ES4F0-15 Advanced Control Systems

24/25

Department
School of Engineering
Level
Undergraduate Level 4
Module leader
Declan Bates
Credit value
15
Module duration
10 weeks
Assessment
100% coursework
Study location
University of Warwick main campus, Coventry

Description

Introductory description

ES4F0-15 Advanced Control Systems

Module web page

Module aims

The aims of the module are to build on the knowledge of control systems that students have acquired in previous years and teach them the advanced techniques for the design and analysis of real-world control systems that are currently used in multiple engineering industries (e.g. aerospace, automotive, robotics, power systems, electronic systems, etc).

We will do this by:

1. Focusing on advanced design and analysis techniques currently used in industry, rather than on outdated or unapplicable theory.
2. Focusing on learning how to use powerful software tools (e.g. the Matlab Robust Control Toolbox) to design and analyse control systems for realistic applications, rather than on pencil-and-paper type solutions to simplified mathematical problems.
3. Embedding consideration of real-world constraints (uncertainty, disturbances, actuator saturation, etc) into all design and analysis frameworks.

4. Teaching theory via detailed examples from a variety of application domains, with Matlab code included throughout.
5. Assessing student's learning via software-based marked assignments, e.g. the complete design and analysis of a controller for a challenging real-world problem, rather than via pencil-and-paper exam questions.

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.

1. Introduction to uncertainty and robustness
2. Useful tools from linear systems theory (signal and system norms, stability, performance measures, etc)
3. Unstructured uncertainty and generalized stability margins
4. H-infinity mixed sensitivity design - single-input-single-output systems
5. H-infinity loopshaping design - single-input-single-output systems
6. Useful tools from linear systems theory (small gain theorem, singular value decomposition, multivariable Nyquist criterion, etc)
7. H-infinity mixed sensitivity design - multi-input-multi-output systems
8. H-infinity loopshaping design - multi-input-multi-output systems
9. Structured uncertainty and mu-analysis
10. Actuator saturation and anti-windup
11. Gain scheduling

Learning outcomes

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

- Model the effects of different forms of uncertainty in control systems, and analyse the robustness of closed-loop systems to unstructured uncertainty
- Design robust multivariable controllers using advanced synthesis methods (H-infinity Loopshaping etc) for challenging application problems
- Analyse the robustness of multivariable controllers to structured uncertainty using advanced methods such as mu-analysis
- Understand how to deal with different sources of nonlinearity (actuator saturation, nonlinear process dynamics) within a linear design and analysis framework using techniques such as anti-windup and gain-scheduling.
- Use advanced control system design and analysis environments and Matlab toolboxes.

Indicative reading list

1. Skogestad and Postlethwaite. Multivariable Feedback Control: Analysis and Design (2nd Edition), Wiley Interscience, 2005. ISBN: 9780-4700-11683.
2. Bates and Postlethwaite, Robust Multivariable Control of Aerospace Systems, Delft University Press, 2002.
3. Balas, Chiang, Packard and Safonov, Matlab Robust Control Toolbox, Getting Started

Guide, Mathworks,
https://uk.mathworks.com/help/releases/R2021b/pdf_doc/robust/robust_gs.pdf
4. Balas, Chiang, Packard and Safonov, Matlab Robust Control Toolbox, User Guide, Mathworks, https://uk.mathworks.com/help/releases/R2021b/pdf_doc/robust/robust_ug.pdf
5. Franklin, Powell, and Emami-Naeini, Feedback Control of Dynamic Systems (7th Edition), Pearson, 2014. ISBN: 9781-2920-68909.
6. Hahn and Valentine, Essential MATLAB for Engineers and Scientists, Academic Press, 2019.

[View reading list on Talis Aspire]

Interdisciplinary

The module is suitable for MSc/MEng students from several disciplines: Systems Engineering, Biomedical Engineering, Mechanical Engineering, Automotive Engineering, Computer Systems Engineering, Power Systems, Renewable Energy.

Subject specific skills

Uncertainty modelling and quantification
Advanced techniques for design of robust multivariable controllers
Advanced techniques for analyzing the robustness of multivariable controllers
Dealing with real-world constraints (uncertainty, disturbances, actuator saturation, etc) in control system design
Software environments and tools for advanced control systems design and analysis

Transferable skills

Uncertainty modelling, MATLAB programming, technical report preparation

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Study

Study time

Type	Required
Lectures	12 sessions of 1 hour (8%)
Supervised practical classes	4 sessions of 4 hours (11%)
Private study	122 hours (81%)
Total	150 hours

Private study description

No private study requirements defined for this module.

Costs

No further costs have been identified for this module.

Assessment

You must pass all assessment components to pass the module.

Students can register for this module without taking any assessment.

Assessment group A

	Weighting	Study time
Individual assignment 1	50%	

Students will be provided with a challenging real-world control problem, including the system model, design specifications to be achieved, and suggested design and analysis methods to be used. Students will design and analyse a feedback controller using Matlab, and verify satisfaction of stability, performance and robustness specifications.
The students will present their results in a written format through a report.

Individual assignment 2	50%	

Students will be provided with a challenging real-world control problem, including the system model, design specifications to be achieved, and suggested design and analysis methods to be used. Students will design and analyse an anti-windup/gain scheduling scheme using Matlab, and verify satisfaction of stability, performance and robustness specifications.
The students will present their results in a written format through a report.

Feedback on assessment

- Support through advice and feedback hours.
- Summative mark and written feedback on coursework elements (two marked assignments).

Availability

Pre-requisites

To take this module, you must have passed:

- All of
  - ES3C8-15 Systems Modelling and Control
  - ES2A9-15 Engineering Mathematics and Technical Computing

Courses

This module is Optional for:

- Year 4 of UESA-H116 MEng Engineering with Exchange Year
- Year 5 of UESA-H115 MEng Engineering with Intercalated Year
- Year 4 of UESA-HH33 MEng Systems Engineering with Exchange 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-H642 Postgraduate Taught Energy and Power Engineering

This module is Option list A for:

- Year 4 of UESA-H163 MEng Biomedical Systems Engineering
- Year 4 of UESA-H114 MEng Engineering
- Year 4 of UESA-HH31 MEng Systems Engineering
- Year 5 of UESA-HH32 MEng Systems Engineering with Intercalated Year
- Year 1 of TESA-H643 Postgraduate Taught Electrical Power Engineering
- Year 1 of TESA-H642 Postgraduate Taught Energy and Power Engineering

This module is Option list B for:

- Year 1 of TESA-H644 Postgraduate Taught Electrical and Electronic Engineering
- Year 4 of UCSA-G408 Undergraduate Computer Systems Engineering
- Year 5 of UCSA-G409 Undergraduate Computer Systems Engineering (with Intercalated Year)