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| **Module Title** | Principles of Control |
| **Level** | 5 |
| **Reference No.**  **(showing level)** | EEA\_5\_008 |
| **Credit Value** | 15 |
| **Student Study Hours** | Contact hours: 48  Student-managed learning hours: 102 |
| **Pre-requisite learning** | BEng: level 4 modules in Engineering Mathematics & Modelling (Advanced). (It would also be helpful for this module to follow the level 5 Advanced Mathematical and Modelling module but could run at the same time)  BSc: level 4 modules in Engineering Mathematics & Modelling or equivalent |
| **Co-requisites** |  |
| **Excluded combinations** | None |
| **Module co-ordinator** |  |
| **Faculty/Department** | ESBE / Engineering & Design |
| **Short Description** | The module is an introduction to the theory and practice of continuous-time feedback control systems to enable the design and implementation of servo tracking systems for linear dynamical systems.  It is designed as a core module studied by most courses in the faculty. BEng courses will take an analytic approach to the modelling of dynamical systems and their analysis by applying engineering mathematics. BSc courses will take a more qualitative approach to be able to predict the performance of feedback systems from knowledge of system parameters and to be able to specify supervisory control and data acquisition systems. However, all courses will be taught jointly except for the first few weeks when they will be taught separately and in parallel to lay the mathematical foundations for the BEng students and to give the BSc students a deeper knowledge of supervisory control and data acquisition systems. |
| **Aims** | The aims:  1. To enable a student to understand the role played by feedback to deal with uncertainty about real physical dynamical systems and to design control systems that are able to follow demands as quickly and with as small an error as possible.  2. To enable BEng students to model a range of dynamical systems from different engineering disciplines and to analytically predict their time and frequency behaviour. To enable BSc students to do this but with look-up tables and control tool simulations.  3. To enable a student to select appropriate sensors, actuators and instrumentation to implement control systems for a variety of engineering systems. |
| **Learning Outcomes** | On successful completion of the module, the students will:  Understand and apply mathematical, scientific and engineering principles and tools for the analysis, synthesis, and performance assessment of control systems including: Mathematical modelling, “Classical” control theory, Theory for steady state and transient solution of dynamical systems, Stability criteria – Root locus, Bode, Routh Hurwitz, Measuring equipment and transducers, Electronic sensor devices, Frequency testing and System Identification.  Be able to apply quantitative methods and computer software relevant to their engineering discipline to solve engineering problems. Examples are Transfer function analysis and Stability analysis, MATLAB/SIMULINK and Real Time Windows Target.  Demonstrate knowledge of characteristics of sensors, actuators, Industrial PID controllers, and SCADA systems.  Demonstrate knowledge and understanding of the operating principles of test and measurement equipment for the measurement of system frequency response and an ability to apply this instrument to practical engineering.  Acquire workshop and laboratory skills that include understanding the use of technical literature and manuals to carry out investigations.  Understand the supervisory control engineering principles applicable to the operation and maintenance of very large industrial processes and facilities, plant and equipment monitoring and performance assessment, Environmental management.  Appreciate the role of feedback to work with technical uncertainty. |
| **Teaching and learning pattern** | Two-hour lecture/week.  Two-hour workshop/week based on MATLAB/SIMULINK to investigate topics 5, 6, 7, & 8 listed in “Indicative content”. See demonstrations of PID control on servomechanisms and process rigs and observe associated sensors and actuators.  At the start, BSc students will do topic 1,while BEng will do topics 2 & 3. Then they will both do topics 4, 5, 6, 7, 8. |
