In The Name of God The Most Compassionate, The Most Merciful

Linear Control Systems

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References

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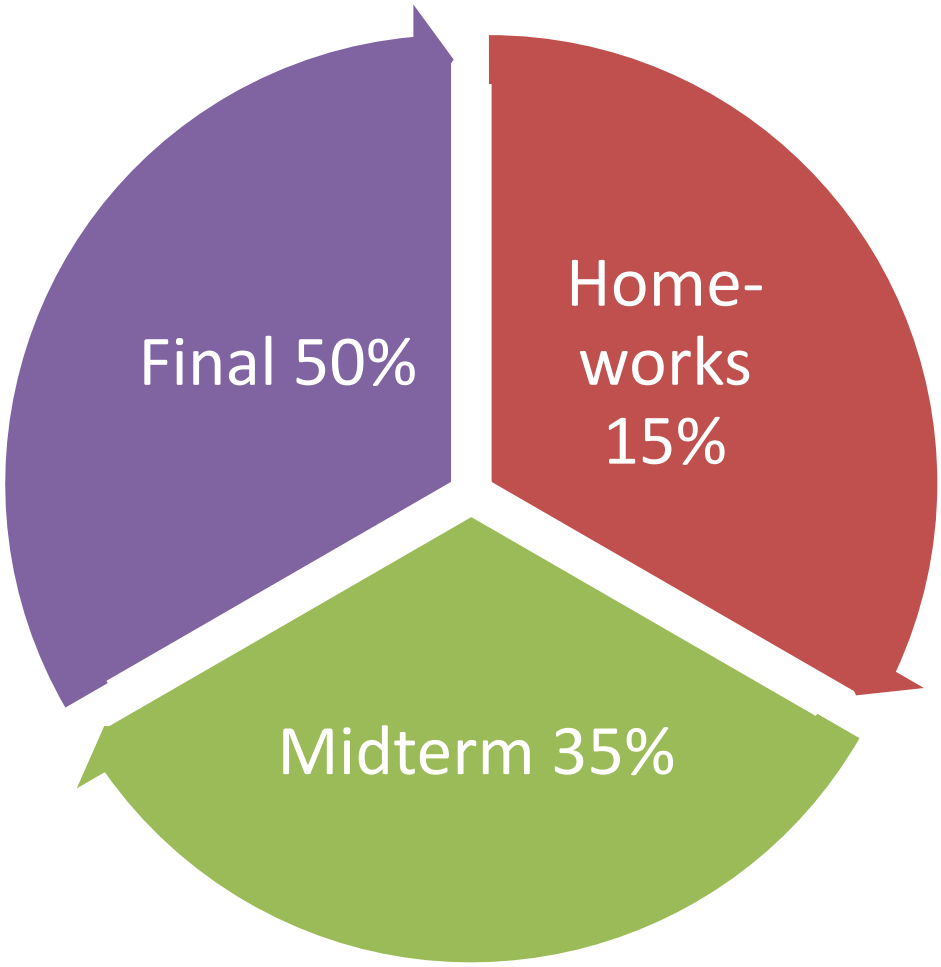
Evaluation



Chapter 1
Introduction to Control Systems

1.1. Control Principle

1.2. Definitions

1.3. Examples of Control Systems

1.4. Closed-loop versus Open-loop Control

1.5. Design of Control Systems

Control Principle

Automatic control is an important part of today's life.

In addition to its importance in space-vehicle systems, missile guidance systems and robotic systems, automatic control plays a crucial role in manufacturing and industrial processes.

For example, automatic control is essential in

- Numerical control of machine tools in the manufacturing industries
- Design of autopilot systems in aerospace industries
- Design of cars and trucks in automobile industries
- Controlling pressure, temperature, humidity, viscosity and flow in process industries

Definitions

Plant	is any physical object to be controlled such as a chemical reactor, a spacecraft or a heating furnace.
Process	is any operation to be controlled such as chemical, economical or biological processes.
System	is a combination of components that act together and perform a certain objective.
Controlled variable	is the quantity that is measured and controlled. It is normally the **output of the plant**.
Manipulated variable	is the quantity that is varied by the controller so that to affect the value of the controlled variable. It is normally the **input of the plant** and the **output of the controller**.

