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# System Modeling & Control

Presented by

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# Module I

## Introduction



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## Lesson - 1

# Introduction to Control System

## Introduction

- A control system consists of subsystems and processes (or plants) assembled for the purpose of obtaining a desired output with desired performance, given a specified input.
- A control system consisting of interconnected components is designed to achieve a desired purpose. To understand the purpose of a control system, it is useful to examine examples of control systems through the course of history. These early systems incorporated many of the same ideas of feedback that are in use today.



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## Introduction (Contd..)

- Modern control engineering practice includes the use of control design strategies for improving manufacturing processes, the efficiency of energy use, advanced automobile control, including rapid transit, among others.
- We also discuss the notion of a design gap. The gap exists between the complex physical system under investigation and the model used in the control system synthesis.
- The iterative nature of design allows us to handle the design gap effectively while accomplishing necessary tradeoffs in complexity, performance, and cost in order to meet the design specifications.



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# Important Definitions.

**System** – An interconnection of elements and devices for a desired purpose

**Control System** – An interconnection of components forming a system configuration that will provide a desired response.

**Process** – The device, plant, or system under control. The input and output relationship represents the cause-and-effect relationship of the process.



Process to be controlled.



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# Advantages of Control Systems

With control systems we can move large equipment with precision that would otherwise be impossible.

We can point huge antennas toward the farthest reaches of the universe to pick up faint radio signals; controlling these antennas by hand would be impossible.

Because of control systems, elevators carry us quickly to our destination, automatically stopping at the right floor.

We alone could not provide the power required for the load and the speed; motors provide the power, and control systems regulate the position and speed.

We build control systems for four primary reasons:

1. Power amplification
2. Remote control
3. Convenience of input form
4. Compensation for disturbances

For example, a radar antenna, positioned by the low-power rotation of a knob at the input, requires a large amount of power for its output rotation.

# Advantages (Contd..)

- A control system can produce the needed power amplification, or power gain-Robots designed by control system principles can compensate for human disabilities.
- Control systems are also useful in remote or dangerous locations. For example, a remote-controlled robot arm can be used to pick up material in a radioactive environment.
- Control systems can also be used to provide convenience by changing the form of the input. For example, in a temperature control system, the input is a position on a thermostat. The output is heat.
- Thus, a convenient position input yields a desired thermal output. Another advantage of a control system is the ability to compensate for disturbances.
- Typically, we control such variables as temperature in thermal systems, position and velocity in mechanical systems, and voltage, current, or frequency in electrical systems.
- The system must be able to yield the correct output even with a disturbance. For example, consider an antenna system this point in a commanded direction.
- If wind forces the antenna from its commanded position, or if noise enters internally, the system must be able to detect the disturbance and correct the antenna's position.
- Obviously, the system's input will not change to make the correction.
- Consequently, the system itself must measure the amount that the disturbance has repositioned the antenna and then return the antenna to the position commanded by the input.



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# A History of Control Systems

## Introduction

Let us now look at a brief history of human-designed control systems. Feedback control systems are older than humanity. Numerous biological control systems were built into the earliest inhabitants of our planet.

## **Liquid-Level Control:-**

The Greeks began engineering feedback systems around 300 a c a water clock invented by Ktesibios operated by having water trickle into a measuring container at a constant rate. The level of water in the measuring container could be used to tell time. For water to trickle at a constant rate, the supply tank had to be kept at a constant level. This was accomplished using a float valve similar to the water-level control in today's flush toilets. Soon after Ktesibios, the idea of liquid-level control was applied to an oil lamp by Philon of Byzantium.





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# Contd....

## Steam Pressure and Temperature Controls

Regulation of steam pressure began around 1681 with Denis Papin's invention of the safety valve. The concept was further elaborated on by weighting the valve top. If the upward pressure from the boiler exceeded the weight, steam was released, and the pressure decreased. If it did not exceed the weight, the valve did not open, and the pressure inside the boiler increased. Thus, the weight on the valve top set the internal pressure of the boiler. Also in the seventeenth century, Cornelis Drebbel in Holland invented a purely mechanical temperature control system for hatching eggs.



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# Contd...

## Speed Control

In 1745, speed control was applied to a windmill by Edmund Lee. Increasing winds pitched the blades farther back, so that less area was available. As the wind decreased, more blade area was available. William Cubitt improved on the idea in 1809 by dividing the windmill sail into movable louvers. Also in the eighteenth century, James Watt invented the fly ball speed governor to control the speed of steam engines. In this device, two spinning fly balls rise as rotational speed increases. A steam valve connected to the fly ball mechanism closes with the ascending fly balls and opens with the descending fly balls, thus regulating the speed.



