

# Automatic Control Systems

## Lecture-1

### Basic Concepts of Classical control

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# What is Control System?

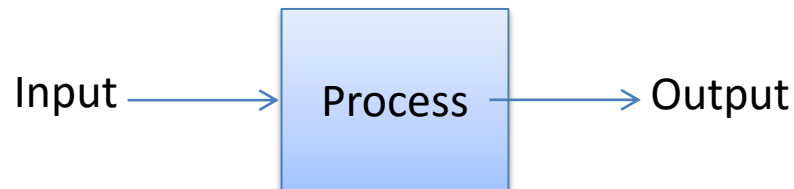
- A system Controlling the operation of another system.
- A system that can regulate itself and another system.
- A control System is a device, or set of devices to manage, command, direct or regulate the behaviour of other device(s) or system(s).

# 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.



# Definitions

**Controlled Variable**– It is the quantity or condition that is measured and Controlled. Normally *controlled variable* is the output of the control system.

**Manipulated Variable**– It is the quantity of the condition that is varied by the controller so as to affect the value of *controlled variable*.

**Control** – Control means measuring the value of *controlled variable* of the system and applying the *manipulated variable* to the system to correct or limit the deviation of the measured value from a desired value.

# Examples

## ● Car cruise control

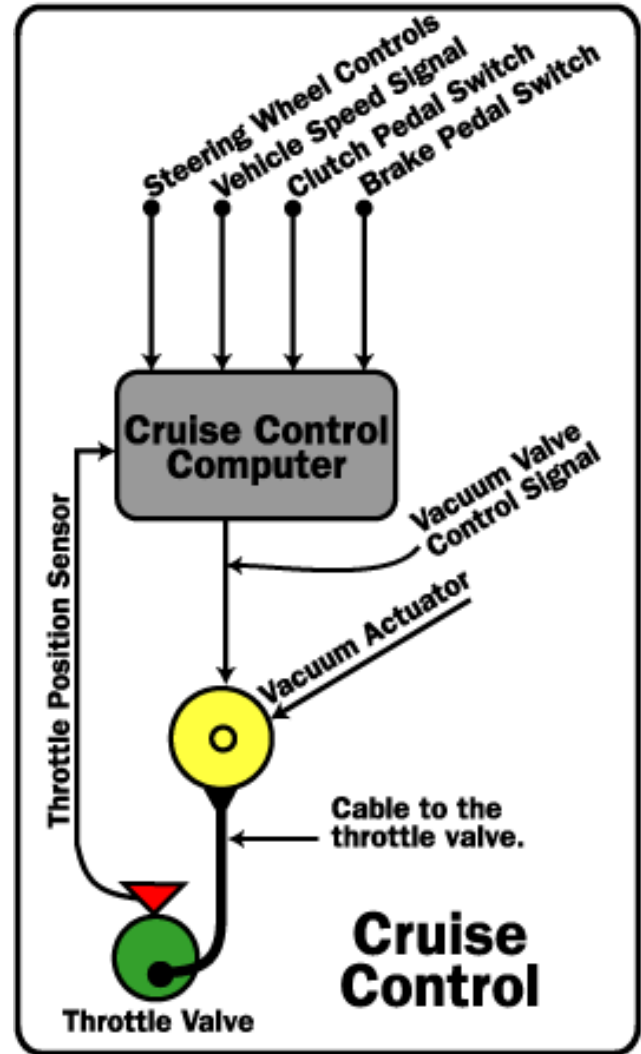
<http://auto.howstuffworks.com/cruise-control3.htm>



Cables



Electronically-controlled  
Vacuum actuator



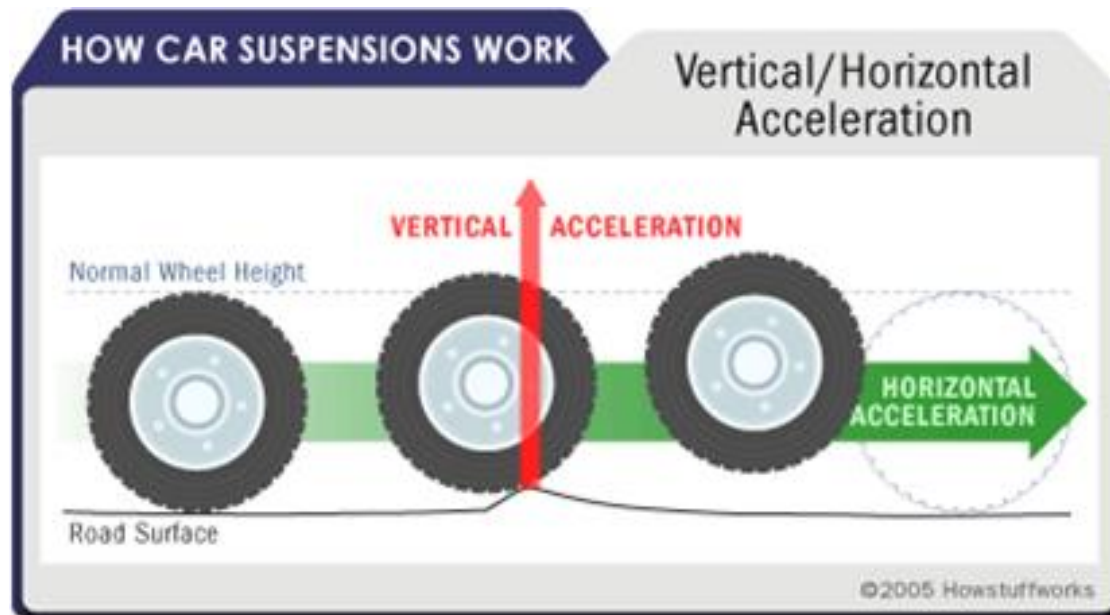
# Other examples

- Anti-lock braking system (ABS)
  - Major components of the typical ABS system
    - four speed sensors (one at each wheel)
    - electronic control unit (ABS computer)



# Other examples

- Vehicle suspension system
  - a system that will absorb the energy of the vertically accelerated wheel, allowing the frame and body to ride undisturbed while the wheels follow bumps in the road



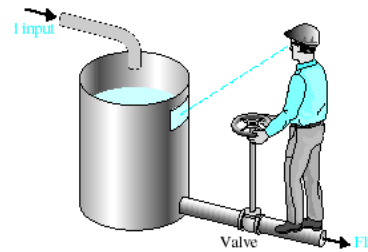
# Types of Control System

- Natural Control System
  - Universe
  - Human Body
- Manmade Control System
  - Vehicles
  - Aeroplanes



# Types of Control System

- Manual Control Systems
  - Room Temperature regulation Via Electric Fan
  - Water Level Control