Definitions

Reference input	is the value or a trajectory which the output of the system should follow. It is also known as **set-point** or **desired output**.
System error	is the difference between the reference input and the corresponding controlled variable.
Disturbance	is a signal that tends to adversely affect the value of the output of a system.
Controller	is a component which generate manipulated variables so that the system error is reduced.
Feedback control	refers to an operation that, in the presence of disturbances, tends to reduce the difference between the output of a system and a reference input.

Definitions

Linear system	is a system in which superposition theorem is held. In other words the system should have additive and homogenous properties.
Nonlinear system	is a system in which superposition theorem is NOT held.
Time-invariant system	is a system in which the parameters and characteristics do NOT change with time.
Time-varying system	is a system in which at least one parameter or characteristic varies with time.
Continuous-time system	is a system in which the signals are continuous function of time.

Definitions

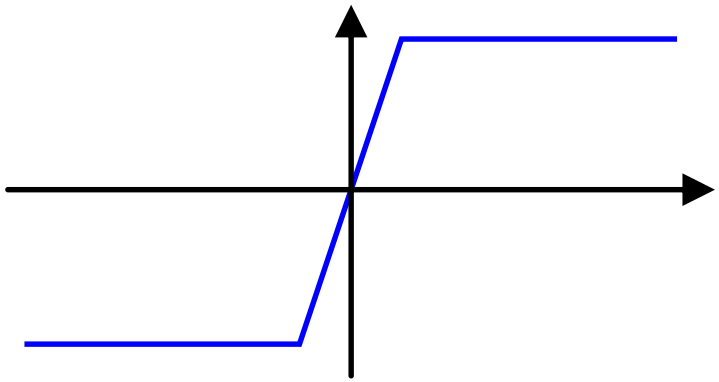
Discrete-time system	is a system in which the signals appear in discrete time.
Tracking system	is a system in which the output should follow a trajectory (varying) reference signal.
Regulator	is a system in which the output should reach a constant reference signal.
Open-loop control	is a system in which the output has no influence on the input signals.
Closed-loop control	is a system in which the output affects the input signals.

SISO vs. MIMO

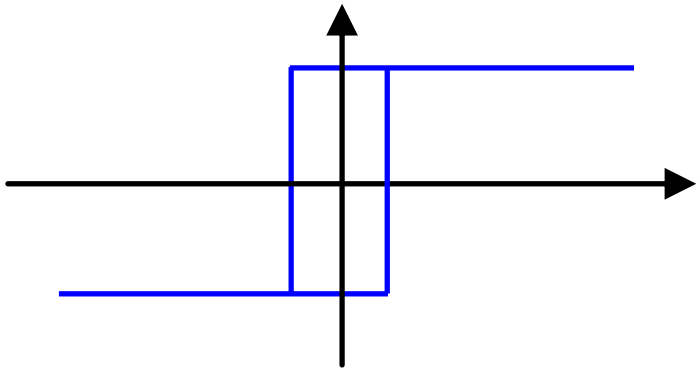
Depending on the number of inputs and number of outputs, a system can be classified as

- Single-input single-output systems (SISO)
- Single-input multiple-output systems (SIMO)
- Multiple-input single-output systems (MISO)
- Multiple-input multiple-output systems (MIMO)