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## Lesson - 2

# Types of Control System

## Linear Systems.

A system is called linear if the principle of superposition applies. The principle of superposition states that the response produced by the simultaneous application of two different forcing functions is the sum of the two individual responses. Hence, for the linear system, the response to several inputs can be calculated by treating one input at a time and adding the results. It is this principle that allows one to build up complicated solutions to the linear differential equation from simple solutions. In an experimental investigation of a dynamic system, if cause and effect are proportional, thus implying that the principle of superposition holds, then the system can be considered linear.



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## 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.



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# Types of Control System

## Open-Loop control Systems (Non feedback Systems)

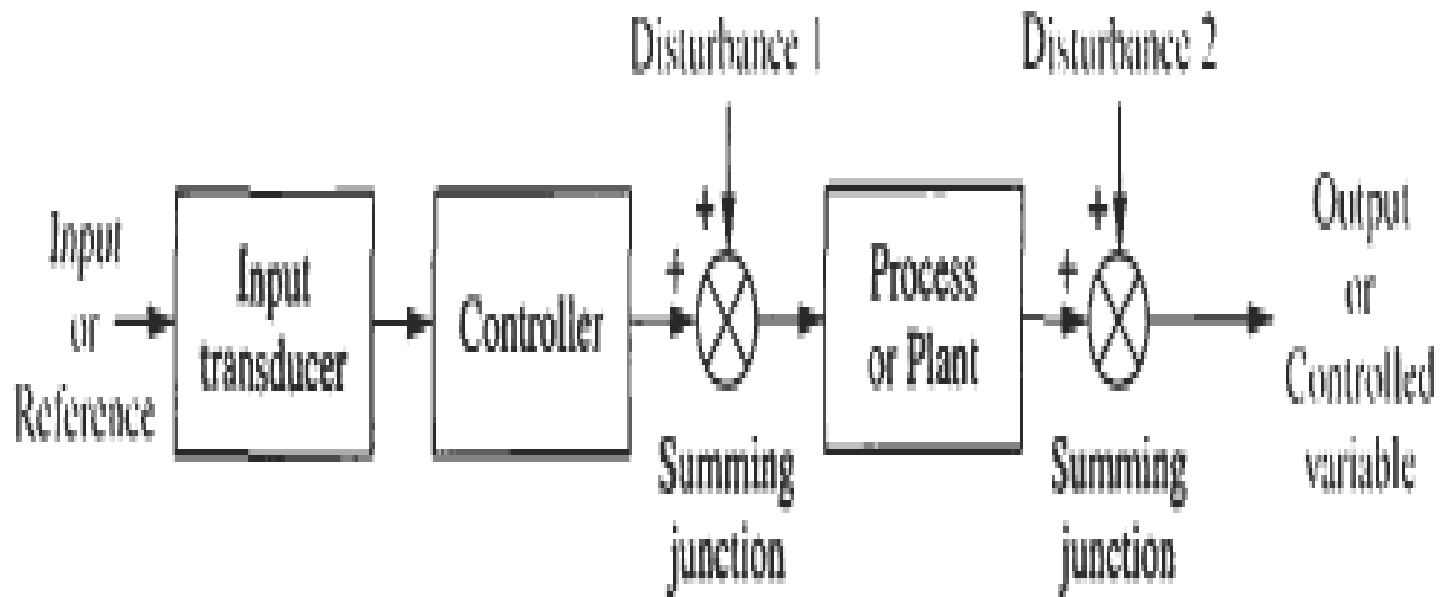
### Introduction

- Open loop system is also known as non feedback system.
- An open-loop control system is shown in Fig. It starts with a subsystem called an input transducer, which converts the form of the input to that used by the controller.
- The controller drives a process or a plant. The input is sometimes called the reference, while the output can be called the controlled variable.
- Other signals, such as disturbances, are shown added to the controller and process outputs via summing junctions, which yield the algebraic sum of their input signals using associated signs



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**Fig. Open loop control system (Non feedback System)**



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For example, the plant can be a furnace or air conditioning system, where the output variable is temperature. The controller in a heating system consists of fuel valves and the electrical system that operates the valves.

Open-loop systems, then, do not correct for disturbances and are simply commanded by the input. For example, toasters are open-loop systems, as anyone with burnt toast can attest.

