LINEAR CONTROL SYSTEM

UNIT – I

Introduction: Basic concept of simple control system – open loop – closed loop control systems. Effect of feedback on overall gain – stability sensitivity and external noise.

Types of feedback control systems – Liner time invariant, time variant systems and nonlinear control systems

Mathematical models and Transfer functions of Physical systems: Differential equations – impulse response and transfer functions – translational and rotational mechanical systems. Transfer functions and open loop and closed loop systems. Block diagram representation of control systems – block diagram algebra – signal flow graph – Mason's gain formula

Components of control systems: DC servo motor – AC servo motor – synchro transmitter & receiver

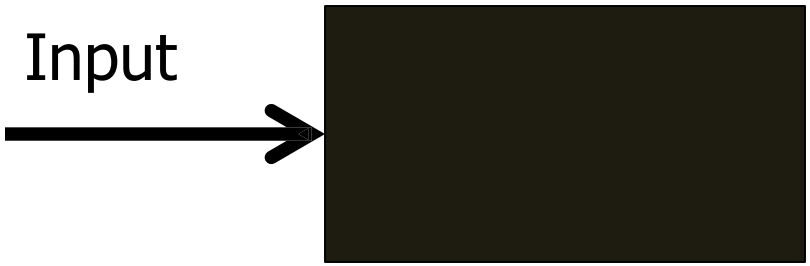
System :

A system is a interconnection of device or components to serve a purpose.

Control System:

A control system is a system of devices or set of devices, that manages, commands, directs or regulates the behavior of other devices or systems to achieve desired results.

Input

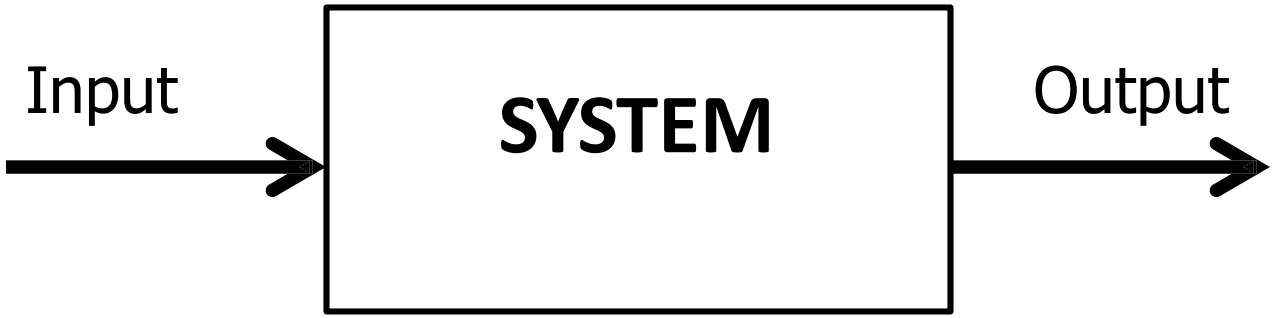


- The stimulus or excitation applied to a control system from an external source in order to produce the output is called input

Output

- The actual response obtained from a system is called output.

“System”



- A system is an arrangement of or a combination of different physical components connected or related in such a manner so as to form an entire unit to attain a certain objective.

Control

- It means to regulate, direct or command a system so that the desired objective is attained

