Control Fundamentals Course

Theory and Practice, and Future Directions
(*3-day Course, 29th April to 1st May 2025, Glasgow*)

The Control Fundamentals Course Agenda has been developed and refined over two decades and has been presented multiple times at companies around the world. It is aimed at engineers that are using control techniques in their everyday work but need a refresher or have only obtained an introduction to control at university. It is also applicable to engineers such as calibration or software engineers that work with control engineering specialists. These may need a deeper understanding of the modelling and control methods they are using to ensure successful and efficient implementation of control laws.

The course material is motivational to encourage the use of the techniques, rather than the background mathematics. The demonstration/hands-on exercises in MATLAB/Simulink software will help engineers understand the modelling and design techniques and can be retained by the attendees. There will be time in coffee and lunch breaks to talk to the instructors about the engineers' own problems whether they are concerned with modelling, simulation, control, condition monitoring, or any problems with implementation.

The ***first day*** begins with a presentation motivating the need for improved control methods. This is followed by an introduction to modelling and simulation needed for the analysis and design of control loops. The frequency response analysis methods that are often used for both analysis and design, including Bode, Nichols and Nyquist methods, are then considered. The hands-on sessions using MATLAB and Simulink reinforce the ideas using a servo-system control design problem. For those that are not familiar with these tools, demonstrations are provided.

The ***second day*** moves on to design rather than analysis problems and the first presentation emphasizes the importance of feedback control for improving performance, disturbance rejection and reducing the effects of uncertainties. The frequency-domain control design methods are based on the analysis tools described in day one and are introduced. The hands-on sessions provide insights into this type of design process. The importance of control system structures, including feedback, feedforward, cascade and others is then considered, and the improvements in performance are described. The final presentation is on PID controllers. This is of course the most common form of control, and the presentation explains why this control method is so successful and simple to use.

The ***final day*** is mostly concerned with more practical aspects including application problems and the problems of implementation and finishes with a look to the future. The types of systems and problems that make control engineering difficult are discussed. The aim is to identify the characteristics of systems that require particular care and to suggest the types of solution that should be used. The important topic of PID controller tuning is covered and a hands-on example provides experience in the methods used. The various problems in implementing controllers are then discussed such as windup and requiring features like bumpless transfer. Since most control loops are now implemented digitally, discrete time systems are covered, including topics such as the form of discrete controllers, sampling, and digital implementation. A hands-on in this session covers issues such as sampling and the digital implementation of control laws.
The final presentation is on the future directions of industrial control and estimation, influenced by developments in AI and Machine Learning that will influence both classical and more advanced control design methods. There will be an opportunity throughout the course to interrupt and ask questions or to raise questions at the end of each presentation or during breaks.

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Control Fundamentals Course Agenda

Theory and Practice, and Future Directions

Day 1: Modelling and Analysis for Linear Systems

09.00 **Welcome**

09.10 **L1.1 Introduction and the Need for Improved Control** – Importance of the topic and relevance to industry. MJG

10.15 **L1.2 Fundamentals of Modelling and Simulation** – Basics of Modelling/Model and introduction to the servo modelling example to be used throughout all hands-on sessions.

11.00 *TEA/COFFEE*

11.15 **H1.1 Hands-On Session**: Modelling for Controller Design using MATLAB/SIMULINK

12.30 *LUNCH*

13.30 **L1.3 Linear Dynamic Systems and Transfer Functions** – linear system representations

14.30 *TEA/COFFEE*

14.45 **L1.4 Frequency Response Analysis** - Bode, Nichols and Nyquist, Gain & Phase Margins.

15.45 **H1.2 Hands-On Session:** Linear System Representations and Controller Design.

17.00 *CLOSE*

Day 2: Classical Control Methods for Design

09.00 **L2.1 Fundamentals of Feedback Control Design -** Performance, Disturbance Rejection, Noise, Stability issues.

10.15 *TEA/COFFEE*

10.30 **H2.1 Hands-On Session:** Control Design Fundamentals for Linearized System.

11.30 **L2.2 Frequency Domain Control Design** – Lead-Lag Bode Compensation Methods

12.30 *LUNCH*

13.30 **H2.2 Hands-On Session:** Frequency Domain Control Design Procedure

14.30 **L2.3 Control System Structures** – Feedforward/Feedback, Cascade Control, Multivariable

15.30 *TEA/COFFEE*

15.45 **L2.4 Introduction to PID Controllers** – Basic ideas of PID Control and the Significance/Role, and the effect of the three gain terms on system responses.

17.00 *CLOSE*

Day 3 Practical Aspects, Implementation of Controllers and a Look to the Future

09.00 **L3.1 Introduction to PID Controllers** – PID Structures and Tuning of PID Controllers.

09.45 **H3.1 Hands-On Session:** PID Controller Tuning for Servo Systems Example.

10.30 *TEA/COFFEE*

10.45 **L3.2 Implementation of Controllers** – Nonlinearities, Anti-windup, Bumpless Transfer.

11.30 **H3.2 Hands-On Session:** Implementation of PID Controllers and Practical Aspects.

12.30 *LUNCH*

13.30 **L3.3 What Makes Control Difficult** – Problems due to Dynamics, Delays, Complexity.

14.15 *TEA/COFFEE*

14.30 **L3.4 Discrete-Time Systems and Control** – Continuous to discrete-time model conversion, sampling, z-transforms, Digital controllers, Discrete-Time classical control/filtering methods, Discrete-time PID controllers.

15.45 **H3.3 Hands-On Session:** Discrete Time Systems Modelling and Control Design Example

16.30 **L3.5: Look to the Future** - Covering New Directions in model based and AI and Machine Learning for both Classical and Advanced Control Methods, Brief Overview including the treatment of Nonlinearities.

17.00 *CLOSE*

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