CONTROL SYSTEMS LABORATORY

DEPARTMENT OF ELECTRICAL ENGINEERING

UNIVERSITY OF ENGINEERING & TECHNOLOGY

LAHORE, PAKISTAN
Control Engineering is of significant interest in most areas of industry - new and established. Control System applications are assuming an increasingly important role in the developing world, making it crucial for the students to be exposed to contemporary control system equipment in a realistic manner, in order to connect theoretical material taught in lecture courses with the realities of physical hardware and simulation through ‘higher-level’ technical computing language. To achieve the goal, Control Systems laboratory has been set up on 1st floor in Department of Electrical Engineering to provide this realistic environment. This laboratory provides university-level students with a test bed to learn and practice fundamental concepts of control systems. Broacher describes the structure of the laboratory, present equipment and features, and the type of experiments students conduct along with a brief experiments list.
STRUCTURE OF THE LABORATORY

Control Systems Laboratory presents facilities of computing and simulation through MATLAB and demonstration on FEEDBACK designed equipment with PCI cards creating an impressive digital control system development environment. MATLAB is a ‘higher-level’ technical computing language that provides a platform for algorithm development, data analysis, data visualization, etc. Together with SIMULINK and additional toolboxes it facilitates control system design and analysis, which can later be implemented in real-time applications using Real-time Workshop.

The Feedback range of Control Systems demonstration equipment has been employed to provide a modern, efficient approach to training the undergraduate students in this field. Our philosophy is to equip students with the fundamental ideas and principles that underpin modern engineering practice by using versatile trainers that quickly and clearly demonstrate the required technology. Feedback control Instruments are compatible with such an environment. Salient features of equipment are:

- Phenomenological process models
- Dynamics analysis
- Discrete models identification
- Controller design
- Controller tests on the model
- Controller implementation in real-time applications
- Implementation of various control strategies
- Data visualization

The Phenomenological process models are designed in SIMULINK to provide initial models for the user to test. Model linearization is then discussed and the use of simple dynamics analysis - like bode diagrams poles and zeros maps are introduced. To obtain accurate models Identification procedures incorporating MATLAB functions are described. Controllers design and PID control is explained and a guide is given for PID controller design, testing, tuning and implementation on the model. Root locus technique is used to illustrate the changes that PID controller tuning inflicts on the control system performance. The designed controllers are prepared in SIMULINK to be built and tested through the Real-time Workshop using the Feedback control applications.

Paramount to all laboratory equipment is the principle that students of Engineering and Technology should work with hardware and be allowed to take a hands-on approach.
This hardware is used in conjunction with a combination of

- Industry standard control devices
- Computer Assisted Learning techniques with Feedback’s Discovery software - offering on-screen instruction and embedded, real-time, virtual instrumentation
- Sophisticated simulation software such as MATLAB to create challenging applications

**EQUIPMENT AND FACILITIES**

**Digital Servo Trainer**
- Open and closed-loop speed and position control
- Demonstrates both Analogue and Digital control techniques
- Built-in PC based instrumentation
- On-board square and triangle waveform generator
- Independent single, two-term, or full PID control
- Absolute position & incremental speed & position encoders
- Continuous analogue position and velocity feedback signals
- Linear or PWM motor drive

**DC Modular Servo System**
- Motor speed characteristics
- DC error channel
- Deadband & step response
- Velocity feedback
- Analysis of simple position control
- with speed response
- Position response
- Closed loop frequency response
- Identification of motor time constants
Identification of velocity error constant \( K_v \)
Frequency and transient response
Measurement of following error
Stability considerations & the use of lead, lag and combined networks
Tachogenerator feedback and its effects on system performance including acceleration feedback
Linearisation of systems

**ac Modular Servo System M S150A**
- Motor characteristics
- AC tachogenerator
- Motor speed control
- Characteristics of 2-phase motors
- Position control systems
- Importance of phasing on torque
- Simple speed control and speed performance
- Compensation using the adjustable notch filter

**Digital Pendulum**
- Pendulum Description
- Equations of motion
- Nonlinear model
- Linear models
- Model identification
- Static friction compensation
- Real time PID control of cart position
Real-time swing-up control
Inverted pendulum control of swing-up mode
Use of the MATLAB system identification toolbox
Crane linear model identification
Inverted pendulum linear model

Pendulum set-up control
Plant control
PID controller
PID control of cart model position
Inverted pendulum stabilization
Crane control
Combined control techniques

Magnetic Levitation Control

- New and innovative form of Magnetic Levitation phenomenon.
- A hollow steel sphere is suspended in space with visually appealing results and convenient time constants.

Both analogue and digital control solutions are implemented.
Convenient sockets on the enclosure panel allow for quick changes of analogue controller gain and compensation components.
The equipment is self-contained in analogue mode, with built-in power supply.
In the digital mode the system operates within a MATLAB environment which allows the system parameters to be determined and the system to be modeled.
The digital controller can be used to run the hardware and the actual control performance can be seen and analysed.
Additional student generated control algorithms may be tested through SIMULINK.