The controlled variable (output) of a toaster is the color of the toast. The device is designed with the assumption that the toast will be darker the longer it is subjected to heat.

The toaster does not measure the color of the toast; it does not correct for the fact that the toast is rye, white, or sourdough, nor does it correct for the fact that toast comes in different thicknesses.



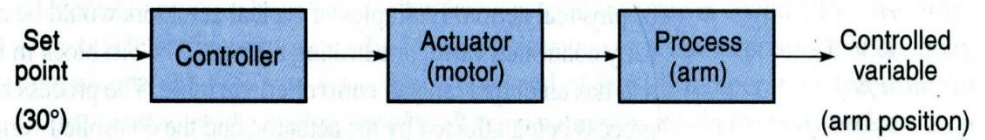


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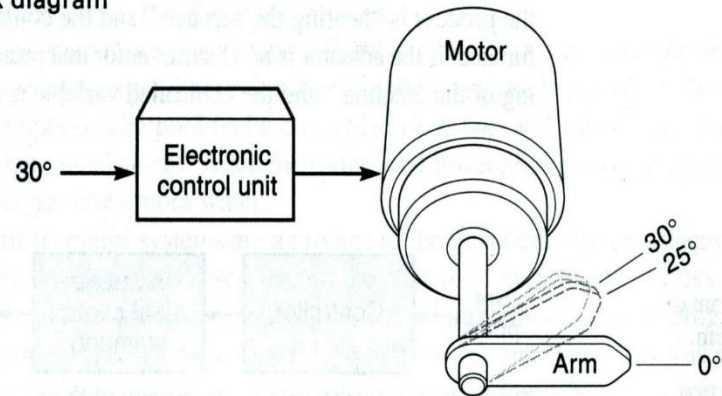
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**Figure 1.2**

Open-loop control system.



(a) Block diagram



(b) A simple open-loop position system (Example 1.1)





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## Open Loop System:

### Advantages:

- **Simplicity and stability:** they are simpler in their layout and hence are economical and stable too due to their simplicity.
- **Construction:** Since these are having a simple layout so are easier to construct.

### Disadvantages:

- **Accuracy and Reliability:** since these systems do not have a feedback mechanism, so they are very inaccurate in terms of result output and hence they are unreliable too.
- Due to the absence of a feedback mechanism, they are unable to remove the disturbances occurring from external sources.

