



Control Fundamentals Course

*Theory and Practice, and Future Directions
Six afternoon sessions UK time (morning US time 08.00 -11.30)*

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 two sessions of the course begin 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 two sessions then move on to design aspects 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 two sessions are 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, for both classical and more advanced model-based 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.



Control Fundamentals Course Agenda

Cummins: Theory and Practice, and Future Directions

Day 1: Modelling for Linear Systems

- 13.00 L1.0 Welcome and Introduction to the Course
- 13.15 **L1.1 The Need for Improved Control** – Importance of the topic and relevance to industry.
- 14.15 **Tea / Coffee**
- 14.30 **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.
- 15.30 **H1.1 Demo/Hands-On Session: Modelling for Controller Design using MATLAB/SIMULINK**
- 16.30 **Close**

Day 2: Frequency and Time-Domain Analysis Methods

- 13.00 **L2.1 Linear Dynamic Systems and Transfer-Functions** – linear system representations
- 14.00 **Tea / Coffee**
- 14.15 **L2.2 Frequency Response Analysis Methods** - Bode, Nichols and Nyquist, Gain & Phase Margins, Robustness, Stability assessment.
- 15.30 **H2.1 Demo/Hands-On Session: Linear System Representations and Controller Design.**
- 16.30 **Close**

Day 3: Classical Control Methods for Design

- 13.00 **L3.1 Fundamentals of Feedback Control Design** - Performance, Disturbance Rejection, Noise, Stability issues.
- 14.15 **Tea / Coffee**
- 14.30 **H3.1 Demo/Hands-On Session: Control Design Fundamentals for Linearized System.**
- 15.30 **L3.2 Frequency Domain Control Design** – Lead-Lag Bode Compensation Methods
- 16.30 **Close**

Day 4: Classical Control and Control Structures

- 13.00 **H4.1 Demo/Hands-On Session: Frequency Domain Control Design Procedure**
- 14.00 **L4.1 Control System Structures** – Feedforward/Feedback, Cascade Control, Multivariable
- 15.00 **Tea / Coffee**
- 15.15 **L4.2 Introduction to PID Controllers I** – Basic ideas of PID Control and the Significance/Role, and the effect of the three gain terms on system responses.
- 16.30 **Close**



Day 5 PID Controllers and Implementation

- 13.00 L5.1 Introduction to PID Controllers II** PID Structures and Tuning of PID Controllers, Ziegler-Nichols tuning methods, Internal Model Control Tuning, Auto-tuning.
- 14.00 H5.1 Demo/Hands-On Session:** PID Controller Tuning for Servo Systems Example.
- 14.45 Tea / Coffee**
- 15.00 L5.2 Implementation of Controllers** – Derivative kick, Nonlinearities, Windup, Bumpless Transfer, Tuning for Systems with Nonlinearities.
- 15.45 H5.2 Demo/Hands-On Session:** Implementation of PID Controllers and Practical Aspects.
- 16.30 Close**

Day 6 Practical Aspects and a Look to the Future

- 13.00 L6.1 What Makes Control Difficult** – Problems due to Dynamics, Delays, Complexity.
- 14.00 Tea / Coffee**
- 14.15 L6.2 Discrete-Time Systems and Control** – Sampling, Latency, DAC, Aliasing, Anti-Aliasing, Quantization, Modelling, Discrete-time PID, Continuous to discrete-time conversion, sampling, z-transforms, Digital controllers, Discrete classical control & filtering, methods.
- 15.15 H6.1 Demo/Hands-On Session:** Discrete Time Systems Modelling and Control Design Example
- 16.00 L6.3: Look to the Future** - Covering new directions in both Classical and model-based Advanced Control Methods, including Nonlinear Systems

16.30 End of Course Questions and Close

Course deliverables:

- Copies of the presentations are provided to all delegates.
- Hands-On MATLAB/Simulink software modelling and design examples are provided with problem and solution notes that contain clear step by step instructions.
- Presenter email addresses are provided so follow up questions can be answered.
- Training course certificates are issued for each attendee on completion of the course together with the course details/agenda for company training department records.