London South Bank University

Module guide

Principles of Control

ENG_5_415

School of Engineering

MODULE:	**ENG_5_415 Principles of Control**
MODULE LEVEL:	5
VALUE:	20 CAT points
STUDY TIME:	Class contact 72 hours: 24 Lecture, 24 Workshop & 24 hours Tutorial, Private study: 128 hours
PREREQUISITES:	Engineering Mathematical Methods, or equivalent
PROVENANCE:	This module, with associated laboratory/tutorials is designed for the Engineering Degree BEng Honours scheme.
ASSESSMENT:	Examination 70%, Coursework 30%
CO-ORDINATOR:	J.M. Selig, Room T400, Tel: 020 7815 7461 Email: seligjm@lsbu.ac.uk
TEACHING TEAM:	Lecturer: J.M. Selig , Workshops: Mehdi Zahir, Peter Adams and Team

Summary

This level 5 module aims to give you a sound understanding of a broad range of topics in Control Systems Engineering.

You will study methods to model and analyse dynamical systems met in the engineering of systems such as robotics, automobiles, aircraft, automatic machinery, chemical process plant, etc.

These methods will enable you to determine the stability of a system and to predict system responses in the time domain (transient and steady state) and in the frequency domain.

You will be able to handle the interconnection of many Single Input Single Output systems connected in feedback and feedforward configurations.

You will become familiar with supervisory control and data acquisition systems and a range of sensors and electronic interfaces to measure physical quantities such as position, speed, acceleration, temperature, pressure, flow rate, level, depth, etc.

Finally, you will learn how to modify the behaviour of a given system by using feedback control to improve stability, to make the system act quickly and precisely, and to reduce the effect of disturbances.

Your learning is supported by a laboratory workshop that enables you to study the behaviour of systems using both analysis methods and computer simulation using MATLAB and SIMULINK.

Contents

1. INTRODUCTION

This Module Guide is intended to provide an overview of the lecture content, details of assessment criteria and teaching and learning methods. The general aims are to provide an introduction to control systems and to offer essential analysis and design tools with which to study dynamical systems and modify their behaviour with feedback. This level five module will be followed by a level 6 module in the final year of your course which will use these tools to develop model-based design methods and laboratory skills to control systems in real time.

2. AIMS

This module is designed to provide the engineering student with a good foundation in control systems. The teaching on the module will emphasise topics in the design and analysis of control systems. The main aims are to provide the tools to model dynamical systems, predict their time and frequency responses, analyse their stability and understand the role of feedback to modify the behaviour of a system.

3. LEARNING OUTCOMES

On successful completion of the module, you should be able to:

- Understand the fundamental concepts and principles of automatic control theory and appreciate the role played by feedback
- Construct mathematical models of simple dynamical systems
- Analyse the behaviour and performance of simple control systems in the time domain and frequency domain
- Relate theoretical knowledge to physical systems
- Appreciate the use of Proportional, Integral and Derivative (PID) controllers as a non-model based method improve the servo following of systems.

4. SYLLABUS

NB. The material will not necessarily be covered in this order in the lectures (see the timetable in section 6 for a plan of its delivery).

1. Modelling of linear systems: The aim is to show that linear dynamical systems are modelled with differential equations, whether they be electrical, mechanical, thermal or hydraulic systems. The dynamics are determined by the energy storage and energy dissipation elements in the system. The number of energy storage elements determines the order of a system. Model first and second order systems e.g. RC and RLC circuits, translation and rotation mechanical systems, DC motors and servomechanisms, flow and liquid level in storage tanks.

2. Transform differential equations to Transfer Functions (TF) using the Laplace Transform and perform prediction of time and frequency responses. Primarily by using tables of Laplace transform pairs and the following properties of the Laplace transform:

- Laplace transform of differentiated and integrated functions of time
- Laplace transforms of unit step, unit ramp and half parabola.
- Final value theorem of Laplace to find steady state value of a signal.
- Inverse Laplace transformations by using partial fraction expansion and tables for the cases (a) distinct and real roots (b) repeated roots (c) complex conjugate roots for second order systems (d) degree of numerator polynomial of a TF equal or greater than degree of denominator polynomial.

3. Perform analysis of first and second order systems from their Transfer function description.

- Determination of system parameters: Open-loop gain, damping ratio, undamped natural frequency, poles and zeros. Relationship of these to constants of the underlying system e.g. resistance, capacitance, inductance, friction, mass, capacity, etc.
- State qualitatively the type and speed of transient response a system will have from knowledge of its pole locations, and relationship of poles to system parameters.
- Approximate higher order systems with a second order model.
- Find the stability of a system using the Routh Hurwitz criteria.
- Find the Zero-state and Zero-input response of a system to inputs such as unit step, unit ramp and parabolic inputs.
- Find the frequency response of a system to pure sinusoidal inputs from its transfer function description – Bode plots of Gain in decibels and phase in degrees as a function of frequency.
- Perform system identification (find transfer function) using measured frequency response.