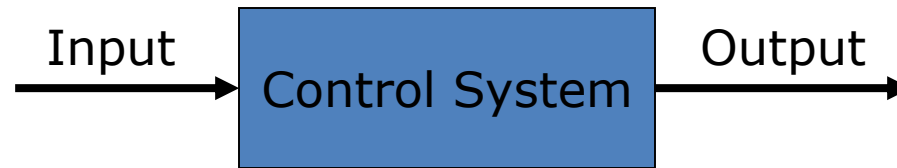


- Automatic Control System
  - Room Temperature regulation Via A.C
  - Human Body Temperature Control

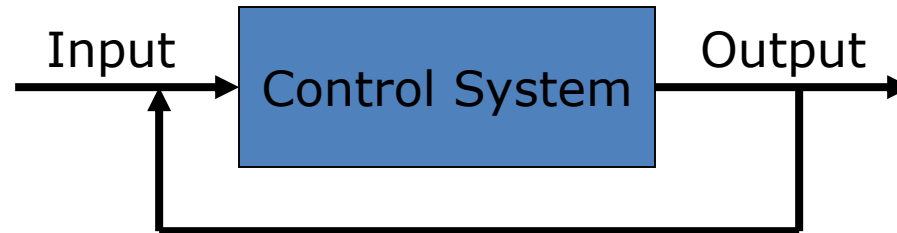
# Type of systems

Control system configuration can be categorized into two:

1) Open-Loop



2) Closed-Loop

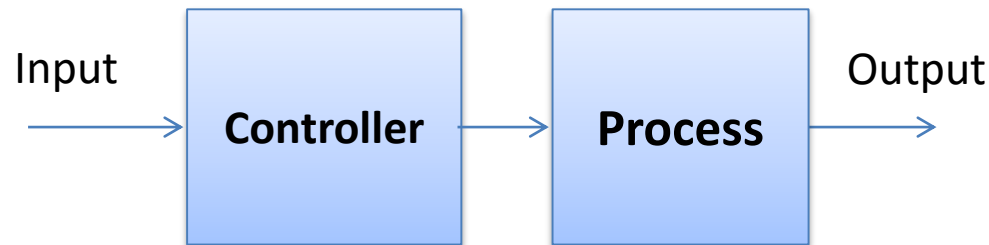


# Types of Control System

## Open-Loop Control Systems

**Open-Loop Control Systems** utilize a controller or control actuator to obtain the desired response.

- Output has no effect on the control action.
- In other words output is neither measured nor fed back.



Open-loop control system (without feedback).

**Examples:- Washing Machine, Toaster, Electric Fan**

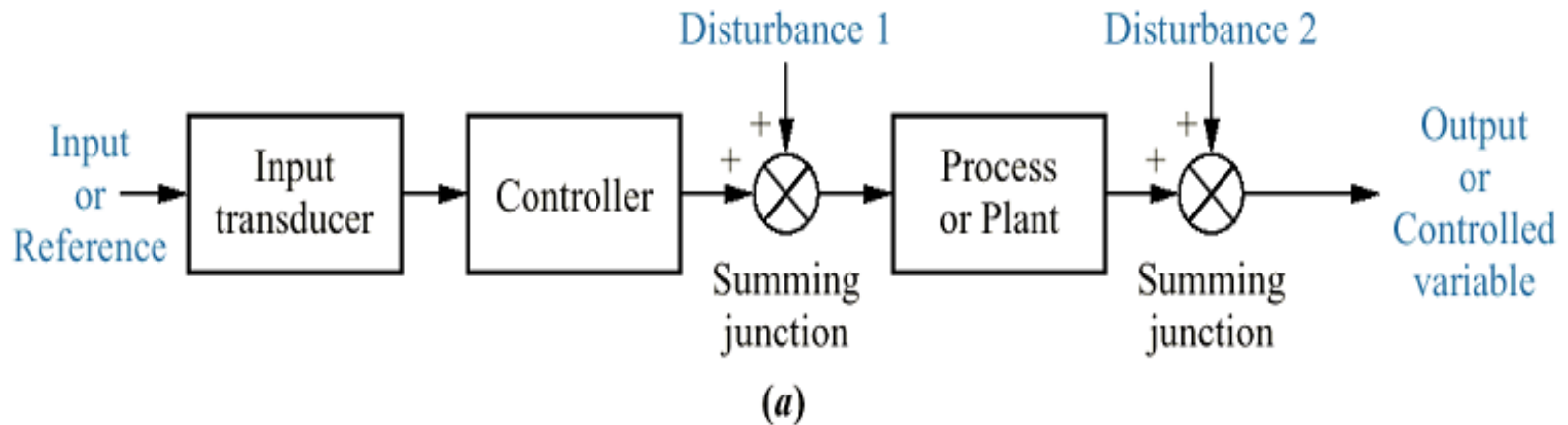
# Types of Control System

## Open-Loop Control Systems

- Since in open loop control systems reference input is not compared with measured output, for each reference input there is fixed operating condition.
- Therefore, the accuracy of the system depends on calibration.
- The performance of open loop system is severely affected by the presence of disturbances, or variation in operating/ environmental conditions.