| **Indicative content** | BSc courses only will do topic 1:  1. Introduction to Supervisory Control and Data Acquisition (SCADA) Systems to include Building Management Systems (BMS). Describe the four functions performed by SCADA i.e. Data acquisition, Communication, Display and Control. Examples of systems monitored and controlled by SCADA. e.g. Power generation, transmission and distribution systems, manufacturing plants, transport systems and traffic control systems, buildings and water treatment plants. Hardware for SCADA i.e. Sensors, Remote Telemetry Modules, SCADA Masters, Communication Networks, Alarm monitoring.  In addition, BSc students will be introduced to the modelling of a few simple first and second order dynamical systems by writing down their differential equations and will transform them to transfer functions using Laplace transform pairs from look-up tables.  BEng courses only will do topics 2 and 3:  2. Modelling of linear dynamical systems with differential equations. Model first and second order systems e.g. RC and RLC circuits, translation and rotation mechanical systems, DC motors and servomechanisms, coupled water tanks and room dynamics for heating/ventilating.  3. Transform differential equations to Transfer Functions (TF) using the Laplace Transform. Primarily by using tables of Laplace transform pairs and the following properties of the Laplace transform:  Laplace transform of differentiated and integrated functions of time  Laplace transforms of module step, module ramp and half parabola.  Final value theorem of Laplace to find steady state value of a signal.  Inverse Laplace transformations by using partial fraction expansion and tables for the cases (a) distinct and real roots (b) repeated roots (c) complex conjugate roots for second order systems (d) degree of numerator polynomial of a TF equal or greater than degree of denominator polynomial.  Both BSc and BEng courses will do topics 4, 5, 6, 7 & 8:  4. Sensors, Actuators and Instrumentation  Accuracy and precision  Sensors: Incremental and Absolute shaft encoders, rotary potentiometers, tachogenerators, temperature sensors, pressure, liquid level, flow rate, load cells, humidity sensors, pneumatic & electronic transmitters  Actuators: Electric motors, linear motors, valves, linear slides, pumps, relays, etc.  Instrumentation: Data acquisition (ADC, I/O cards, WinRtTgt) and signal conditioning, Transfer Function Analyser, Analogue Computer, Windows Real Time Target.  5. Perform analysis of first and second order systems from their Transfer function description.  Determination of system parameters: Open-loop gain, damping ratio, undamped natural frequency, poles and zeros.  State qualitatively the type and speed of transient response a system will have from knowledge of its pole locations, and relationship of poles to system parameters.  Approximate higher order systems with a second order model.  Find the stability of a system using the Routh Hurwitz criteria.  Find the frequency response of a system to pure sinusoidal inputs from its transfer function description – Sketch straight line asymptotic Bode plots.  Perform system identification (find transfer function) using measured frequency response.  BEng courses will do additionally:  Find, analytically, the Zero-state and Zero-input response of a system to inputs such as module step, module ramp.  6. Block diagram and signal flow graph representation of interconnection of systems and their reduction to a single transfer function.  7. Simple Feedback control  The root locus method to predict movement of closed-loop poles with increasing system gain. Sketch the root loci, determine the range of gains for which the system remains stable.  Design feedback controllers using the root locus method.  Tracking systems. Find the Type Number of a system and state the ability of type zero, type one, type two systems to follow power-of-time inputs such as step inputs, ramp inputs and half parabola inputs.  8. Proportional Integral and Derivative (PID) control  Proportional Control. Show the effect of Proportional gain on the undamped natural frequency and hence speed of response of a system. Show its undesirable effect on the damping ratio.  Proportional and Derivative Control. Show the effect of using Derivative gain in moving the damping ratio of a closed-loop system towards critical damping.  Proportional, Derivative and Integral Control. Show the effect of using Integral gain in reducing steady-state errors to command inputs.  Experimental methods to find initial estimates PID parameters.  Examples of commercially available industrial PID control modules. |
| **Assessment**  ***Elements & weightings*** | End of Module Examination 70%, Coursework 30% (written assessment of laboratory work 15% plus assessment of logbook 15%)  Common Exam paper with some parts to be answered only by BSc or BEng. Coursework assessment similar for both. |
| **Indicative Sources**  ***(Reading lists)*** | **1.** Feedback control of dynamic systems / Gene Franklin, J. David Powell, Abbas Emami-Naeini. Upper Saddle River, N.J.; Harlow: Pearson Education, 2010.  2. Modern control systems / Richard C. Dorf, Robert H. Bishop. Dorf, Richard C.  Upper Saddle River, NJ: Pearson Prentice Hall, c2008.  **3.** Design of feedback control systems / Raymond T. Stefani ... [et al.].Stefani, Raymond T.  New York; Oxford: Oxford University Press, 2002  4. Practical data acquisition for instrumentation and control systems / John Park, Steve Mackay.  Oxford ; Boston : Elsevier, 2003.  5. Principles and practice of automatic process control / Carlos A. Smith, Armando B. Corripio.  Wiley, 2006. |