4. Block diagram representation of interconnection of systems and their reduction to a single transfer function.

5. Simple Feedback control

- The root locus method to predict movement of closed-loop poles with increasing system gain. Sketch the root loci, determine the range of gains for which the system remains stable.
- Design feedback controllers using the root locus method.
- Tracking systems. Find the Type Number of a system and state the ability of type zero, type one, type two systems to follow power-of-time inputs such as step inputs, ramp inputs and half parabola inputs.

6. Proportional Integral and Derivative (PID) control
   - Proportional Control. Show the effect of Proportional gain on the undamped natural frequency and hence speed of response of a system. Show its undesirable effect on the damping ratio.
   - Proportional and Derivative Control. Show the effect of using Derivative gain in moving the damping ratio of a closed-loop system towards critical damping.
   - Proportional, Derivative and Integral Control. Show the effect of using Integral gain in reducing steady-state errors to command inputs.
   - Experimental methods to find initial estimates of PID parameters.
   - Examples of commercially available industrial PID control modules.
7. Supervisory Control and Data Acquisition Systems (SCADA)

5. TEACHING & LEARNING METHOD

5.1 Lectures

The taught material will be covered by lectures supported by printed notes that were given out in the first session. There are two hours of lectures scheduled per week. *You must organise yourself so that you have about 6 hours of your own time per week for private study to do the tutorial problems, self check on your understanding of the material just covered and prepare for the next sessions lectures.* This time should be increased as the examination approaches.

5.2 Tutorial questions and sessions

Tutorials and drill exercises are in a separate book that was given to you at the start of the module. Full working and answers are available from the MOODLE site for this module. *You should attempt these as soon as possible after the lecture;* some will be covered in the lectures. There are also copies of recent past examination papers on MOODLE together with model answers. *A selection of questions will also be covered in additional tutorial sessions.*

5.3 Workshop sessions

In the workshop sessions in T405 you will be using the control systems analysis package *MatLab* - developed by MathWorks Inc.

You will be divided into groups for the laboratory so that ideally no more than two are in each group. *Before each scheduled workshop session you should read through the instructions in the workshop manual* ***BEFORE*** *you attend the workshop session to become familiar with the contents.*

The principles of control explored with *MatLab* simulations are assessed by submission of your log book.

5.4 Private study time

In the private study time your main tasks are to assimilate the lecture material, attempt the tutorial questions, and manage the upkeep of material in your log book on the *MatLab* sessions and the exercises. To succeed in this and get the most from the module, you will need to exert good self discipline to manage your private study time effectively particularly as you will be studying other level 5 modules at the same time. Below are some suggestions that may aid you in this (see also the Study Skills Survival Guide available from the Study Skills Centre).

General:

- Always try to re-read the lecture material within 24 hours of the lecture - retention will be helped if the material is still fresh in your mind.
- Plan the pace of your studies with great care and coordinate across modules so that you are not left with a large amount of work to do in the last few weeks when you should be concentrating on revision of the material.
- Try to get into regular study habits at set times and places. Find out when and where you best study and optimise the arrangements for this. For example, find sufficient space for your papers with preferably a dedicated table so that papers do not continually have to be cleared and material for individual modules can be easily accessed and filed.
- Try to minimise external disruptions when you study but give yourself time for rest periods and food.

Before each lecture/workshop session you should:

- Consult the course notes and read the lecture material.
- Consult the laboratory Workshop Manual to peruse the appropriate instruction sheet to get an overall view of what you will be doing.

After each lecture you should:

- Re read the material within 24 hours.
- Attempt tutorial and past examination questions on the lecture topic doing any further reading as necessary to improve your understanding.

After each workshop session you should:

- Ensure that any MatLab print outs are positioned in the log book and questions posed by the instruction sheet are answered. Draw up any comparison tables needed and try to take an overview on what has been achieved.

6. TIMETABLE

Study week	
1	**SCADA systems, Sensors commonly used in SCADA**. Read Prof Sattar's notes (SCADA pages 4-10)
2	**Laplace transforms,** (For Laplace transformations, read Prof Sattar's notes pages 11-15 and do tutorials).
3	**Inverse Laplace transformation** with partial fraction expansion and tables of transforms. (Read pages 16-19)
4	**System modelling: Modelling of dynamic systems with differential equations and Transfer functions and Canonical representation of Second Order Systems** (Read pages 20-33 and do tutorials) For transfer functions and canonical representation of 2nd order systems, read pages 21-23)
5	**Modelling** of Electrical, mechanical (rotational and translational) systems. Servomechanisms, Liquid level and flow. (Read pages 24-33)
6	**Control system structure.** Types of controller such as feedback and feedforward control systems. Block diagram reduction. Read pages 34-36 Steady state value of the output of a system and approximation of higher order systems by second order systems. (Read page 37)
7	**Stability assessment techniques** **Routh Hurwitz method**, (pages 38-40 and do tutorials) Introduction to **Root locus method**, (pages 41-45 and do tutorials)
8	**Root locus method continued**. (Pages 41-45)
9	**Feedback controllers.** Proportional, Integral and Derivative (PID) control. (Pages 46-51) Tuning of PID controllers. (Pages 52-54). **Industrial PID controllers** (Pages 55-57)
10	**Transient response of systems and Tracking systems** First and second order systems. Time responses, specifications and performance indicators (see pages 58-64 and do tutorials)
11	**Steady state tracking errors to unit step, unit ramp and half parabola inputs,** (pages 65-71 and do tutorials)
12	Frequency response testing of systems (read pages 72-77)
13	**Revision**