# Type of systems

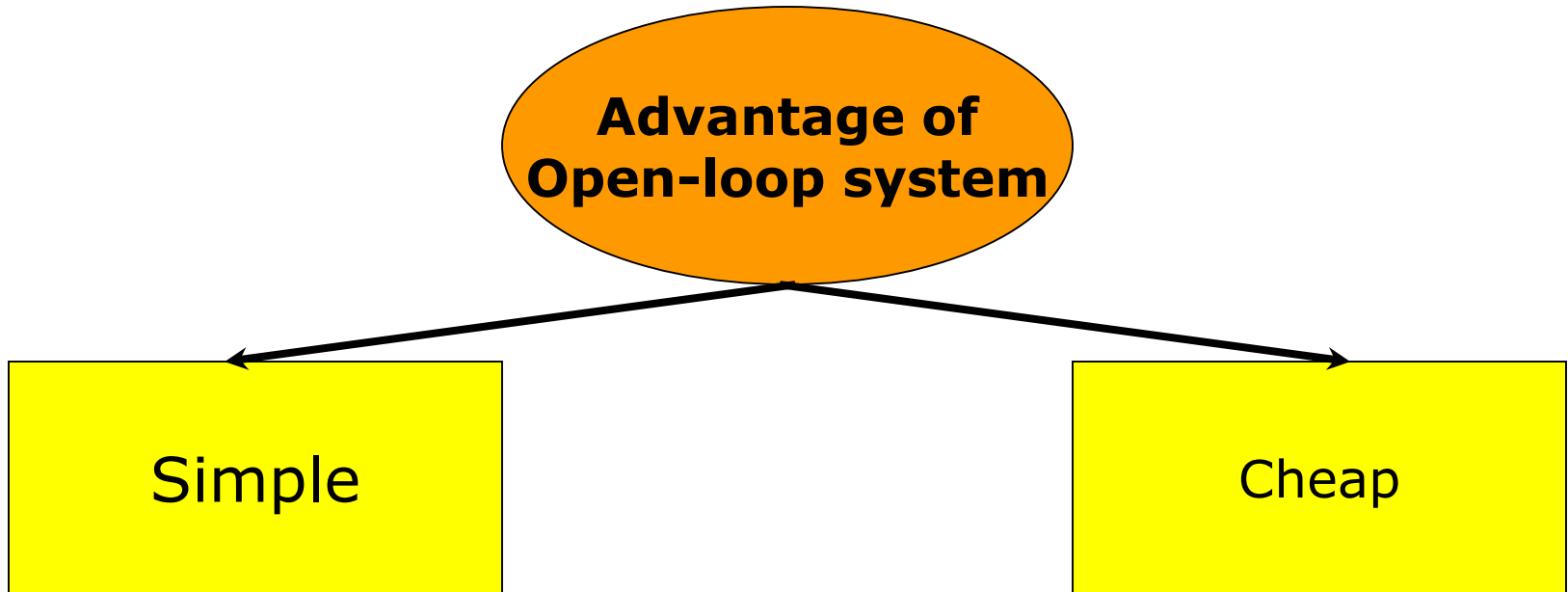
## Open-loop system



A generic open-loop system

# Type of systems

## Open-loop system



# Type of systems

## Open-loop system

**Disadvantage of  
Open-loop system**



```
graph TD; A([Disadvantage of Open-loop system]) --> B[Sensitive to disturbance]; A --> C[Inability to correct for disturbance]; B --> D[Solution]; C --> D;
```

Sensitive to  
disturbance

Inability to correct  
for disturbance

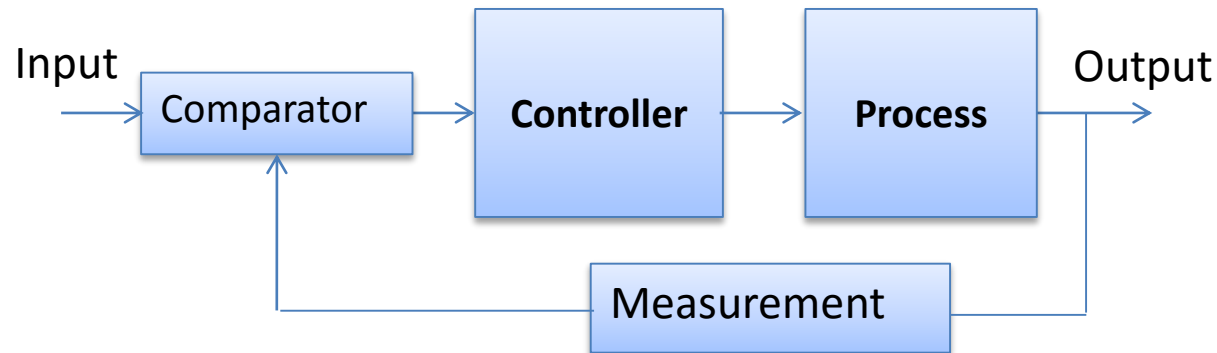
## **Solution**

Use closed-loop system

# Types of Control System

## Closed-Loop Control Systems

**Closed-Loop Control Systems** utilizes feedback to compare the actual output to the desired output response.



Closed-loop feedback control system (with feedback).

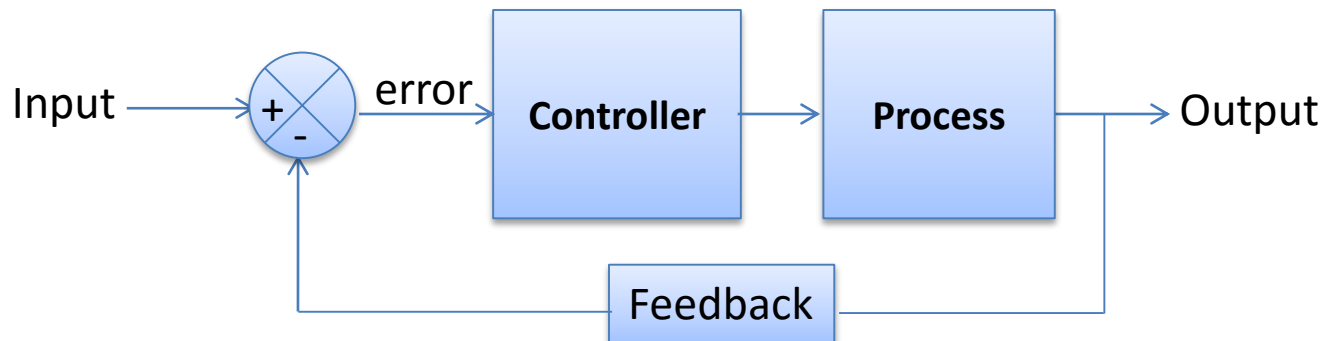
**Examples:- Refrigerator, Iron**



# Types of Control System

## Feedback Control System

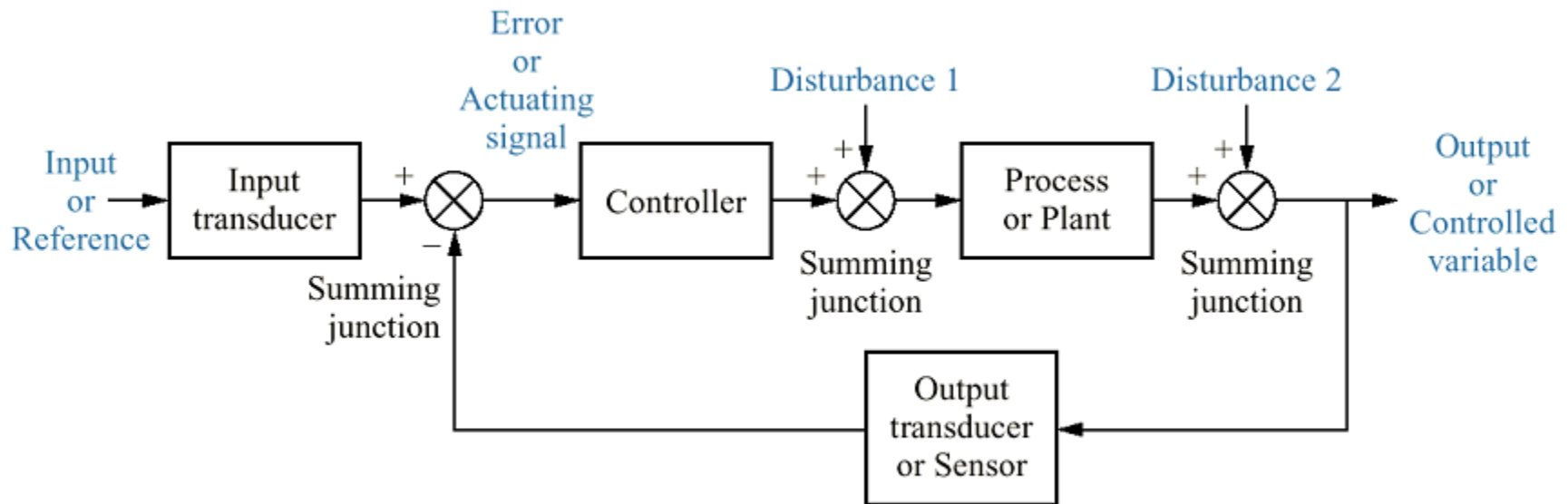
- A system that maintains a prescribed relationship between the output and some reference input by comparing them and using the difference (i.e. error) as a means of control is called a feedback control system.