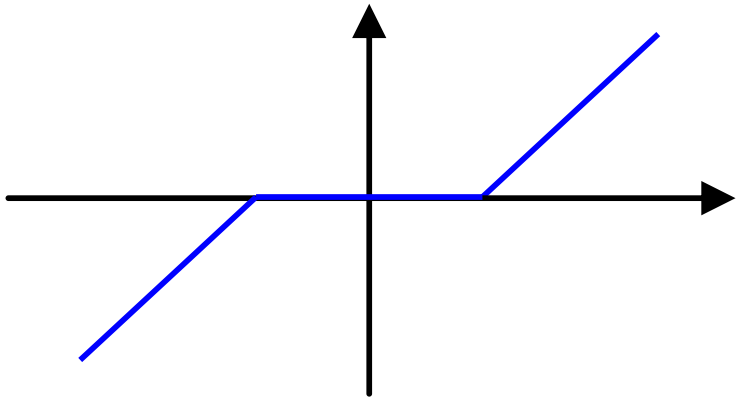
Some Nonlinear Phenomena



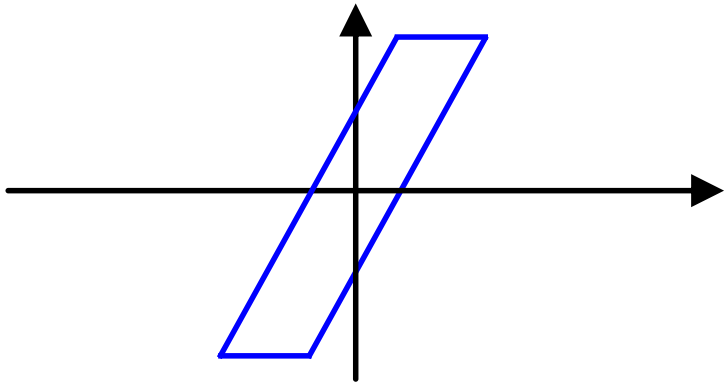
Saturation



Hysteresis



Dead-zone



Backlash

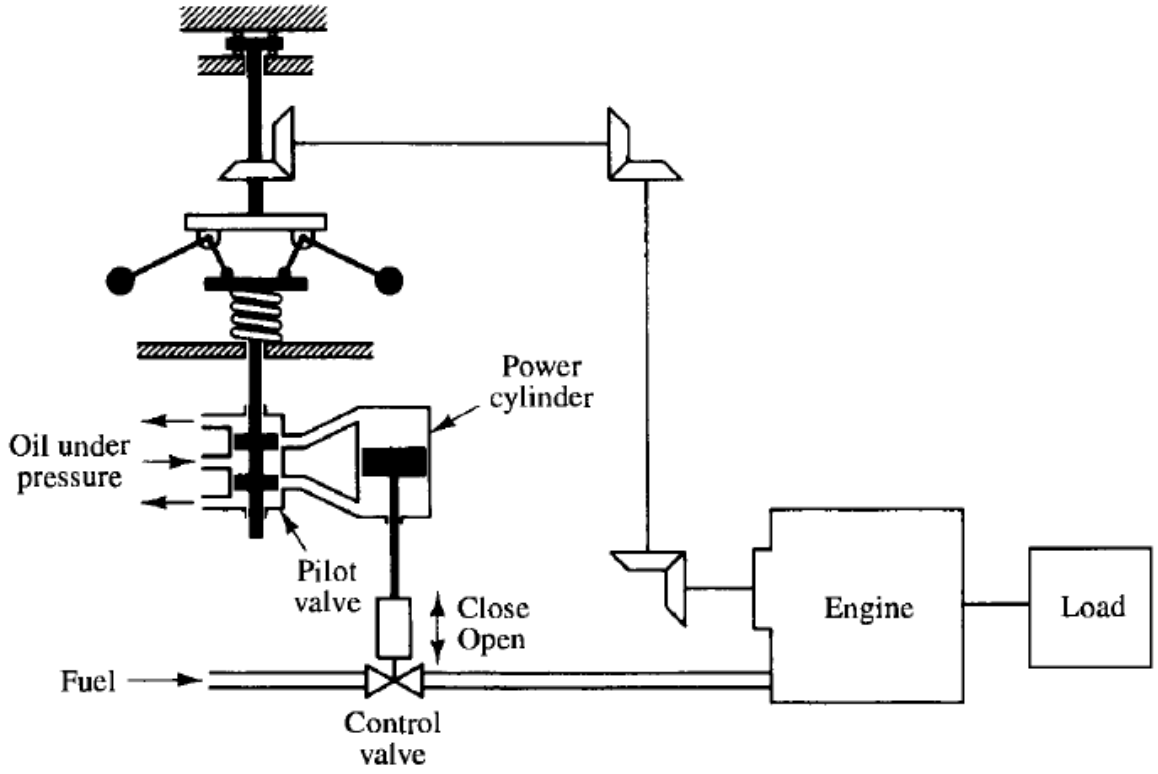
Focus

The focus of this course is on **linear**, **time-invariant** and **continuous-time** systems