The Twin Rotor System

- Demonstrates the principles of a non-linear MIMO system with significant cross-coupling.
Its behavior resembles a helicopter but the angle of attack of the rotors is fixed and the aerodynamic forces are controlled by varying the speeds of the motors.

Significant cross-coupling is observed between the actions of the rotors, with each rotor influencing both angle positions.

The MATLAB software allows the student to design and test stabilizing controllers with independent control applied to each co-ordinate of the system.

Pneumatic Servo

- Widely used in today's manufacturing industries.
- Position, speed and pressure control.
- Motor control with speed control in single and both direction.

Hydraulic Servo

- Widely used in today's manufacturing industries.
- Position, speed and pressure control.
- Motor control with speed control in single and both direction.

More advanced investigations may be carried-out through user-defined algorithms from within SIMULINK.
EDUCATION AND COURSES

Various courses are taught both at the undergraduate and graduate levels. These courses provide students with a broad fundamental basis in theoretical, numerical, and practical skills, so that graduates are well prepared experts in the area.

UNDERGRADUATE COURSES

- EE 363 Control Systems

GRADUATE COURSES

- EE 680 Digital Control Systems
- EE 684 Adaptive Control Systems
- EE 580 Advanced Control Systems
- EE 681 Stability of Control Systems
- EE 683 Non-Linear Dynamic Systems
- EE 535 Control of DC Drives
- EE 536 Control of AC Drives
- EE 512 Intelligent Agents
- EE 661 Expert systems and artificial intelligence
- EE 583 Dynamics of Robotics
- EE 584 Optimal Control Theory

TERM PROJECTS

Students are to present term projects on the completion of all lab sessions utilizing the theoretical concepts learned in the class and practical work carried out during the semester. These projects provide students with a broad fundamental basis in practical skills. Students are encouraged to explore industry related problems in their work.

Some significant and recently completed projects by undergraduate students are:
Laboratory Experiments performed by undergraduate students are:

**Differential Equations Modeling**
To get familiar with the SIMULINK working environment. Solving differential equations, time domain approach

**Mathematical Models of Systems**
To declare Transfer Function, Calculate Transfer Function of mass-damper-spring system. Impulse Response and Step Response. Concept of Damping Ratio and Natural Frequency. Open-loop and Closed-loop Transfer Function

**State Variable Models**
To learn how to convert the transfer function of a system into state variable representation and vice versa. Simulate a system expressed in state variable form. Change the System parameters to obtain over damped, under damped, critically damped and oscillatory
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<tr>
<th><strong>Control of Transient and Steady State Response of Systems</strong></th>
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<th><strong>Stability of Control Systems</strong></th>
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<tr>
<td>To explore the stability of a control system using pole zero map of transfer function. Routh-Hurwitz criteria to determine stability.</td>
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<th><strong>Root Locus Analysis of Control Systems</strong></th>
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<td>To explore the root-locus analysis of a control system. Range of gain for stable operation using root locus. Effect of PI controller and integral controller on system response.</td>
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<th><strong>Frequency Domain Analysis of Control Systems</strong></th>
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<td>To explore the Frequency Response of a Control System. Find phase margins and gain margins.</td>
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<th><strong>Digital Control Systems</strong></th>
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<tr>
<td>To explore the Properties of Digital Control Systems. Convert continuous time system to discrete system and vice versa. Root Locus of Digital control system on z-plane.</td>
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<td>Study the function of each component of DC servo system. Sketching Open-loop step response with and without the mechanical load.</td>
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<td><strong>Magnetic Levitation System</strong></td>
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An e-group is maintained for important announcements, assignments and assist students overcoming difficulties being faced during semester. Group for recent semester is:

EE363_Control_System@yahoogroups.com
FUTURE PLANS

The laboratory has already encouraged many students to carry out interesting research projects on dc and ac drives and fuzzy logic. Although laboratory was planned to be a resource for undergraduate students, it was found it to be of interest and value to Graduate students as well, although it did require greater effort to develop experiments at a more sophisticated level.

Finances and human resources permitting, our future plans call for the augmentation of this laboratory with:

Process Control Instrumentation

A fundamental Control Engineering discipline which has got importance in many industries. Process Control depends upon measurement, requiring a detailed understanding of the relevance, accuracy and different techniques which may be used and applied in open and closed loop systems. Depending on the process requirement, different levels of control will be addressed, using different devices such as Process Controllers and PLCs.

Robotics

The handling of various industrial materials now has been undertaken using some form of automation as a substitute for human effort. Today, the majority of mass-produced items are made using very complex and highly sophisticated manufacturing systems. These employ many types of versatile robotic mechanisms that can be programmed to be used for different applications. The number of robotic systems in manufacturing now runs into millions and their use has extended to other areas, such as medical, and domestic and where human activity would not be possible. Keeping this in view, future plan is to ensure the availability of robotic trainers for the laboratory. These trainers involve electrical, hydraulic and pneumatic devices that are used to make fully working, industrially representative systems but on a much smaller scale and at lower cost.
## PUBLISHED WORK

Some selected research publication are as under:

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<th>Title</th>
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<th>Journal/Conference</th>
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