- Feedback can be positive or negative.

# Type of systems

## Closed-loop system

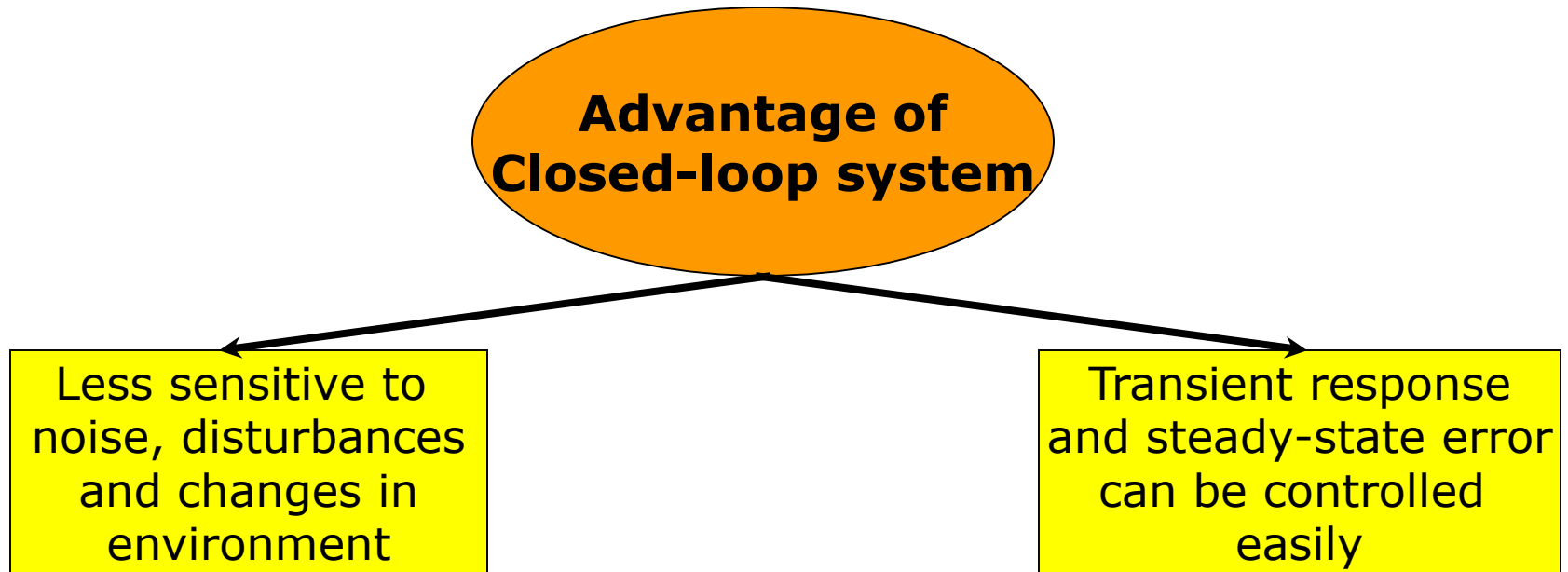


(b)

A generic closed-loop system

# Type of systems

## Closed-loop system



Transient response and steady-state error can be controlled by redesigning the controller. The process of redesigning is called *compensating* the system and the resulting hardware is a *compensator*

# Type of systems

## Closed-loop system

**Disadvantage of  
Closed-loop system**

```
graph TD; A([Disadvantage of Closed-loop system]) --> B[More complex]; A --> C[More expensive];
```

More complex

More expensive

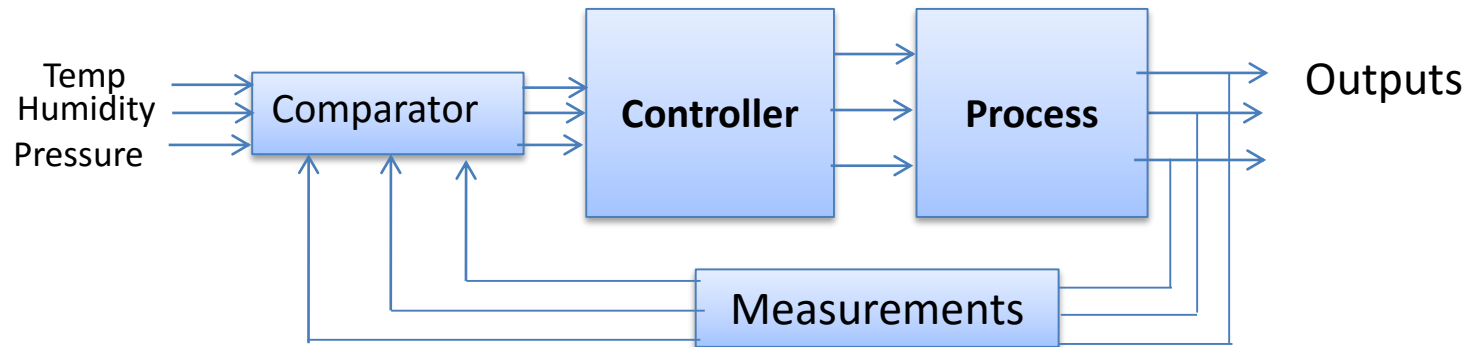
# Type of systems

## Open loop vs. Closed-loop system

- How do we choose OL or CL?
  - Criticality of application
    - The need to monitor output
    - The need to control the output
    - The need for reduced error or zero error
    - Cost / budget
    - Safety

# Types of Control System

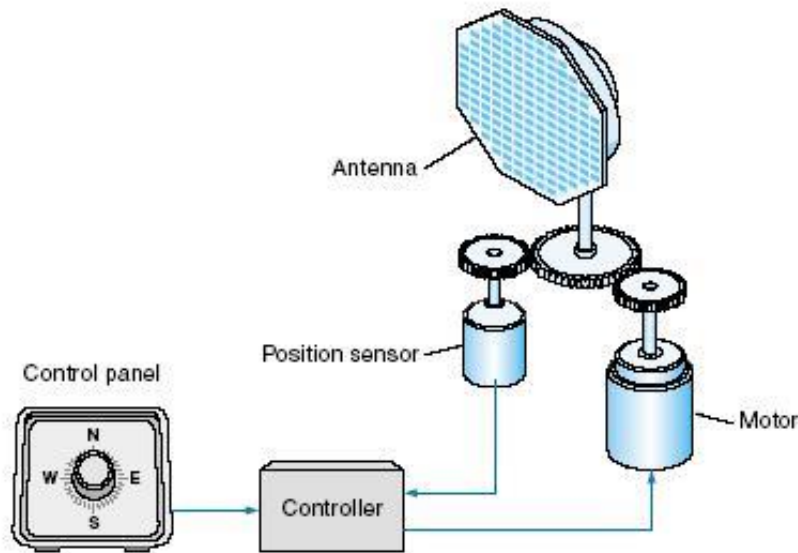
## Multivariable Control System



# Types of Control System

## Servo System

- A Servo System (or servomechanism) is a feedback control system in which the output is some mechanical position, velocity or acceleration.



