Course Brief and Outline – 2013

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1 Course Background and Purpose

Control system design is arguably the broadest and most important subject in an engineering curriculum, bringing together knowledge from a number of disciplines. Automatic controllers can be found in electrical, aeronautical, biological, mechanical, chemical, industrial, thermodynamic, economic and medical systems, to name but a few.

Perhaps the most important aspect in the design of a robust control strategy is mathematically quantifying (or modelling) the dynamic behaviour of a given plant (or process) such that it is in a suitable form for control design. This quantification process may require significant interfacing with plant experts from a wide variety of fields. Once the dynamic behaviour of a plant is suitably modelled, the control engineer can follow a structured methodology to design an appropriate control strategy to enhance the output performance of the plant. This control strategy is typically implemented in a digital computing environment. Feedback control is accomplished by monitoring plant outputs and/or states (with the aid of sensors) and suitably modifying plant inputs (with the aid of actuators) such that the plant outputs track a desired objective function (command input) within pre-specified tolerance bounds. Furthermore, often the control strategy is designed to minimize the influence of plant disturbances.

This course aims to introduce the control system design process in an intuitive and methodical fashion with the aid of powerful frequency domain analysis and design techniques. It addresses the following key areas:

1. Modelling and representation of a plant/process in a suitably quantifiable manner.
2. Specification of closed-loop performance parameters.
3. Design, simulation and verification of a feedback control solution.
4. Implementation of a controller in a digital computing environment.

To achieve the above, the control engineer should be aware of control system design issues and have sufficient mathematical insight. Often understanding is accomplished with visual explanation and analysis of dynamic equations and their solutions. To enable this visualization process, Matlab®/Simulink® based work will be covered in tutorials and the laboratory session – the objective of which is to make the student aware of practical design and implementation issues.

2 Course Outcomes

The primary objective of this course is to provide the student with fundamental techniques to design and implement control systems for linear (and a limited number of non-linear) uncertain systems/processes. It is envisaged that this course will lay the necessary foundations for advanced undergraduate and postgraduate studies as well as industry related design work.

On successful completion of this course, the student is capable of:

1. Derive representations of physical systems which can be used for simulation and control system design. Such representations include differential equation, state-space and algebraic models derived by means of the Laplace and Z-transforms;
2. Simulate the behaviour of physical systems in Matlab®;
3. Transform non-linear systems to suitable uncertain linear representations;
4. Analyse and quantify the behaviour of non-linear systems using linear techniques;
5. Design Matlab® routines to assist in the design of control systems;
6. Implement controllers in both analogue and digital paradigms.

3 Course Content

The content of this course is as per *Rules & Syllabuses: Faculty of Engineering and the Built Environment*.

4 Prior knowledge Assumed

The prerequisites and co-requisites for this course are as per *Rules & Syllabuses: Faculty of Engineering and the Built Environment*.

Prior to attending the course students should be able to:

1. Derive transfer functions from differential equations and vice versa;
2. Derive the impulse and step responses of linear systems;
3. Make use of Laplace and Z-transform lookup tables (i.e. interchanging between the time, s-domain and z-domain);
4. Derive differential equation models of simple electrical, mechanical and electromechanical systems;
5. Sketch Bode plots for linear systems;
6. Write simple Matlab® m-files to simulate linear system models.

5 Assessment

All submissions must be in strict accordance with the guidelines contained in the *School's Blue Book* and the rules contained in the *School's Red Book*. No exceptions will be considered.

5.1 Components of the Assessment

This is described in the School's document entitled *Application of Rule G.13 and Calculator Requirements* on the School notice board.

All listed components are compulsory.

5.2 Assessment Criteria

Laboratory: Students must perform a set of two experiments, answer questions posed and submit reports by the required deadline. Although Matlab® is the official simulation language for the course, students may also use Octave or Scilab.

Class Test: The class test will cover all material completed up until the test date and will set the tone for the final examination. In addition, the class test will also assess the student's assimilation and understanding of fundamental definitions, theorems and related concepts.

Examination: The examination will test all topics covered in the course, with emphasis on analysis, design and application as opposed to regurgitation of bookwork. Tables of Laplace transforms, Fourier transforms, Z-transforms, and any other pertinent information will be provided with the examination paper at the discretion of the lecturer and will be confirmed not later than the last official lecture.

Note: If any student has plagiarized work from any other student (in any of the above assessment components), both parties will be given zero for this work and will be reported to the university's legal office, who will take the appropriate disciplinary action.