Examples of Control Systems

1. Speed Control System of an Engine

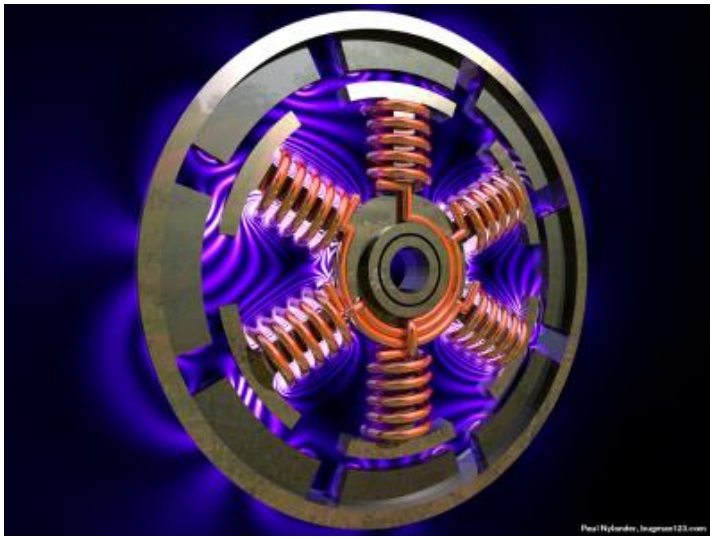
- **Plant** is the **engine**
- **Controlled variable** is **speed**
- **Manipulated variable** is the **fuel**

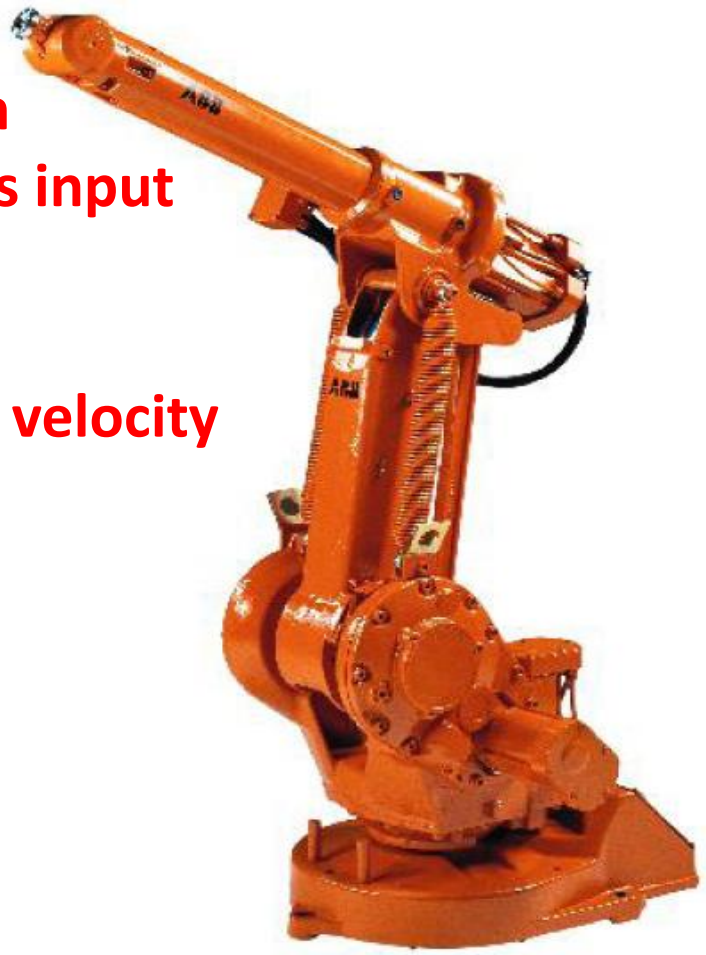


Examples of Control Systems

2. Robot System

- **Plant** is the **robot arm**
- **Controlled variable** is the **tip position**
- **Manipulated variable** is the **actuators input**
- **Actuators** can be **electric motors**
- **Actuator input** is **voltage/current**
- **Actuator output** is **torque/rotational velocity**