Antenna Positioning System

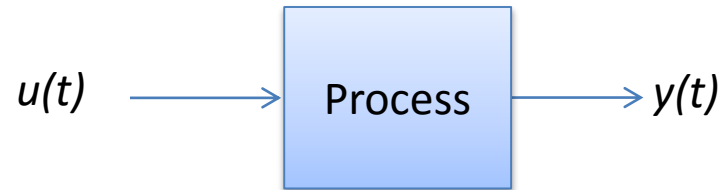


Modular Servo System (MS150)

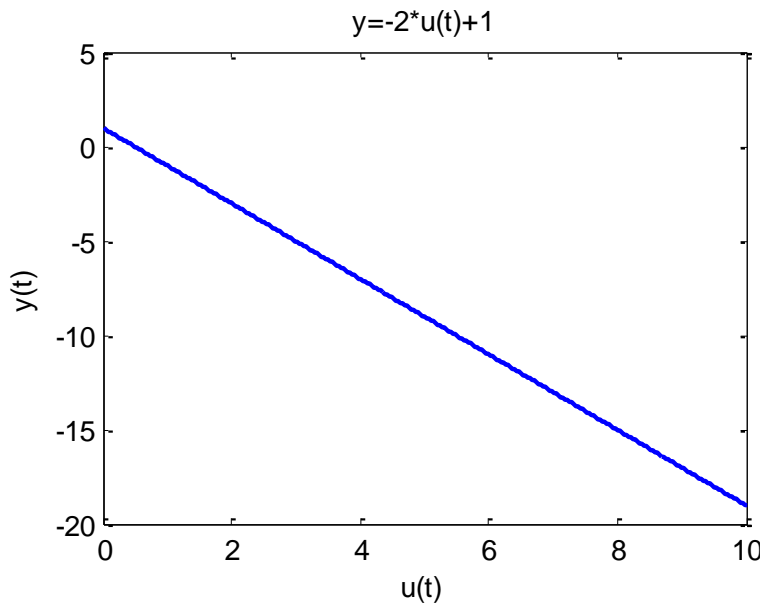
# Types of Control System

## Linear Vs Nonlinear Control System

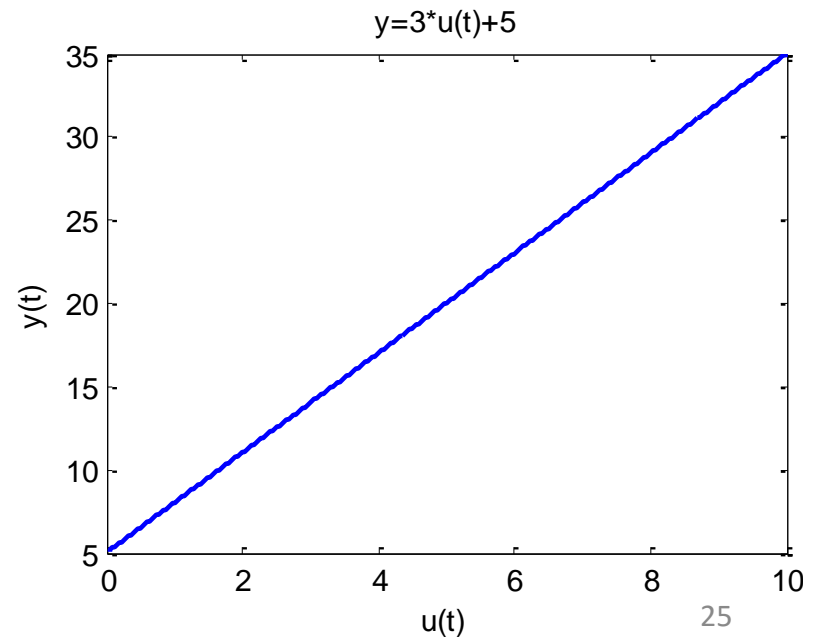
- A Control System in which output varies linearly with the input is called a linear control system.



$$y(t) = -2u(t) + 1$$



$$y(t) = 3u(t) + 5$$

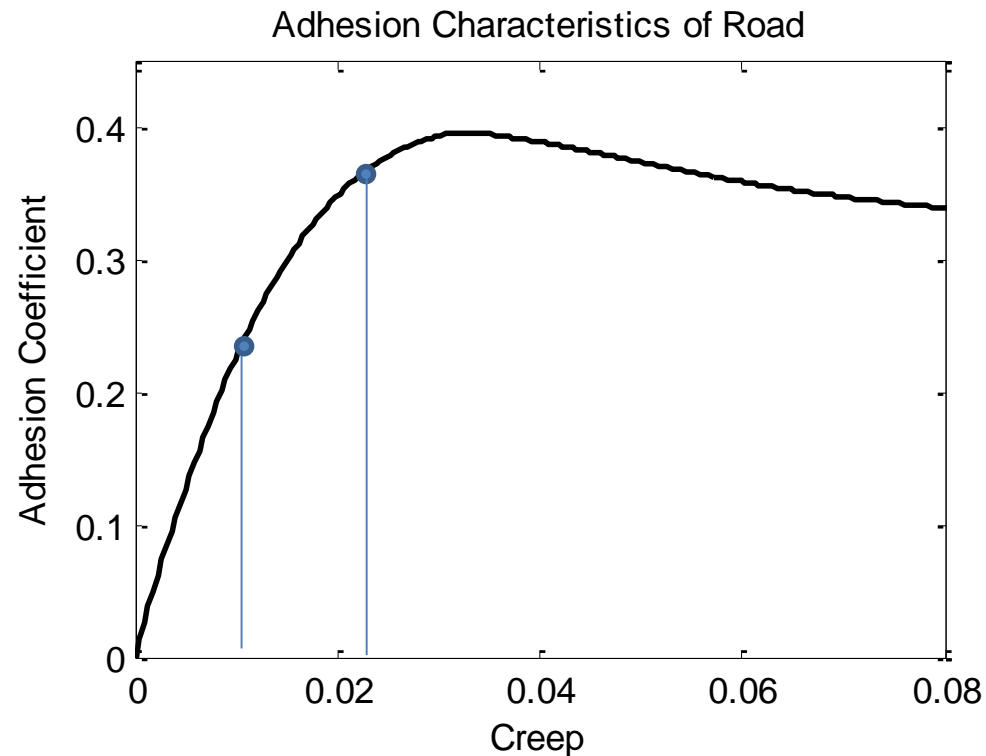




# Types of Control System

## Linear Vs Nonlinear Control System

- Linear control System Does not exist in practice.
- Linear control systems are idealized models fabricated by the analyst purely for the simplicity of analysis and design.
- When the magnitude of signals in a control system are limited to range in which system components exhibit linear characteristics the system is essentially linear.



