# Engineering Tripos Part IB, 2P6: Linear Systems and Control, 2020-21

### Course Leader

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### Lecturer

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### Timing and Structure

Weeks 1-4 and 7-8, 2 lectures/week. Weeks 5-6, 1 lecture/week. 14 lectures.

## Aims

The aims of the course are to:

- Introduce and motivate the use of feedback control systems.
- Introduce analysis techniques for linear systems which are used in control, signal processing, communications, and other branches of engineering.
- Introduce the specification, analysis and design of feedback control systems.
- Extend the ideas and techniques learnt in the IA Mechanical Vibrations course.

## Objectives

As specific objectives, by the end of the course students should be able to:

- Develop and interpret block diagrams and transfer functions for simple systems.
- Relate the time response of a system to its transfer function and/or its poles.
- Understand the term 'stability', its definition, and its relation to the poles of a system.
- Understand the term 'frequency response' (or 'harmonic response'), and its relation to the transfer function of a system.
- Interpret Bode and Nyquist diagrams, and to sketch them for simple systems.
- Understand the purpose of, and operation of, feedback systems.
- Understand the purpose of proportional, integral, and derivative controller elements, and of velocity feedback.
- Possess a basic knowledge of how controller elements may be implemented using operational amplifiers, software, or mechanical devices.
- Apply Nyquist's stability theorem, to predict closed-loop stability from open-loop Nyquist or Bode diagrams.
- Assess the quality of a given feedback system, as regards stability margins and attenuation of uncertainty, using open-loop Bode and Nyquist diagrams.

## Content

| | Section numbers in books | | |
|---|---|---|---|
| | *(1)* | *(2)* | *(3)* |

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|---|---|---|---|
| Examples of feedback control systems. Use of block diagrams. Differential equation models. Meaning of 'Linear System'. | *1.1-1.11, 2.2-2.3* | *1.1-1.3, 2.1-2.6.1* | *1.1-1* |
| Review of Laplace transforms. Transfer functions. Poles (characteristic roots) and zeros. Impulse and step responses. Convolution integral. Block diagrams of complex systems. | *2.4-2.6* | *3.1-3.2* | *3.8-3*<br>*6.1-6* |
| Definition of stability. Pole locations and stability. Pole locations and transient characteristics. | *5.6, 6.1* | *3.3-3.4, 4.4.1* | *5.1-5* |
| Frequency response (harmonic response). Nyquist (polar) and Bode diagrams. | *8.1-8.3* | *6.1* | *6.5,*<br>*15.1* |
| Terminology of feedback systems. Use of feedback to reduce sensitivity. Disturbances and steady-state errors in feedback systems. Final value theorem. | *4.1-4.2, 4.4-4.5* | *4.1* | *9.2,* |
| Proportional, integral, and derivative control. Velocity (rate) feedback. Implementation of controllers in various technologies. | *10.6, 12.6* | *4.2* | |
| Nyquist's stability theorem. Predicting closed-loop stability from open-loop Nyquist and Bode plots. | *9.1-9.3* | *6.3* | *11.1* |
| Performance of feedback systems: Stability margins, speed of response, sensitivity reduction. | *6.3,8.5, 9.4, 9.6, 12.5, 12.8-12.9* | *6.4, 6.6, 6.9* | *10.4,*<br>*15.6* |

**REFERENCES**

(1) DISTEFANO, J.J., STUBBERUD, A.R. & WILLIAMS, I.J. FEEDBACK AND CONTROL SYSTEMS
(2) FRANKLIN, G.F., POWELL; J.D. & EMAMI-NAEINI, A. FEEDBACK CONTROL OF DYNAMIC SYSTEMS
(3) OPPENHEIM, A.V., WILLSKY, A.S. & NAWAB, S.H. SIGNALS AND SYSTEMS
(4) ÅSTRÖM, K.J. & MURRAY, R.M. FEEDBACK SYSTEMS: AN INTRODUCTION FOR SCIENTISTS AND ENGINEERS
(5) DORF, R.C. & BISHOP, R.H. MODERN CONTROL SYSTEMS

## Booklists

Please refer to the Booklist for Part IB Courses for references to this module, this can be found on the associated Moodle course.

## Examination Guidelines

Please refer to [Form & conduct of the examinations] [3].

## UK-SPEC

This syllabus contributes to the following areas of the [UK-SPEC] [4] standard:

[Toggle display of UK-SPEC areas].

### GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the

Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

**IA1**

Apply appropriate quantitative science and engineering tools to the analysis of problems.

**IA3**

Comprehend the broad picture and thus work with an appropriate level of detail.

**KU1**

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

**KU2**

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

**E1**

Ability to use fundamental knowledge to investigate new and emerging technologies.

**E2**

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

**E3**

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

**E4**

Understanding of and ability to apply a systems approach to engineering problems.

**P1**

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

**P3**

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

**US1**

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

**US2**

A comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering discipline, and an appreciation of their limitations.

**US3**

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

**US4**

An awareness of developing technologies related to own specialisation.

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