC for systems with delay. Undesirable poles	*7* **Class 6** *§3 IMC for MIMO systems*	*8*
11 **Class 7** *§4 Design limitations in control. Design considerations*	*12*	*13* **Tut 4** §3 IMC with anti-windup. IMC for unstable systems	*14* **Class 8** *§4 Limitations in the step response*	*15*
18 **Class 9** *§5 Modelling and system identification*	*19*	*20* **Tut 5** §4 Performance limitations	*21* **Class 10** *§5 Modelling and system identification*	*22*
25 **Class 11** *§6 State space system realisations*	*26*	*27* **Tut 6** §5 Solution of state equations. SYSID	*28* **Class 12** *§6 Revision of Linear Algebra. Equivalent state space equations*	*29*
Sep 1 **Class 13** *§6 Stability*	*2*	*3* **Tut 7** §6 Equivalence, stability	*4* **Class 14** *§6 Stability. Discrete systems. Controllability*	*5*
8 **Class 15** *§6 Controllability.*	*9*	*10* **Tut 8** §6 Controllability and observability	*11* **Class 16** *§6 Observability. Canonical forms*	*12*
15 **Class 17** *§6 Discrete equations. Talk: Industrial Control by Sam Crisafulli*	*16*	*17* *Quiz*	*18* **Class 18** *§7 State feedback*	*19*
22 **Class 19** *§7 Regulation and tracking, state estimation.*	*23*	*24* **Tut 9** §6 State feedback control design	*25* **Class 20** *§7 Feedback from estimated states.*	*26*
29 Recess	*30*	*Oct 1* Recess	*2* Recess	*3*
6 Recess	*7*	*8* Recess	*9* Recess	*10*
13 **Class 21** *§7 State feedback MIMO*	*14*	*15* **Tut 10** §6 State feedback regulation and tracking	*16* **Class 22** *§7 State estimation MIMO. Feedback from estimated states MIMO*	*17*
20 **Class 23** *§7 Antiwindup in state space design*	*21*	*22* **Tut 11** §7 Discrete-time state feedback	*23* **Class 24** *§8 The basic optimal control problem*	*24*
27 **Class 25** *§8 Optimal estimation and Course Review*	*28*	*29* **Tut 12** §7 MIMO and optimal control design	*30* ***Revision***	*31*
Nov 3 ***Revision***	*4*	*5* ***Revision***	*6* ***Revision***	*7*

14 Plagiarism

University policy prohibits students plagiarising any material under any circumstances. A student plagiarises if he or she presents the thoughts or works of another as one's own. Without limiting the generality of this definition, it may include:

- copying or paraphrasing material from any source without due acknowledgement
- using another's ideas without due acknowledgement
- working with others without permission and presenting the resulting work as though it was completed independently.

Plagiarism is not only related to written works, but also to material such as data, images, music, formulae, websites and computer programs. Aiding another student to plagiarise is also a violation of the Plagiarism Policy and may invoke a penalty.

For further information on the University policy on plagiarism, please refer to the Policy on Student Academic Integrity at the following link: http://www.newcastle.edu.au/policylibrary/000608.html

The University has established a software plagiarism detection system called Turnitin. When you submit assessment items please be aware that for the purpose of assessing any assessment item the University may:

- reproduce this assessment item and provide a copy to another member of the University

  and/or

- communicate a copy of this assessment item to a plagiarism checking service (which may then retain a copy of the item on its database for the purpose of future plagiarism checking)
- submit the assessment item to other forms of plagiarism checking.

15 Written Assessment Items

Students may be required to provide written assessment items in electronic form as well as hard copy.

16 Marks and Grades Released During Term

All marks and grades released during the term, are indicative only until formally approved by the Head of School on the recommendation of the School Assessment body.

17 Extension of Time for Assessment Items, Deferred Assessment and Special Consideration for Assessment Items or Formal Written Examinations

Students are required to submit assessment items by the due date, as advised in the Course Outline, unless the Course Coordinator approves an extension of time for submission of the item. University policy is that an assessment item submitted after the due date, without an approved extension, will be penalised. Any student:

1. who is applying for an extension of time for submission of an assessment item on the basis of medical, compassionate, hardship/trauma or unavoidable commitment

   or

2. whose attendance at or performance in an assessment item or formal written examination has been or will be affected by medical, compassionate, hardship/trauma or unavoidable commitment;

must report the circumstances, with supporting documentation, to the appropriate officer following the instructions provided in the Special Circumstances Affecting Assessment Procedure - Policy 000641.

Note: different procedures apply for minor and major assessment tasks. Please go to the Policy at http://www.newcastle.edu.au/policylibrary/000641.html

Students should be aware of the following important deadlines:

- **Requests for Special Consideration** must be lodged no later than 3 working days after the date of submission or examination.
- **Requests for Extensions of Time on Assessment Items** must be lodged no later than the due date of the item.

- **Requests for Rescheduling Exams** must be received no later than ten working days prior the first date of the examination period.

Your application may not be accepted if it is received after the deadline. Students who are unable to meet the above deadlines due to extenuating circumstances should speak to their Program Officer.

18 Changing your Enrolment

The census date, August 31 2008, is the last date to withdraw without academic penalty.

Students may withdraw from a course without academic penalty on or before the last day of semester. Any withdrawal from a course after the last day of semester will result in a fail grade.

Students cannot enrol in a new course after the second week of semester/trimester, except under exceptional circumstances. Any application to add a course after the second week of semester/trimester must be on the appropriate form, and should be discussed with staff in the Student Hubs.

To check or change your enrolment online, please refer to myHub - Self Service for Students
https://myhub.newcastle.edu.au

19 Web Address for Rules Governing Undergraduate Academic Awards

http://www.newcastle.edu.au/policylibrary/000311.html

20 Web Address for Rules Governing Postgraduate Academic Awards

http://www.newcastle.edu.au/policylibrary/000306.html

21 Students with a Disability or Chronic Illness

The University is committed to providing a range of support services for students with a disability or chronic illness.

If you have a disability or chronic illness which you feel may impact on your studies, please feel free to discuss your support needs with your lecturer or course coordinator.

Disability Support may also be provided by the Student Support Service (Disability). Students must be registered to receive this type of support. To register please contact the Disability Liaison Officer on 49215766, or via email at: student-disability@newcastle.edu.au

As some forms of support can take a few weeks to implement it is extremely important that you discuss your needs with your lecturer, course coordinator or Student Support Service staff at the beginning of each semester. For more information related to confidentiality and documentation please visit the Student Support Service (Disability) website at: http://www.newcastle.edu.au/services/disability

22 Alteration of this Course Outline

No change to this course outline will be permitted after the end of the second week of the term except in exceptional circumstances and with Head of School approval. Students will be notified in advance of any approved changes to this outline.