# Types of Control System

## Time invariant vs Time variant

- When the characteristics of the system do not depend upon time itself then the system is said to time invariant control system.

$$y(t) = -2u(t) + 1$$

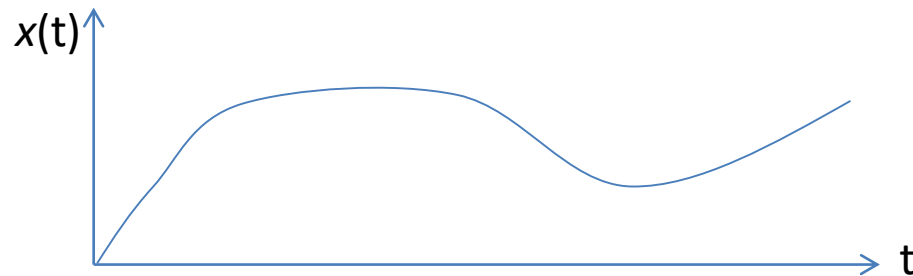
- Time varying control system is a system in which one or more parameters vary with time.

$$y(t) = 2u(t) - 3t$$

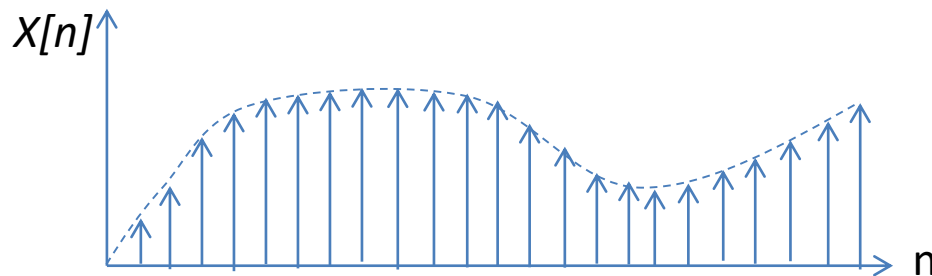
# Types of Control System

## Continuous Data Vs Discrete Data System

- In continuous data control system all system variables are function of a continuous time  $t$ .



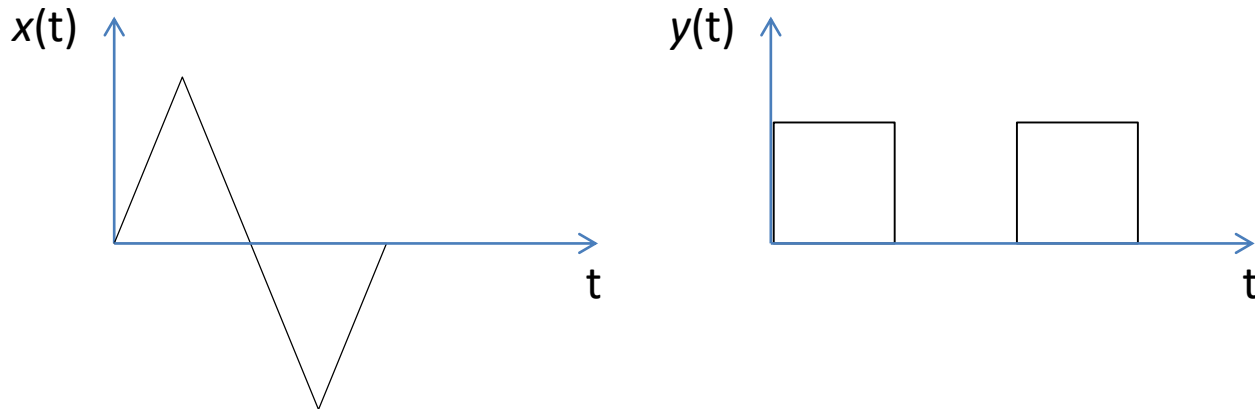
- A discrete time control system involves one or more variables that are known only at discrete time intervals.



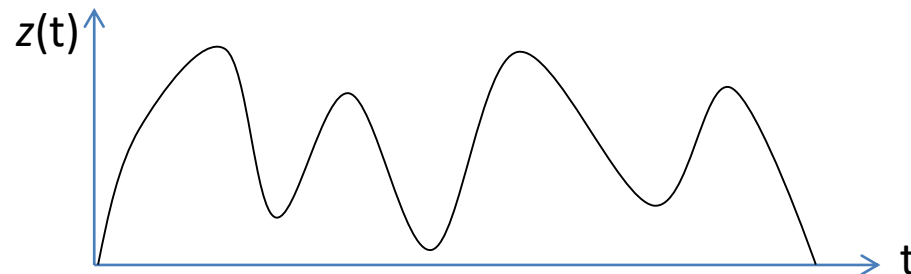
# Types of Control System

## Deterministic vs Stochastic Control System

- A control System is deterministic if the response to input is predictable and repeatable.



