Lecture 01: Introduction to control system Engineering

System:

A system is a collection of components which interact with each other and with the environment (by information or energy links) from which the system is separated by a notational boundary.

Systems include physical, biological, organizational, and other entities, and combinations thereof, which can be represented through a common mathematical symbolism. The study of feedback control systems is essentially a study of an important aspect of systems engineering and its application.

**Input:**
- The input is the stimulus, excitation or command applied to a control system.
- Typically from external energy source, usually in order to produce a specified response from the control system.

**Output:**
- The output is the actual response obtained from a control system.
- It may or may not be equal to specified response implied by the input.

**Control Engineering:**

Control engineering or Control systems engineering is based on the foundations of feedback theory and linear system analysis, and it integrates the concepts of network theory and communication theory. It is the engineering discipline that applies control theory to design systems with predictable behaviors. The practice uses sensors to measure the output performance of the device being controlled (often a vehicle) and those measurements can be used to give feedback to the input actuators that can make corrections toward desired performance. When a device is designed to perform without the need of human inputs for correction it is called automatic control (such as cruise control for regulating a car’s speed). Multi-disciplinary in nature, control systems engineering activities focus on implementation of control systems mainly derived by mathematical modeling of systems of a diverse range.
Why control is important (for production process / in plant)?

(1) Safety: Prevent injury to plant personnel, protect the environment by preventing emission and minimizing waste and prevent damage to the process equipment.
(2) Maintain product quality (composition, purity, color, etc.) on a continuous basis and with minimum cost.
(3) Maintain plant production rate at minimum cost.

So, we can say that the reasons for automation of process plants are to provide safety and at same time maintain desired product quality, high plant throughput, and reduce demand on human labor.

Control system:

A control system is a system capable of monitoring and regulating the operation of a process or a plant. The study of control system is essentially a study of an important aspect of systems engineering and its applications.

A control system consists of subsystems and processes (or plants) assembled for the purpose of controlling the outputs of the process. For example, a furnace produces heat as a result of the flow of fuel. In this process, flow of fuel in the input, and heat to be controlled is the output.

There are two common classes of control systems, with many variations and combinations: logic or sequential controls, and feedback or linear controls. There is also fuzzy logic, which attempts to combine some of the design simplicity of logic with the utility of linear control. Some devices or systems are inherently not controllable.

Controls are classified with respect to:

- technique involved to perform control (i.e. human/machines): manual/automatic control
- Time dependence of output variable (i.e. constant/changing): regulator/servo, (also known as regulating/tracking control)
- fundamental structure of the control (i.e. the information used for computing the control): Openloop/feedback control, (also known as open-loop/closed-loop control) Manual/Automatic Controls - Examples A system that involves:
  - a person controlling a machine is called manual control. Ex: Driving a car
  - machines only is called a automatic control. Ex: Central AC Servo/Regulator Controls – Examples An automatic control system designed to:
    - follow a changing reference is called tracking control or a servo. Ex: Remote control car
    - maintain an output fixed (regardless of the disturbances present) is called a regulating control or a regulator. Ex: Cruise control

Open-Loop Control /Feedback control

The structures are fundamentally different:

- In an open-loop control, the system does NOT measure the actual output and there is no correction to make that output conform to the desired output.
- In a closed loop control the system includes a sensor to measure the output and uses feedback of the sensed value to influence the control input variable.

Examples of Open-Loop & Feedback Controls

An Electric toaster is an open-loop control. Since:
- The controller is based on the knowledge.
- The output is not used in control computation

A water tank of an ordinary flush toilet is a (basic) feedback control, since the output is fed back for control computation.
Advantage of Control system

We build control systems for four primary reasons
1. Power amplification
2. Remote control
3. Convenience of input form
4. Compensation of the disturbances

Block Diagram
- It represents the structure of a control system.
- It helps to organize the variables and equations representing the control system.
- It is composed of:
  - boxes, that represents the components of the system including their causality;
  - Lines with arrows that represents the actual dynamic variables, such as speed, pressure, velocity, etc.

Simplest Open-Loop Control Example & Associated Block Diagrams

- **System** = mass + spring
- **Control Input**: force $u$
- **Output**: displacement $x(t)$

- Block diagram (derived using Laplace transforms, more on this later)
- Component block diagram for the system examined

Specific & Generic Component Block Diagrams
Definitions of Process, Actuator & Plant

- **Process** = component whose the output is to be controlled,  
  Ex: *Mass*
- **Actuator** = device that can influence the control input variable of the process,  
  Ex: *Spring*
- **Plant** = actuator + process,  
  Ex: *Spring/mass system*
- **Control input** = external variable (signal/action) applied to the plant
- **Controller** = computes the desired control input variable
- **Sensor** = measures the actual output variable
- **Comparator** (or Σ) = computes the difference between the desired and actual output variables to give the controller a measure of the system error
- Our general system also includes: Disturbance & Sensor noise
- Typically, the sensor converts the measured output into an electric signal for use by the controller. An input filter is then required.
- **Input filter** = converts the desired output variable to electric form for later manipulation by the controller
System configurations - open and closed loop systems

- **Open-loop control**: An open-loop control is applied to achieve desired system response using a controller or an actuator without feedback.

  Features of open loop control:

  Two outstanding features of open-loop control systems are:
  1. Their ability to perform accurately is determined by their calibration. To *calibrate* means to establish or reestablish the input-output relation to obtain desired system accuracy.
  2. They are not usually troubled with problems of *instability*.

- **Closed-loop/feedback control**: A closed-loop control is used to achieve desired system response using a controller with the output measurement as a feedback signal. The use of feedback enables us to improve system performance at the cost of introducing the measurement noise and stability problem.