# **Closed-Loop Control Systems (Feedback Control Systems)**

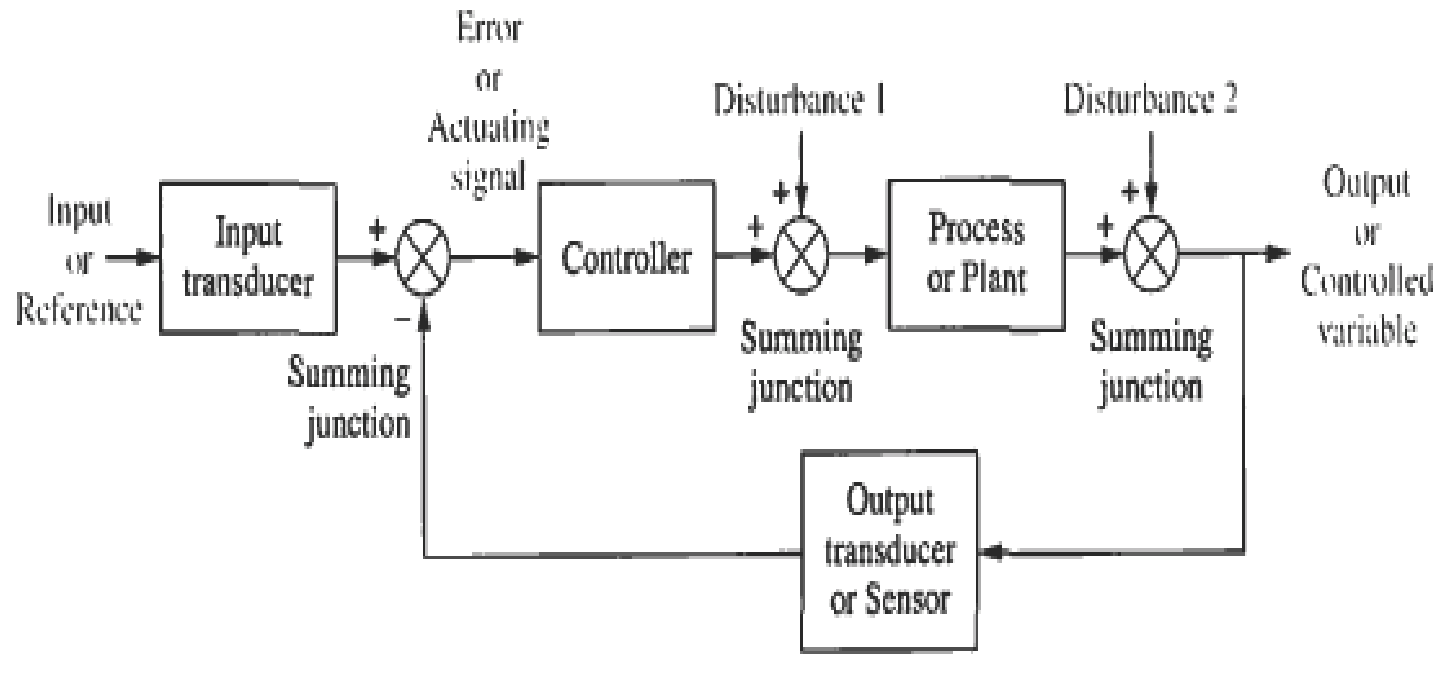
## **Introduction**

- Disadvantages of open loop control system are corrected through the close loop control system. The input transducer converts the form of the input to the form used by the controller.
- A system with one or more feedback paths such as that just described is called a closed-loop system.
- An output transducer, or sensor, measures the output response and converts it into the form used by the controller.
- For example, if the controller uses electrical signals to operate the valves of a temperature control system, the input position and the output temperature are converted to electrical signals.
- The input position can be converted to a voltage by a potentiometer, a variable resistor, and the output temperature can be converted to a voltage by a thermistor.
- A device whose electrical resistance changes with temperature. The first summing junction algebraically adds the signal from the input to the signal from the output, which arrives via the feedback path, the return path from the output to the summing junction.



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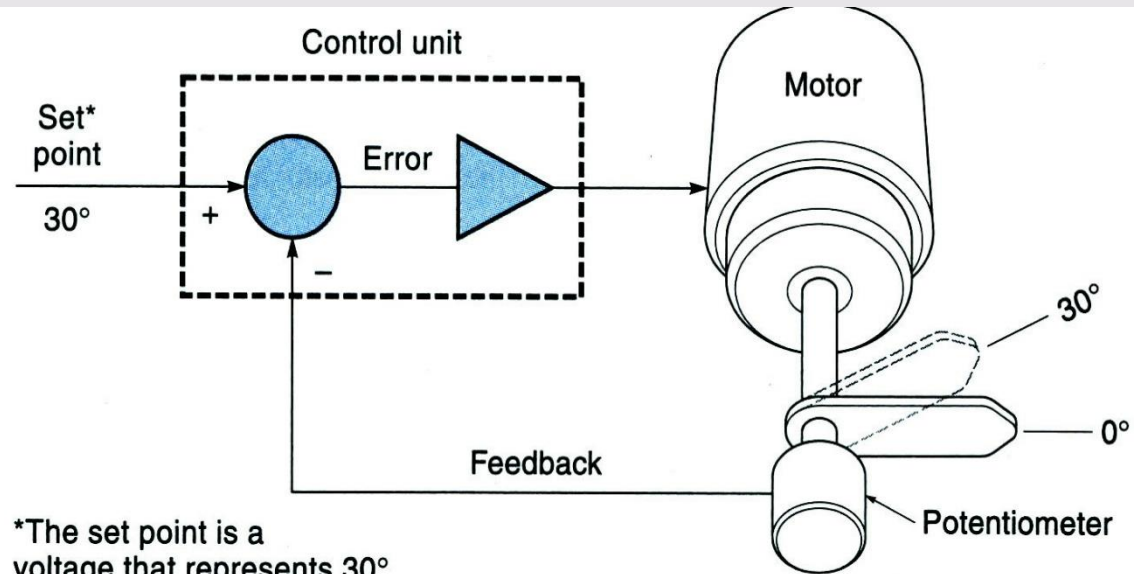


**Fig. Closed loop control system ( feedback Control System)**



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\*The set point is a voltage that represents 30°

(b) A simple closed-loop position system (Example 1.2)

# Closed Loop System:

## Advantages:

- **Accuracy:** They are more accurate than open loop system due to their complex construction. They are equally accurate and are not disturbed in the presence of non-linearities.
- **Noise reduction ability:** Since they are composed of a feedback mechanism, so they clear out the errors between input and output signals, and hence remain unaffected to the external noise sources.