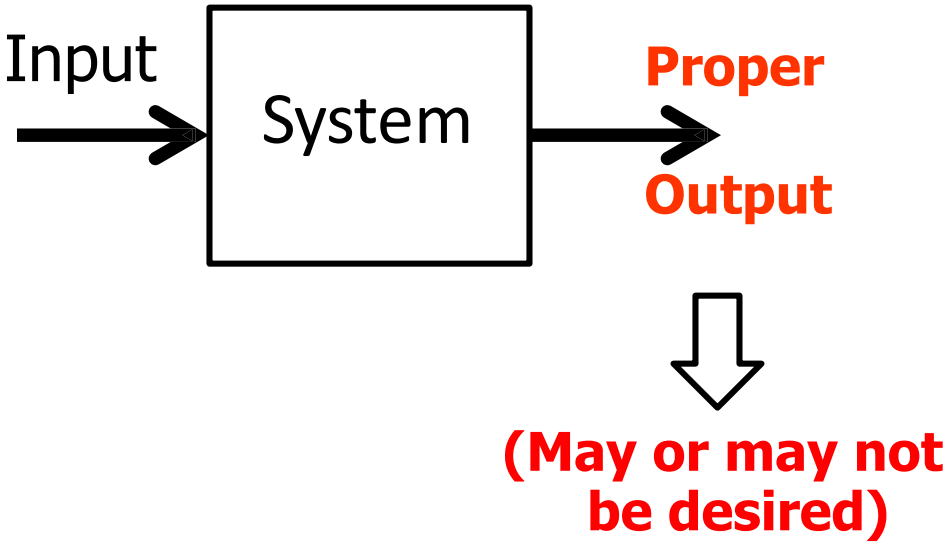
Combining above definitions

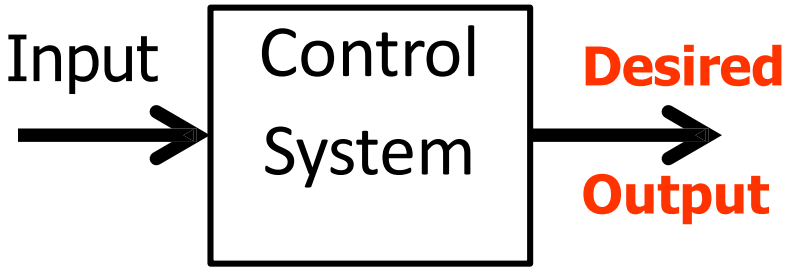
System + Control = Control System

Control System

- It is an arrangement of different physical elements connected in such a manner so as to regulate, direct or command itself to achieve a certain objective.

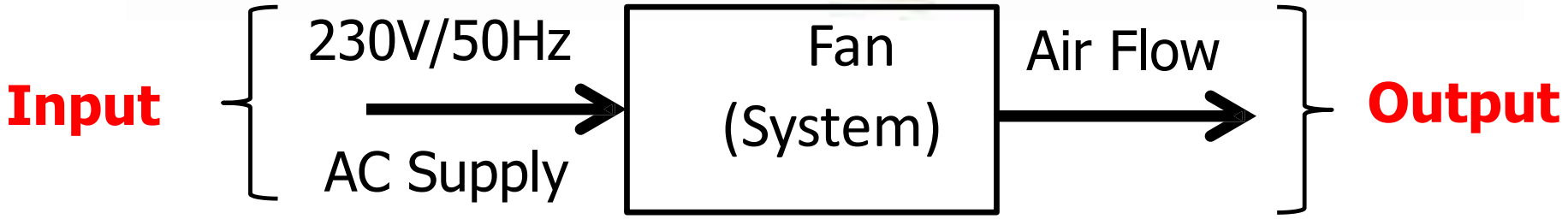
Difference between System and Control System





Difference between System and Control System

An example : Fan



A Fan: Can't Say System

- A Fan without blades cannot be a "SYSTEM"

  Because it cannot provide a desired/proper output

  i.e. airflow

Input

230V/50Hz

AC Supply

Output

No Airflow

(No Proper/ Desired Output)

