Electrical Engineering Technical College	30 Weeks	No. of week hours		
Department of Medical Instrumentation Engineering Techniques		Th.	Pr.	Unit
		2	2	6
Fourth Year	Subject: Control System.			

Week	Syllabus
1st	Introduction to linear control engineering.
2nd , 3rd	Mathematical background; Laplace transform, complex variable, matrices.
4th , 5th , 6th	Transfer function, block diagram representation and reduction, signal flow diagram.
7th , 8th , 9th	Time domain analysis, steady – state transient analysis.
10th , 11th	Stability analysis; Routh, Nyquist.
12th , 13th	Root locus technique.
14th , 15th , 16th	Frequency domain analysis, Gain margin, phase margin and bode plot.
17th , 18th	Frequency domain synthesis, phase lead.
19th , 20th	Compensation, phase – lag compensation lag – lead compensation.
21st , 22nd , 23^{r}, 24th	PID controllers design.
25th, 26th , 27th	State space representation and analysis.
28th , 29th	State diagram; analogue computer.
30th	Block diagram representation.

Objectives:

- Introduce students to the mathematical modeling of physical systems
- – Mechanical, electrical, fluid, and thermal systems
- – Show “real-world” examples from ASME articles, industry
- Introduce students to analytical and numerical methods for obtaining a system’s dynamic response to various initial conditions and input functions
- – Analytical: solving ODEs “by hand”
- – Numerical: MATLAB and Simulink
- Analyze and design feedback control systems in order to achieve a desirable system response

References:

1. Modern Control Systems, R. C. Dorf and R. H. Bishop, Pearson Prentice Hall, 14th edition, 2022.

2. Modern Control Engineering, Ogata Katsuhiko, 5th Edition, Prentice-Hall, 2010.

3. Control System Engineering, Norman S. Nise, California State Polytechnic University, Pomona, John Wiley & Sons, Inc. ,6th_Edition, 2011.

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A basic control system includes an input, controller, actuator, process, and sensor/output to monitor and regulate processes, offering benefits such as increased efficiency, reduced costs, improved safety, consistent quality, and better decision-making by automating tasks and providing data. The overall goal of a control system is to maintain stability and performance by comparing a system's desired state (setpoint) with its actual output.

Parts of a Control System

A typical feedback control system is comprised of the following core components:

Input/Setpoint: The desired state or value the system is meant to achieve (e.g., a desired temperature in a room).

Controller: The "brain" of the system, which compares the input (setpoint) with the current output and determines the necessary adjustments.

Actuator: A device that receives commands from the controller and performs a physical action to influence the system's output (e.g., a motor, valve, or compressor).

Process: The system or physical phenomenon being controlled.

Sensing Element/Output: A component that measures the actual output of the process and provides this information back to the controller, closing the feedback loop.

Benefits of Control Systems

- **Improved Efficiency and Reduced Costs:** Automating processes with control systems can reduce manual labor, minimize material waste, and optimize resource usage, leading to lower operating costs.
- **Enhanced Safety:** Automation reduces human error, a common cause of accidents, and allows for faster detection and response to hazards or faults, creating a safer work environment.
- Consistent Product Quality: Control systems ensure processes operate within specified parameters, maintaining consistent product quality and composition without constant human intervention.
- **Data for Decision-Making:** By collecting and monitoring process data, control systems provide valuable insights for management, enabling better strategic decisions regarding production, planning, and identifying areas for improvement.

- **Automation of Complex Tasks:** Control systems can manage complex or hazardous tasks and environmental conditions that may be difficult or dangerous for humans to handle.
- **Compliance with Regulations:** For certain industries, control systems are crucial for ensuring adherence to legal and regulatory requirements, particularly in financial, public, and government sectors.

Definitions:

System: A combination of components acting together to perform a specified objective. The components or interacting elements have cause-and-effect (or input/output) relationships. We will investigate mechanical, electrical, fluid, and mixed systems.

Dynamic system: The current output variables of a system depend on the initial conditions (or stored energy) of the system and/or the previous input variables. The dynamic variables of the system (e.g., displacement, velocity, voltage, pressure, etc) vary with time.

Modeling: The process of applying the appropriate fundamental physical laws in order to derive mathematical equations that adequately describe the physics of the engineering system.

Mathematical models: A mathematical description of a system's behavior, usually a set of differential equations for a dynamic system

Simulation: The process of obtaining the system's dynamic response by numerically solving the governing modeling equations. Simulation involves numerical integration of the model's differential equations and is performed by digital computers and simulation software.

System analysis: The use of analytical calculations or numerical simulation tools to determine the system response in order to assess its performance.

Control Theory: It is that part of science which concern with control problems.

Control Problem: If we want something to act or vary according to a certain performance specification, then we say that we have a control problem.

Plant: A piece of equipments the purpose of which is to perform a particular operation (we will call any object to be controlled a plant). Ex. Heating furnace, chemical reactor or space craft.

Process: A progressively continuing operation (natural or artificial) that consist of a series of actions or changes in a certain way leading towards a particular result or end. We will call any operation to be controlled a process. Processes could be chemical, economic, or biological.

System: A combination of components that act together and perform a certain objective (could be physical, biological, or economic).

Disturbance: A signal which tends to conversely affect the value of the output of a system (of course it is undesired signal).

Command input i/p: The motivating input signal to the system which is independent of the output of the system.

Reference i/p elements: An element which modifies the command i/p into suitable signal (called reference i/p) for the controlled system.

Reference input: It is almost the desired output.

Actuating signal: The difference between the reference input and feedback (f/b) signals. It actuates the control unit (controller) to maintain the output at the desired value.

Control unit: The unit which receives the actuating signal and delivers the control signal.

Controlled variable (actual o/p): The variable which we need actually to control it. Ex. temperature, pressure, liquid level, flow rate, etc.

Feedback signal: A signal representing a measure of the actual o/p which is fed back into control system for purpose of comparison with the reference signal.

Feedback element: Usually it represents a transducer, the purpose of which is to convert the o/p of the system in to a signal of suitable physical nature for the next stage in the system (error detector).

Feedback control: An operation which tends to reduce the difference between the o/p of the system and the reference i/p.

Servomechanism control system: A feedback control system in which the o/p is mechanical variable (position, speed, acceleration).

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Process control system: A feedback control system in which the o/p is a variable such as temperature, pressure liquid level.

Automatic regulating system: A feedback control system in which the reference i/p (desired output) is either constant or slowly varying with time and the primary task is to maintain the o/p at the desired value in the presences of disturbance.

Linear Time-Invariant Systems and Linear Time-Varying Systems: A differential equation is linear if the coefficients are constants or functions only of the independent variable. Dynamic systems that are composed of linear time-invariant lumped-parameter components may be described by linear time-invariant differential equations—that is, constant-coefficient differential equations. Such systems are called linear time-invariant (or linear constant-coefficient) systems. Systems that are represented by differential equations whose coefficients are functions of time are called linear time-varying systems. An example of a time-varying control system is a spacecraft control system. (The mass of a spacecraft changes due to fuel consumption).

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