Examples of Control Systems

3. Aircraft Flight Control

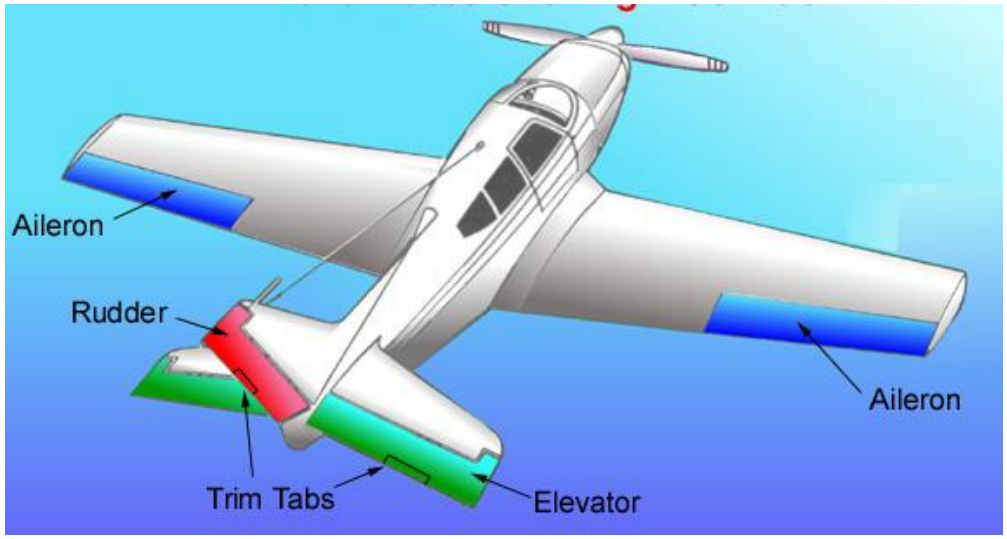
- **Plant** is the **aircraft**
- **Controlled variables** are the **Thrust and orientation** of the aircraft
- **Manipulated variables** are the **fuel flow rate, control surfaces commands**

Orientations are expressed by:

- Pitch
- Roll
- Yaw

Control surfaces are:

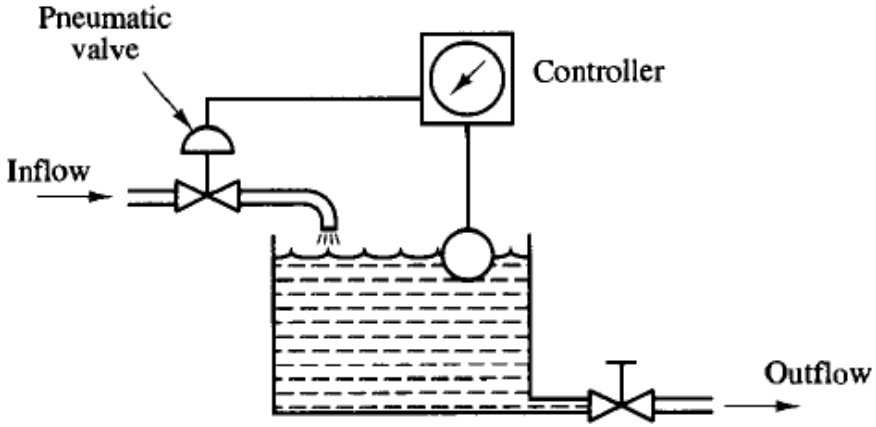
- Elevator
- Aileron
- Rudder

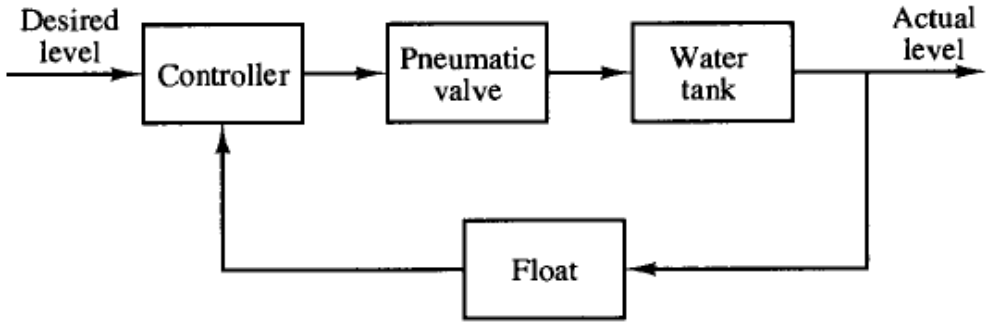


Examples of Control Systems

4. Liquid Level Control System

- **Plant** is the **water tank**
- **Controlled variable** is **level**
- **Manipulated variable** is the **position of the valve**