7. ASSESSMENT

There are two components of assessment – an examination (component 1) and coursework (component 2). The pass mark for the module is 40% and you must obtain a minimum mark of 30% in each component.

7.1 Examination

A **two** hour unseen written examination at the end of the module which will contribute 70% of the module mark, see the table below. The exam paper will have 6, equal value, 30-minute questions. Your exam mark will be calculated from your answers to 4 questions which achieve the best marks. The university's examination rules apply and you must make yourself familiar with these.

7.2 Coursework

i) The laboratory logbook, and ii) an on-line Phase-test.

These are treated together as one assessment component and will contribute 30% of the module mark, see the table below. The date and time of the Phase-test is shown in the calendar in Appendix 1. The logbook must be handed in by the Friday of **Week 11 (see calendar) and will be returned in week 13**.

Assessment Component	Type of assessment	Timing of assessment	Length	Contribution to module mark
1	Examination	End of module	2 hours	0.70
2	i) Phase Test	Week 11 during scheduled lab period	50 mins	0.15)) 0.3 total
	ii) Submission of log book	Log book by week 11	10 weeks	0.15)

All deadlines should be strictly met, otherwise you run the risk of loosing part or all of the marks for work submitted late.

7.3 Coursework Assessment Criteria

Logbook	
Marks awarded for:	*Marks may be deducted for:*
maintaining an accurate and chronological record of your work as it is carried out exercises completed and questions answered tabulating your results and data if appropriate clear graphs with correctly labelled axes and titles, and experimental points clearly shown accuracy and clarity of results and analysis comments/observations on your results the provision of brief conclusions quality of the presentation and structure of your log book; dating your work provision of a contents list at the front	missed work, failure to document work, poor presentation and inadequate 'signposting' failure to correctly follow the instructions in the workshop manual failure to submit by the deadline

8. LEARNING SUPPORT MATERIAL

8.1 In house support material

The following materials are provided for learning support in the module:

- **Module Guide (this document!).** This contains details on how the module is organised and assessed and gives a weekly teaching and learning schedule. One copy given to each person studying the module.
- **Course Notes (lecture notes).** This contains the lecture material. One copy given to each person studying the module.
- **Workshop Manual.** This contains the workshop tutorial and exercise sheets, the instructions for the workshop exercises. One copy given to each person studying the module.

  Tutorial and Drill exercises. This contains the drill exercises and past examination questions.. One copy given to each person studying the module.
- **Solutions to Exam and Tutorials.** These contain past examination questions, model answers and solutions to the tutorials. They are on the MOODLE Virtual Learning Environment (VLE) site for this module.

8.2 On-line tests

The MOODLE site for this module contains a number of practice tests. You can do these tests as many times as you want and on completion of the test you will get immediate feedback and a score.

We may use this method to conduct the Phase Test in week 11. Therefore, you should practice doing the on-line tests so that you know how to work your way through the questions and submit your answers.

8.3 Core text book

The core material is contained in the following book (hardcopy handed to you on first day and on MOODLE):

Principles of Control Lecture Notes, Tutorial Workbook – Professor Tariq Sattar

The recommended book for the module is:

Gene F. Franklin, J. David Powell & Abbas Emami-Naeini [2014] Feedback Control of Dynamic Systems, 7th Edition, Prentice Hall

If you need to expand on the material in the course notes you should try to use this book most of the time and also if you feel the need for a more rigorous, formal (though necessarily more expanded) approach. This book covers most of the topics in the module (it is also recommended for later level 6 control modules).

8.4 Optional Reading

Other books in the Perry Library that you could refer to:

Ogata, Katsuhiko, [2010] Modern Control Engineering, 5^{th} Edition, Pearson, ISBN 10:0-13-713337-5. This book contains all the syllabus topics for continuous-time systems.

Dorf, Richard C., and Bishop, Robert H., [2011] Modern control systems, 12th ed.: Pearson education Limited

9. WEBSITE - MOODLE

The MOODLE site for this module provides backups of this module guide, all lecture notes, Power point presentations used during the lectures, and tutorial/past exam questions and worked solutions. It also provides ON-LINE practice tests with which you can evaluate your learning.

NOTES