ES9ZP-15 Systems Modelling and Control

24/25

Department
School of Engineering
Level
Taught Postgraduate Level
Module leader
Natasha Khovanova
Credit value
15
Module duration
10 weeks
Assessment
40% coursework, 60% exam
Study location
University of Warwick main campus, Coventry

Description

Introductory description

Systems Modelling and Control (for MSc courses)

Module web page

Module aims

Most disciplines of the engineering profession require a sound understanding of the techniques used in the modelling and control of dynamic, multi-domain physical, and other, systems. The aims of this module are: to build on techniques and computer tools for modelling, predicting and analysing the behaviour of dynamic systems; and to build on concepts, principles and techniques employed in classical methods of single loop feedback control system design.

Outline syllabus

This is an indicative module outline only to give an indication of the sort of topics that may be covered. Actual sessions held may differ.

The module will focus on a broad and generic systems approach to understanding physical systems modelling and their control. Techniques for systems analysis, approaches to systems modelling and the techniques for the simulation of systems models will be considered together with control algorithms and the conditions for which a system is controllable. In particular, a rigorous approach to the application of physical laws to formulate appropriate dynamical systems representations, and their subsequent analysis using linear and nonlinear methods, will be taught. The application of appropriate computational tools for systems analysis and simulation will naturally be included. The examples presented will be drawn from a range of different engineering disciplines ranging from mechanical and electrical to biological systems to illustrate the advantages of a systems approach.

In particular the module includes:

System modelling and analysis in time domain: review of systems modelling (1st and 2nd order) linking behavior to physical parameters, block diagrams, signal-flow graphs, system classification, input-output models, free and forced responses, transient and steady state responses, poles, Argand diagram.

System modelling and analysis in complex frequency domain: transfer function analysis, Laplace transform, initial and final value theorems, characteristic polynomial, stable/unstable/marginally stable systems with examples, systems modes; system representation: convolution in time domain, unit impulse and unit step responses and their applications.

Frequency domain analysis: frequency response, steady state frequency response, gain and phase, graphical representations of frequency response, magnitude and phase, Bode plots, Nyquist plots, links between time-domain specifications and frequency domain specifications; stability analysis using root locus, Nyquist plot, and Bode plots; robustness characterization using gain margin and phase margin.

Systems control: stability and feedback, feedback systems, open-loop and closed loop transfer functions, root locus plots, Nyquist stability criterion, conditionally stable systems, phase crossover frequency and gain margin, gain crossover frequency and phase margin, feedback control of linear systems, PID controllers, conditions on controllers parameters for their optimal performance, realizable controllers.

State space modelling and analysis: state space description, linear state space models, transfer function, transient response, characteristic equation and stability, system diagonalization and normal modes, stiff systems; nonlinear systems: equilibrium points/steady states, linearization around equilibrium points, Jacobian matrices, stability; state space analysis: systems controllability and observability, controllability and observability matrices, rank criteria, system in a diagonal form and normal modes, relationship with transfer function, minimal realization of a system; state feedback: feedback control and stability.

Computer tools for modelling: simulating and analysing dynamical systems in MATLAB/Simulink.

Learning outcomes

By the end of the module, students should be able to:

- Develop state space models for both linear and nonlinear systems, and utilize appropriate

- techniques to perform state space analysis including design of state space feedback control systems. [M1, M2, M3]
- Develop mathematical models of physical systems using appropriate physical laws and expressing the models with ordinary differential equations, utilise engineering analysis to demonstrate commonality in behaviour. [M2, M6]
- Apply analytical techniques for analyzing the response of both linear and nonlinear systems in time and frequency domain to a range of inputs. [M1, M3]
- Utilise computational methods (Matlab/Simulink) to analyse and predict dynamical behaviour of physical systems (e.g. steady-state and transient response to a range of inputs) including stability performance analysis. [M3]
- Utilize computational methods in MATLAB/SIMULINK to apply concepts and techniques for analysis of the behaviour of open loop physical systems, and to design feedback control systems (PID), analyse their behaviour and assess their stability. [M3, M12]

Indicative reading list

1. Close C.M., Frederick D.H., Newell J.C., Modelling and Analysis of Dynamic Systems, M John Wiley and Sons Ltd, 1995, ISBN 9780395661581
2. Norman Nise, Control Systems Engineering (7th Edition). John Wiley & Sons, 2013.
3. Franklin, G.F., Powell, J.D. and Emami-Naeini, A., Feedback Control of Dynamic Systems (6th Edition), Pearson Academic Computing, 2012.

Subject specific skills

Ability to apply relevant practical and laboratory skills
Ability to be pragmatic, taking a systematic approach and the logical and practical steps necessary for, often complex, concepts to become reality

Transferable skills

Numeracy: apply mathematical and computational methods to communicate parameters, model and optimize solutions.

Apply problem solving skills, information retrieval, and the effective use of general IT facilities.

Overcome difficulties by employing skills, knowledge and understanding in a flexible manner

Be professional in their outlook, be capable of team working, be effective communicators, and be able to exercise responsibility and sound management approaches.

Study

Study time

Type	Required
Lectures	16 sessions of 1 hour (11%)
Seminars	6 sessions of 2 hours (8%)
Practical classes	(0%)
Supervised practical classes	2 sessions of 4 hours (5%)
Other activity	3 hours (2%)
Private study	111 hours (74%)
Total	150 hours

Private study description

111 hrs guided independent learning

Other activity description

Laboratory - Control of Hot Air using PID controller

Costs

No further costs have been identified for this module.

Assessment

You must pass all assessment components to pass the module.

Assessment group D

	Weighting	Study time	Eligible for self-certification
Systems Modelling & Control Assignment	40%		Yes (extension)

Systems Modelling & Control Design Assignment
Maximum number of pages is 12; students must follow the proforma template.

Written on-campus exam	60%		No

- Answerbook Pink (12 page)
- Students may use a calculator
- Engineering Data Book 8th Edition
- Graph paper

Feedback on assessment

- Model solutions to past papers (if available).

- Support through advice and feedback hours.
- Cohort-level feedback on assignment
- Cohort-level feedback on final exam.

Past exam papers for ES9ZP

Availability

Anti-requisite modules

If you take this module, you cannot also take:

- ES3C8-15 Systems Modelling and Control

Courses

This module is Optional for:

- Year 1 of TESA-H800 Postgraduate Taught Biomedical Engineering

This module is Option list A for:

- Year 1 of TESA-H643 Postgraduate Taught Electrical Power Engineering

This module is Option list B for:

- Year 1 of TESA-H644 Postgraduate Taught Electrical and Electronic Engineering