## Disadvantages:

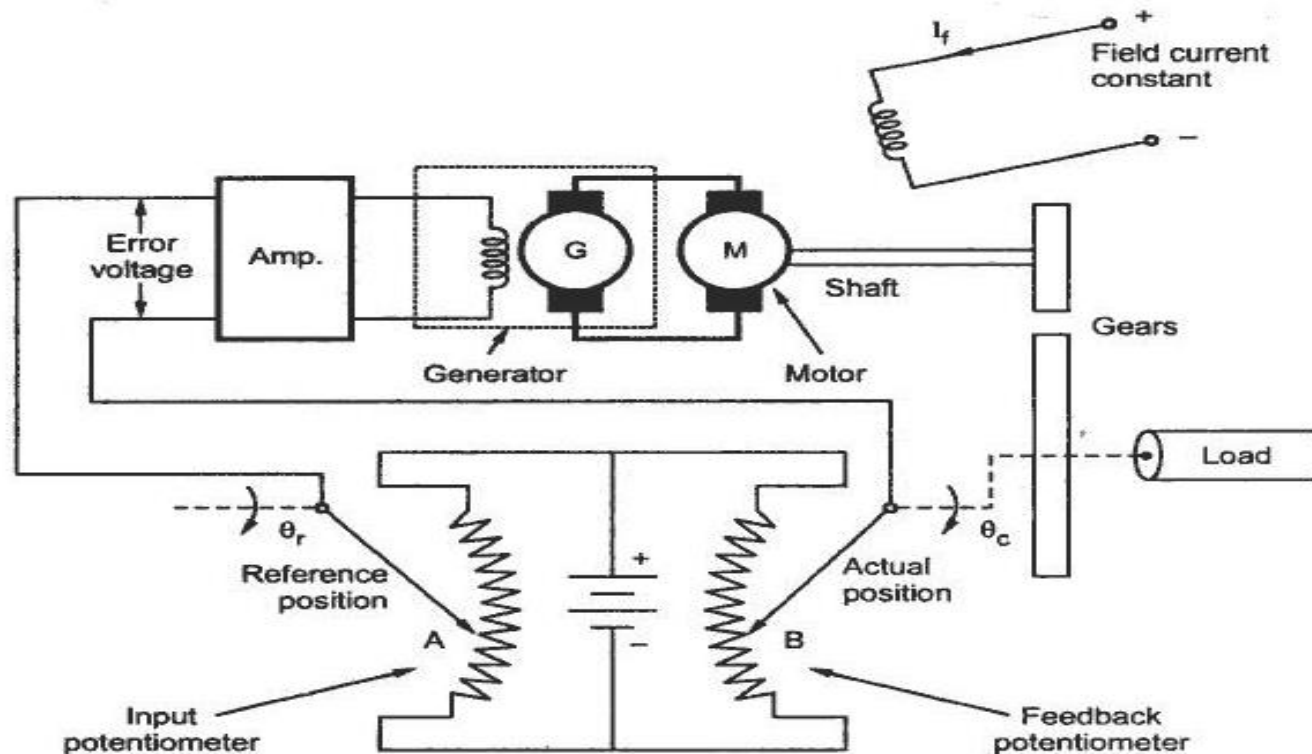
- **Construction:** They are relatively more complex in construction and hence it adds up to the cost making it costlier than open loop system.
- Since it consists of feedback loop, it may create oscillatory response of the system and it also reduces the overall gain of the system.
- **Stability:** It is less stable than open loop system but this disadvantage can be striked off since we can make the sensitivity of the system very small so as to make the system as stable as possible.

# Servomechanisms

## Lesson - 3

**Definition :** *It is a feedback control system in which the controlled variable or the output is a mechanical position or its time derivatives such as velocity or acceleration.*

A simple example of servomechanism is a **position control system**. Consider a load which requires a constant position in its application. The position is sensed and converted to voltage using feedback potentiometer. It is compared with input potentiometer voltage to generate error signal. This is amplified and given to the controller. The controller in turn controls the voltage given to motor, due to which it changes its position.



**Fig. 1.24 Position control system**



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Few other examples of servomechanisms are,

- 1) Power steering apparatus for an automobile.
- 2) Machine tool position control.
- 3) Missile launchers.
- 4) Roll stabilization of ships.