- If not, the control system is a stochastic control system



# Types of Control System

## Adaptive Control System

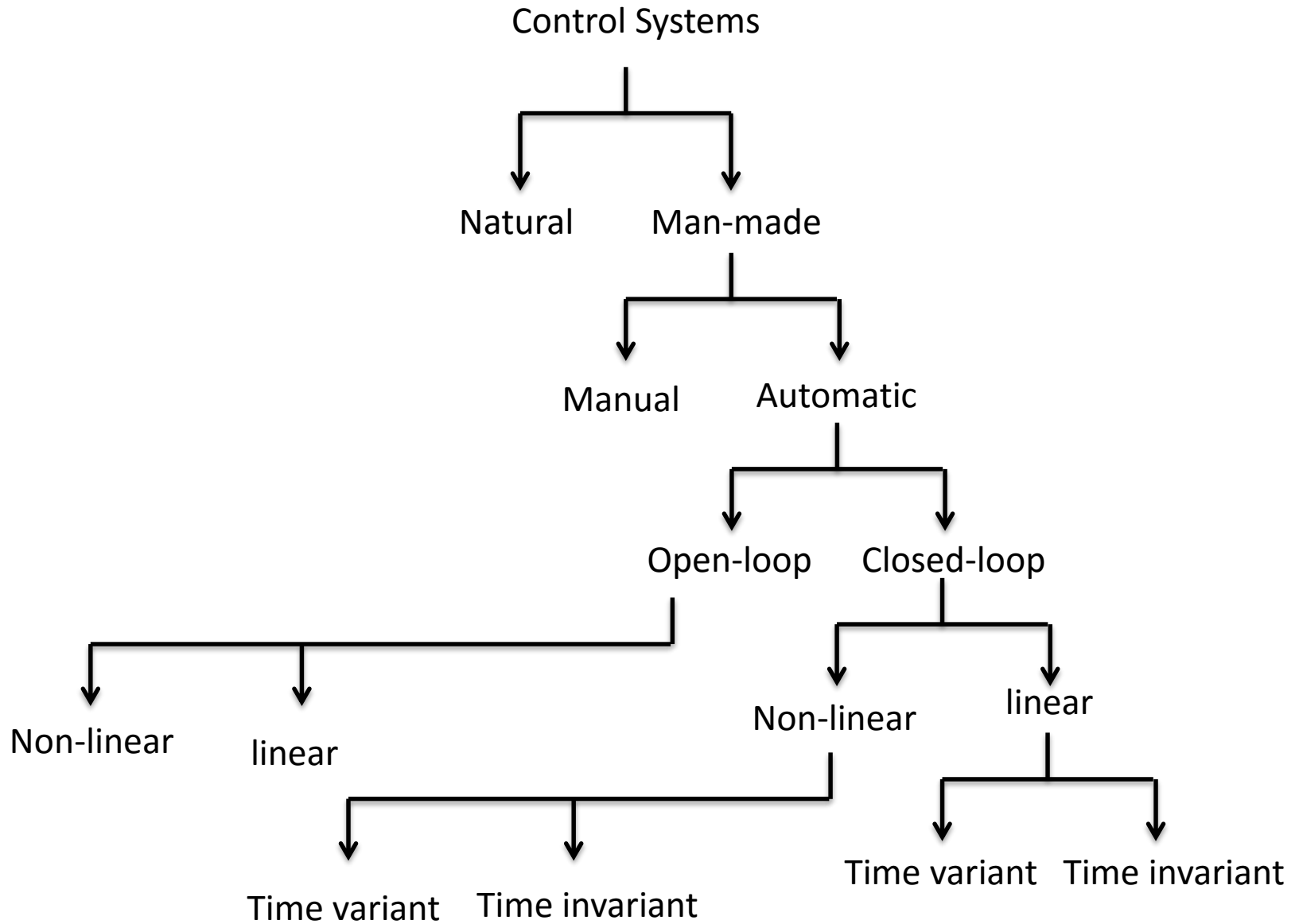
- The dynamic characteristics of most control systems are not constant for several reasons.
- The effect of small changes on the system parameters is attenuated in a feedback control system.
- An adaptive control system is required when the changes in the system parameters are significant.

# Types of Control System

## Learning Control System

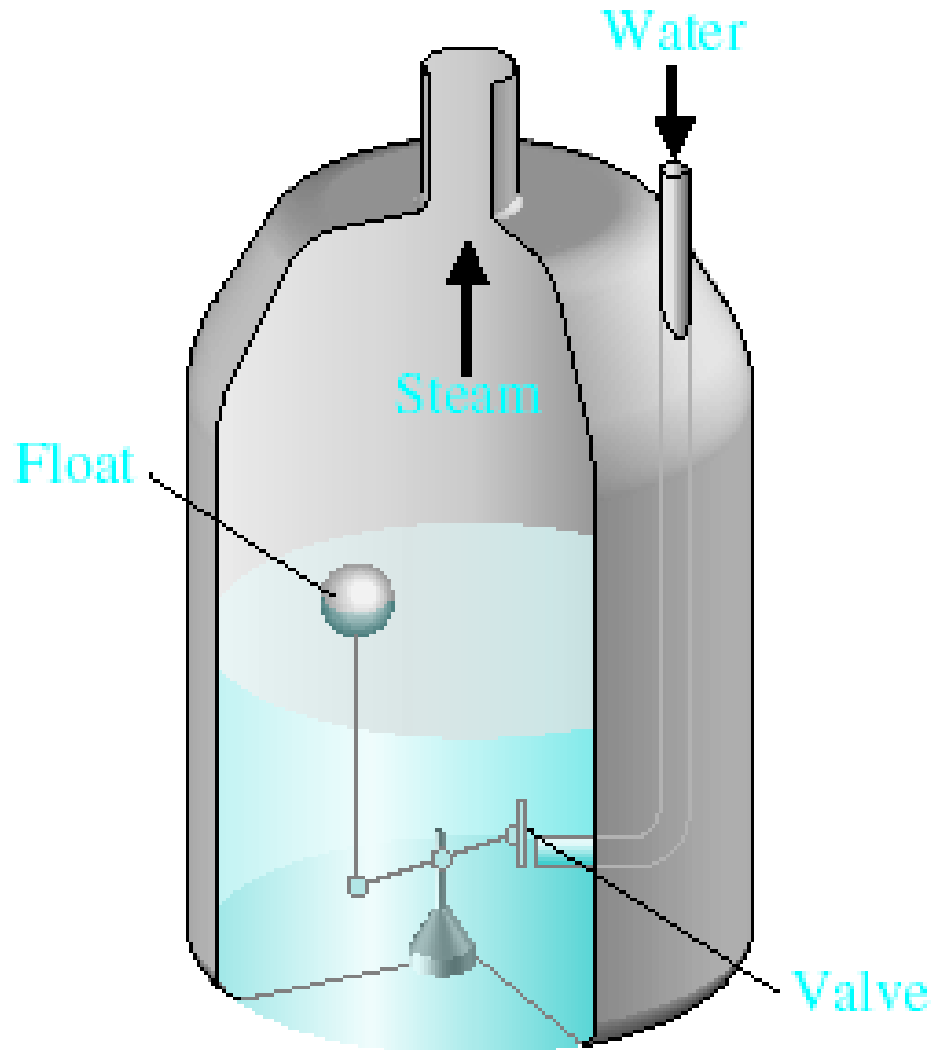
- A control system that can learn from the environment it is operating is called a learning control system.