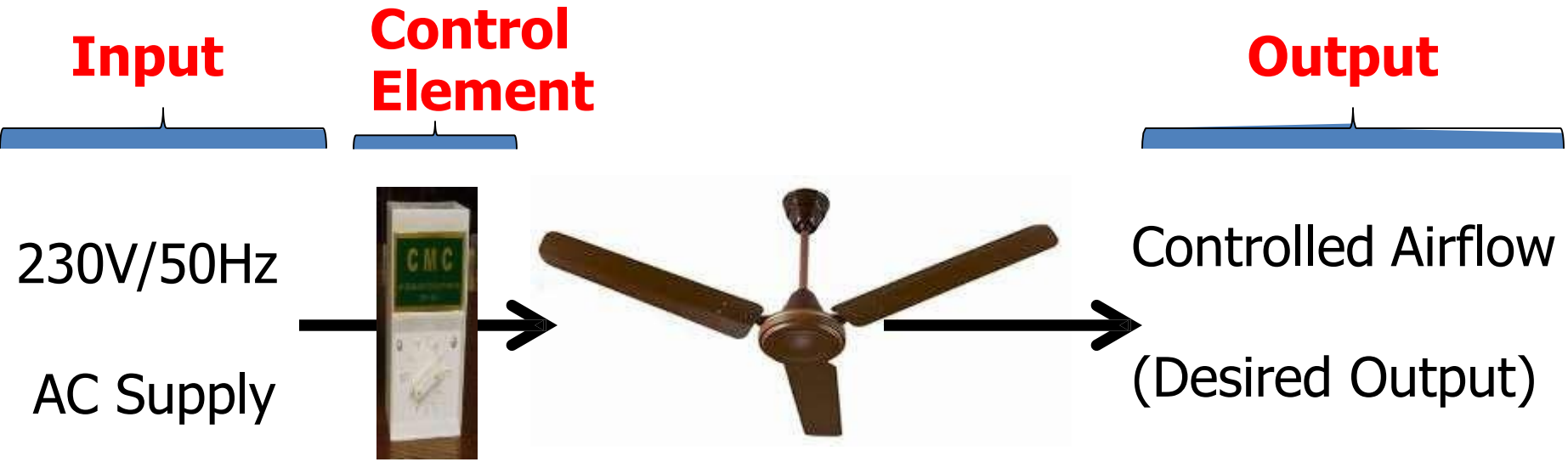
A Fan: Can be a System

- A Fan with blades but without regulator can be a "SYSTEM"
  Because it can provide a **proper output** i.e. airflow
- But it cannot be a "Control System" Because it cannot provide desired output i.e. controlled airflow

