# ES3C8-15 Systems Modelling and Control

## 20/21

**Department**
School of Engineering
**Level**
Undergraduate Level 3
**Module leader**
Natasha Khovanova
**Credit value**
15
**Module duration**
10 weeks
**Assessment**
40% coursework, 60% exam
**Study location**
University of Warwick main campus, Coventry

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## Description

## Introductory description

ES3C8-15 Systems Modelling and Control

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:

- 4. 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.

- 1. 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.
- 2. Apply analytical techniques for analyzing the response of both linear and nonlinear systems in time and frequency domain to a range of inputs.
- 3. 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.
- 5. 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.

## 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

TBC

## Transferable skills

TBC

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## 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%) |
| Private study | 114 hours (76%) |
| Total | 150 hours |

## Private study description

114 hrs guided independent learning

## Costs

No further costs have been identified for this module.

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## Assessment

You must pass all assessment components to pass the module.

Students can register for this module without taking any assessment.

### Assessment group D3

| | Weighting | Study time | Eligible for self-certification |
|---|---|---|---|
| **Assessment component** | | | |
| Systems Modelling & Control Assignment | 40% | | No |
| Systems Modelling & Control Design Assignment | | | |
| **Reassessment component is the same** | | | |
| **Assessment component** | | | |
| Online Examination | 60% | | No |
| QMP<br><br>~Platforms - QMP | | | |

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

**Reassessment component is the same**

### Feedback on assessment

- Model solutions to past papers.
- Support through advice and feedback hours.
- Cohort-level feedback on assignment
- Cohort-level feedback on final exam.

Past exam papers for ES3C8

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## Availability

## Courses

This module is Core for:

- Year 3 of UESA-H335 BEng Automotive Engineering
- Year 4 of UESA-H334 BEng Automotive Engineering with Intercalated Year
- Year 3 of UESA-H161 BEng Biomedical Systems Engineering
- Year 3 of UESA-HH35 BEng Systems Engineering
- Year 3 of UESA-HH36 BEng Systems Engineering
- Year 4 of UESA-HH34 BEng Systems Engineering with Intercalated Year
- Year 3 of UESA-H336 MEng Automotive Engineering
- Year 3 of UESA-H163 MEng Biomedical Systems Engineering
- UESA-HH31 MEng Systems Engineering
  - Year 3 of HH31 Systems Engineering
  - Year 3 of HH35 Systems Engineering
- Year 3 of UESA-H605 Undergraduate Electrical and Electronic Engineering
- Year 3 of UESA-H606 Undergraduate Electrical and Electronic Engineering MEng
- Year 4 of UESA-H607 Undergraduate Electrical and Electronic Engineering with Intercalated Year

This module is Core optional for:

- Year 4 of UESA-H337 MEng Automotive Engineering with Intercalated Year
- Year 3 of UESA-H115 MEng Engineering with Intercalated Year
- Year 4 of UESA-HH32 MEng Systems Engineering with Intercalated Year
- UESA-H607 Undergraduate Electrical and Electronic Engineering with Intercalated Year
  - Year 3 of H607 Electrical and Electronic Engineering with Intercalated year
  - Year 4 of H607 Electrical and Electronic Engineering with Intercalated year

This module is Optional for:

- Year 3 of UESA-H113 BEng Engineering
- Year 3 of UESA-H114 MEng Engineering
- Year 4 of UESA-H115 MEng Engineering with Intercalated Year

- RESA-H6P9 Postgraduate Research Wide Bandgap Power Electronics
  - Year 1 of H6P9 Wide Bandgap Power Electronics (EngD)
  - Year 2 of H6P9 Wide Bandgap Power Electronics (EngD)
- Year 1 of TESA-H800 Postgraduate Taught Biomedical Engineering

This module is Option list A for:

- Year 3 of UESA-H112 BSc Engineering
- Year 1 of TESA-H643 Postgraduate Taught Electrical Power Engineering
- Year 1 of TESA-H642 Postgraduate Taught Energy and Power Engineering
- Year 3 of UMAA-G100 Undergraduate Mathematics (BSc)
- Year 3 of UMAA-G103 Undergraduate Mathematics (MMath)
- Year 4 of UMAA-G101 Undergraduate Mathematics with Intercalated Year

This module is Option list B for:

- Year 3 of UCSA-G406 Undergraduate Computer Systems Engineering
- Year 3 of UCSA-G408 Undergraduate Computer Systems Engineering
- Year 4 of UCSA-G407 Undergraduate Computer Systems Engineering (with Intercalated Year)
- Year 4 of UCSA-G409 Undergraduate Computer Systems Engineering (with Intercalated Year)
- UMAA-G105 Undergraduate Master of Mathematics (with Intercalated Year)
  - Year 3 of G105 Mathematics (MMath) with Intercalated Year
  - Year 5 of G105 Mathematics (MMath) with Intercalated Year
- UMAA-G103 Undergraduate Mathematics (MMath)
  - Year 3 of G103 Mathematics (MMath)
  - Year 4 of G103 Mathematics (MMath)
- UMAA-G106 Undergraduate Mathematics (MMath) with Study in Europe
  - Year 3 of G106 Mathematics (MMath) with Study in Europe
  - Year 4 of G106 Mathematics (MMath) with Study in Europe