5.3 Satisfactory Performance (SP) Requirements

Rule G.13 and the School's documents entitled *Application of Rule G.13 and Calculator Requirements* and the *School's Red Book* (see the School notice board) apply.

5.4 Calculators in Examinations

See the School's document entitled *Application of Rule G.13 and Calculator Requirements* on the School notice board.

6 Teaching and Learning Process

6.1 Teaching and Learning Approach

The emphasis of this course is on analysis and design. The necessary foundation material will be covered in lectures; however students must do their own independent background reading (and tutorial work) to consolidate their knowledge. Students are expected to keep up to date and to prepare in advance for lectures.

The tutorial questions are graded and designed to lead the student to more advanced design problems at their conclusion. The nature of tutorial periods will generally be unstructured, although structured solutions will be provided at the discretion of the lecturer. Students must not expect the lecturer to provide solutions to problems for which no prior attempt has been made. The onus is on the student to take the initiative and do the work that has been set, using Matlab® where applicable. A self-checking culture is an essential quality required by all engineers. The course laboratory/project will further consolidate tutorial work and if done comprehensively will assist in preparing the student for the final exam.

Students are expected to do a significant amount of pre-lab work for the laboratory project exercises, which rely on the class and tutorial work and is seen as an examinable extension of it.

6.2 Arrangements

Lectures:

There will be three lectures per week. Students are expected to attend all lectures and to make their own notes.

The lectures are not intended to merely convey the course material to the student – the course notes serve that purpose. Instead, the lectures will aim to place the course material in context, highlight important thought processes, demonstrate the approach to problem solving and create a learning environment for the student. The student is expected to pre-study relevant material for each lecture. Additional material and course notes may be provided in lectures. These materials will be made available on the course home page where possible.

Tutorials:

One lecture per week may be used for discussion of tutorial problems. Informal tutorial assistance will be available on a regular basis throughout the term during such tutorial lectures. Students are expected to make use of this assistance regularly and not at the last minute before tests and examinations.

A range of tutorial problems will be set – from almost trivial to more difficult than exam standard. It is essential for each student to make a serious attempt at solving every tutorial problem.

Project:

This course does not have a project component. Refer to the section on Laboratories.

Laboratory:

The course material is supported by laboratories, details of which will be provided in class. If laboratory equipment is needed for performing the laboratory project students are expected to book their laboratory sessions at reception.

Consultation:

In consultation with the students attending lectures a suitable timeslot will be identified and set aside for consultation. This timeslot will be blocked for the remainder of the semester and student are encouraged to make use of this facility to clarify difficulties experienced in the course of studying the prescribed textbook and lecture notes.

7 Information to Support the Course

7.1 Prescribed Text/Reading

R.S. Burns, *Advanced Control Engineering*, Butterworth-Heinemann, 2001. (ISBN 0-7506-5100-8)

7.2 Other References

1. N.S. Nise, *Control System Engineering*, 4th edition, John Wiley & Sons Inc., 2004.

2. J. van de Vegte, *Feedback Control Systems*, Prentice Hall, New Jersey, 3rd edition, 1994.

3. B.C. Kuo, *Automatic Control System*, Prentice Hall, New Jersey, 7th edition, 1995.

4. G.F. Franklin, J.D. Powell, M. Workmann, *Digital Control of Dynamic Systems*, Addison Wesley, California, 1998.

5. R.H. Middelton, G.C. Goodwin, *Digital Control and Estimation*, Prentice Hall, New Jersey, 3rd edition, 1990 (ISBN 0-13-211665-0).

6. G.H. Hostetter, C.J. Savant, R.T. Stefani, *Design of Feedback Control Systems*, Saunders College Publishing, New York, 2nd edition (or later), 1989.

7. G.F. Franklin, J.D. Powell, A. Enami-Naeni, *Feedback Control of Dynamic Systems*, Addison-Wesley, Massachusetts, 2nd edition (or later), 1986.

8. B. Shahian, M. Hassul, *Control System Design using Matlab*, Prentice Hall, New Jersey, 1993. (ISBN 0-13-174061-X)

7.3 Course Home Page

Further information and announcements regarding the course are posted on the course homepage http://dept.ee.wits.ac.za/~nyandoro/elen3016. All students are expected to consult the course home page at regular intervals.

8 Other Information

Additional information, as and when required, will be provided during formal lectures and tutorials.