# Classification of Control Systems



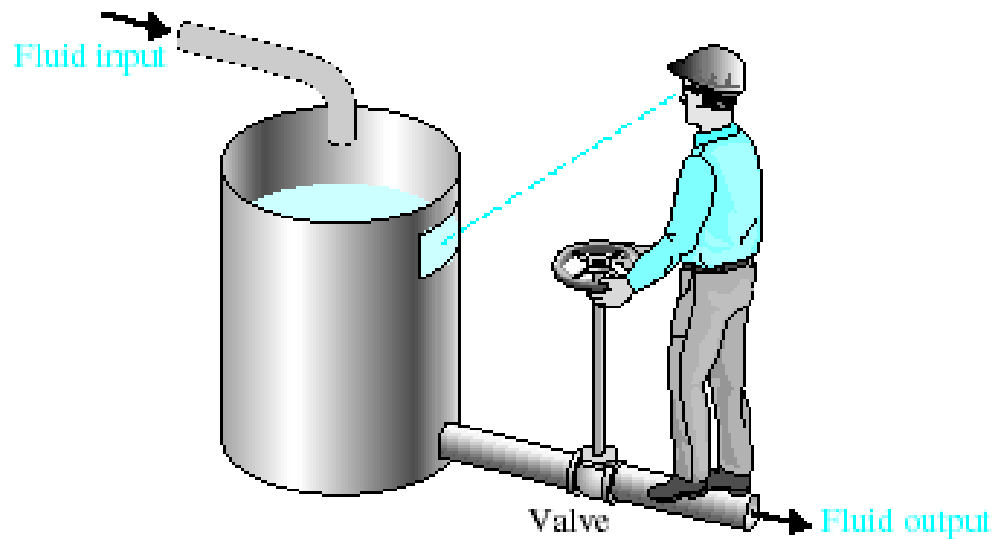
# Examples of Control Systems

Water-level float regulator



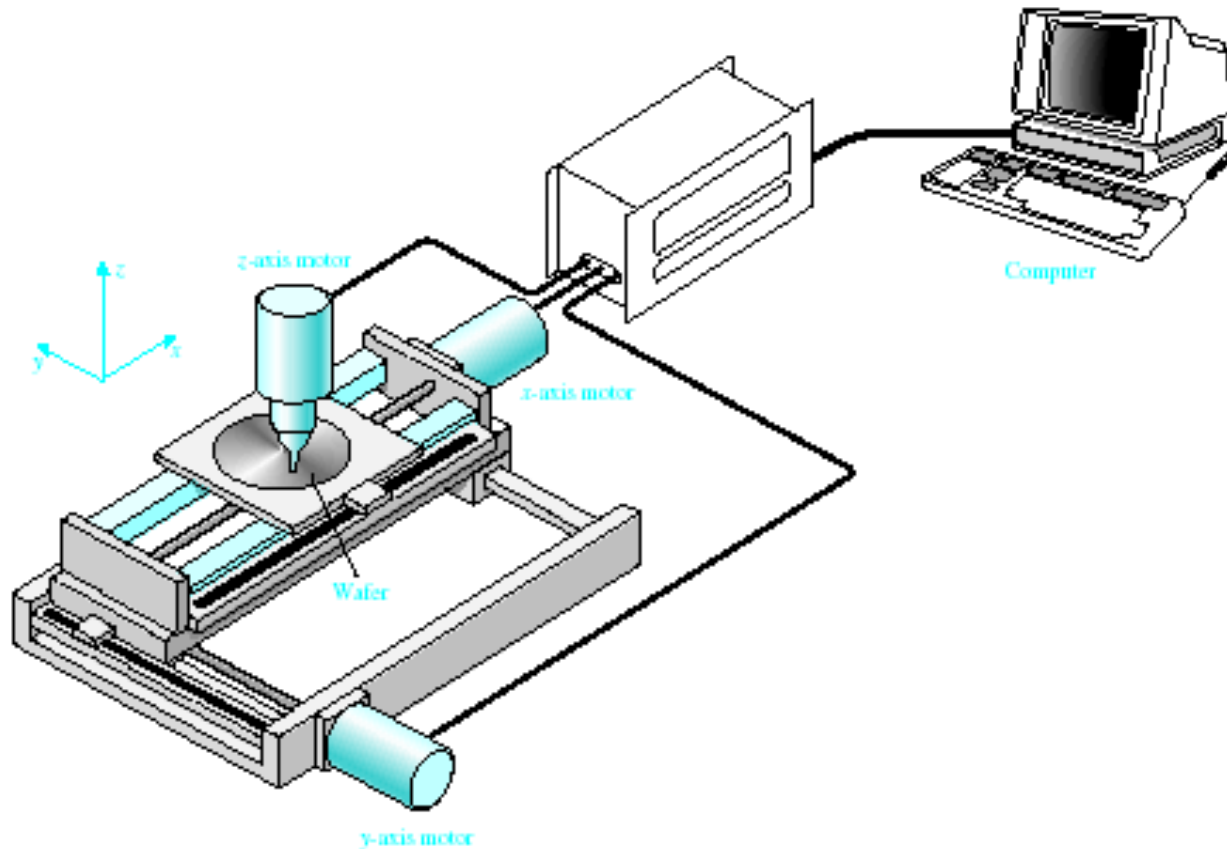


# Examples of Control Systems



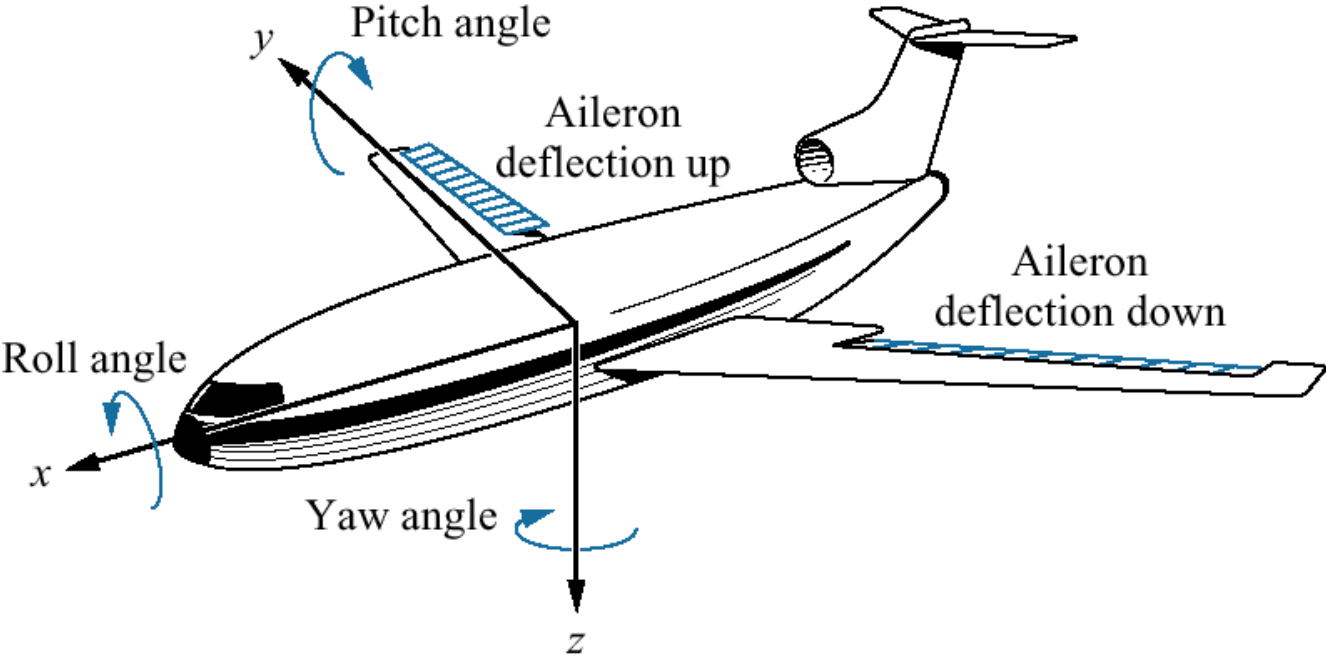
A manual control system for regulating the level of fluid in a tank by adjusting the output valve. The operator views the level of fluid through a port in the side of the tank.

# Examples of Modern Control Systems



A three-axis control system for inspecting individual semiconductor wafers with a highly sensitive camera.

# Examples of Modern Control Systems



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