Closed-loop vs. Open-loop Control

Feedback Control System

A feedback control system

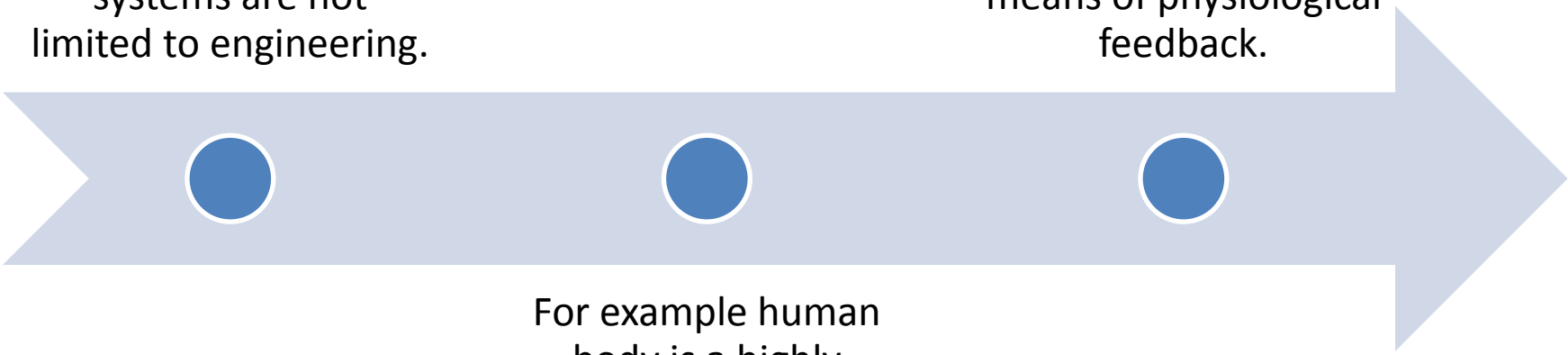
- maintains a prescribed relationship between the output and the reference input by comparing them and
- using the difference as a means of control.

An example would be a room-temperature control system

- By measuring the actual room temperature and
- comparing it with the reference temperature (desired temperature
- The thermostat turns the heating or cooling equipment on or off
- so that to ensure that the room temperature remains at a comfortable level
- Regardless of outside temperature.

Closed-loop vs. Open-loop Control

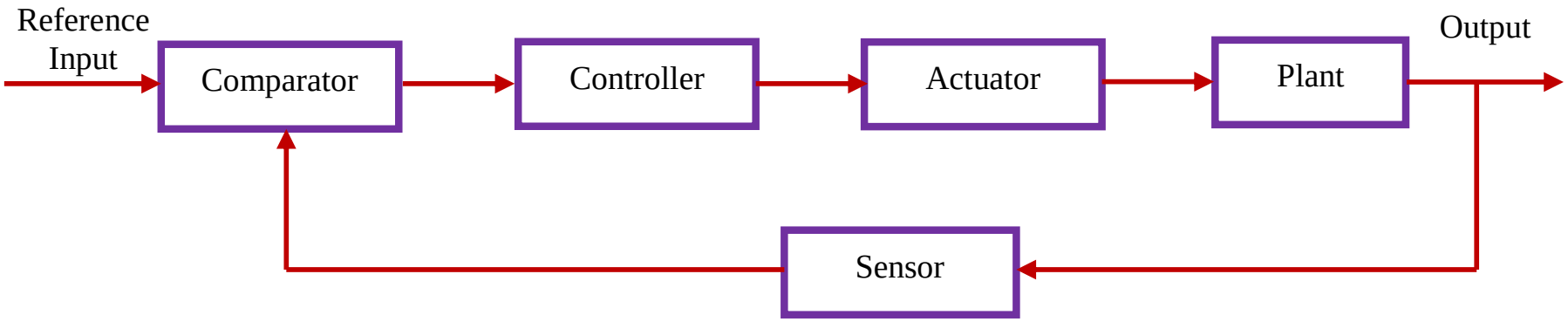
Feedback Control System



Closed-loop vs. Open-loop Control

Closed-loop Control Systems

- Feedback control systems are often referred to as closed-loop control systems.
- In practice, the terms feedback control and closed-loop control are used interchangeably.



Closed-loop vs. Open-loop Control

Open-loop Control System

- Those systems in which the output has no effect on the control action are called open-loop control systems.

- In an open-loop control system the output is neither measured nor fed back for comparison with the input.

- One practical example is a washing machine. Soaking, washing and rinsing in the washer operate on a time basis. The machine does not measure the output signal, that is, the cleanliness of the cloths.