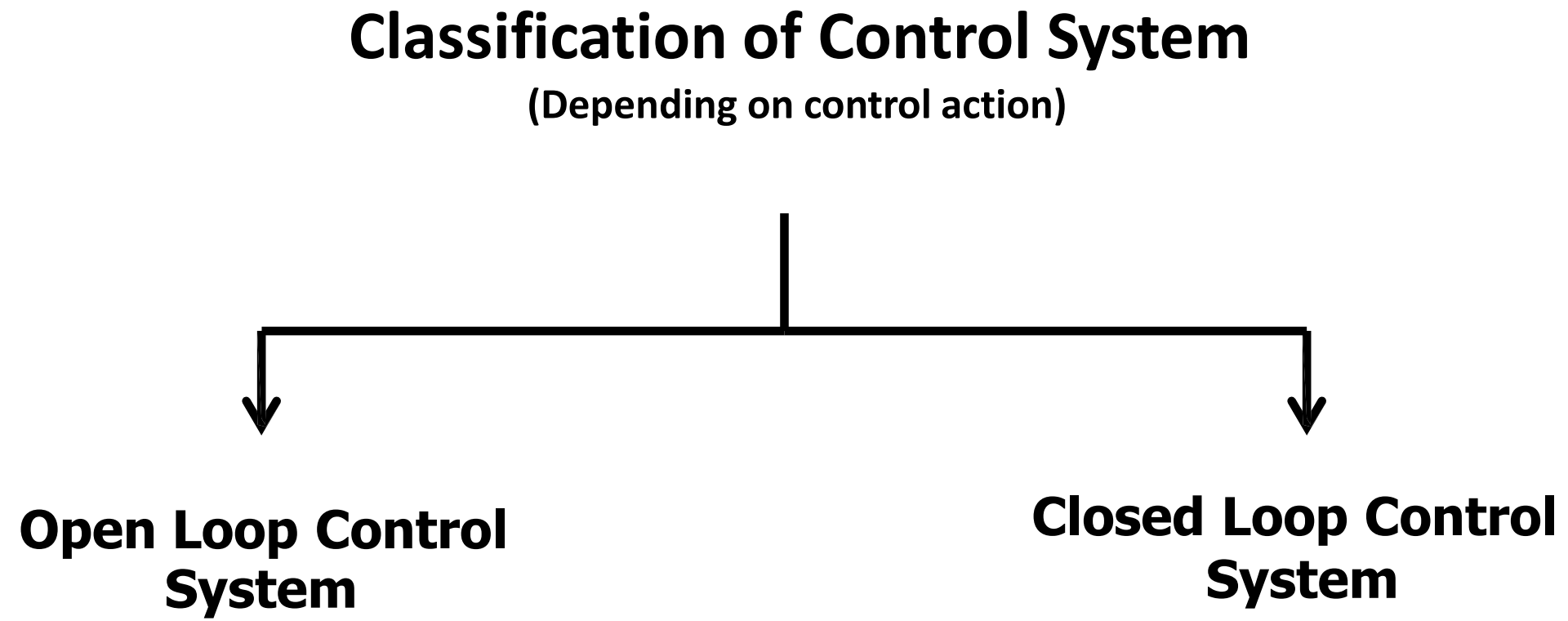
A Fan: Can be a Control System

- A Fan with blades and with regulator can be a "CONTROL SYSTEM" Because it can provide a **Desired output.**

  i.e. Controlled airflow



Classification of Control System



Open Loop Control System

Definition:

"A system in which the control action is totally independent of the output of the system is called as open loop system"

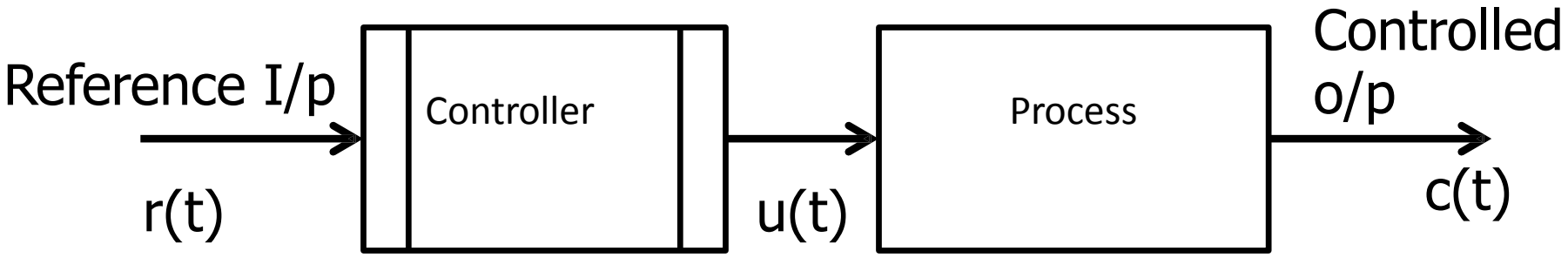


Fig. Block Diagram of Open loop Control System

Open Loop Control Systems Examples

- **Electric hand drier** – Hot air (output) comes out as long as you keep your hand under the machine, irrespective of how much your hand is dried.

Open Loop Control Systems Examples

- **Automatic washing machine**
  - This machine runs according to the pre-set time irrespective of washing is completed or not.

Open-loop Control System

Washing Machine

- A washing machine is an example of an open loop control system
- The input and output of an open loop system are unrelated
- An example is the operation of a washing machine does not depend on the cleanliness of the clothes, but rather on the "preset-time"

Block diagram of Open-loop Control System (Washing Machine)

OLCS Examples

- **Bread toaster** - This machine runs as per adjusted time irrespective of toasting is completed or not.

OLCS Examples

- **Automatic tea/coffee Vending Machine** – These machines also function for pre adjusted time only.

OLCS Examples

- **Light switch** – lamps glow whenever light switch is on irrespective of light is required or not.

- **Volume on stereo system** – Volume is adjusted manually irrespective of output volume level.

Advantages of OLCS

- Simple in construction and design.
- Economical.
- Easy to maintain.
- Generally stable.
- Convenient to use as output is difficult to measure.

Disadvantages of OLCS

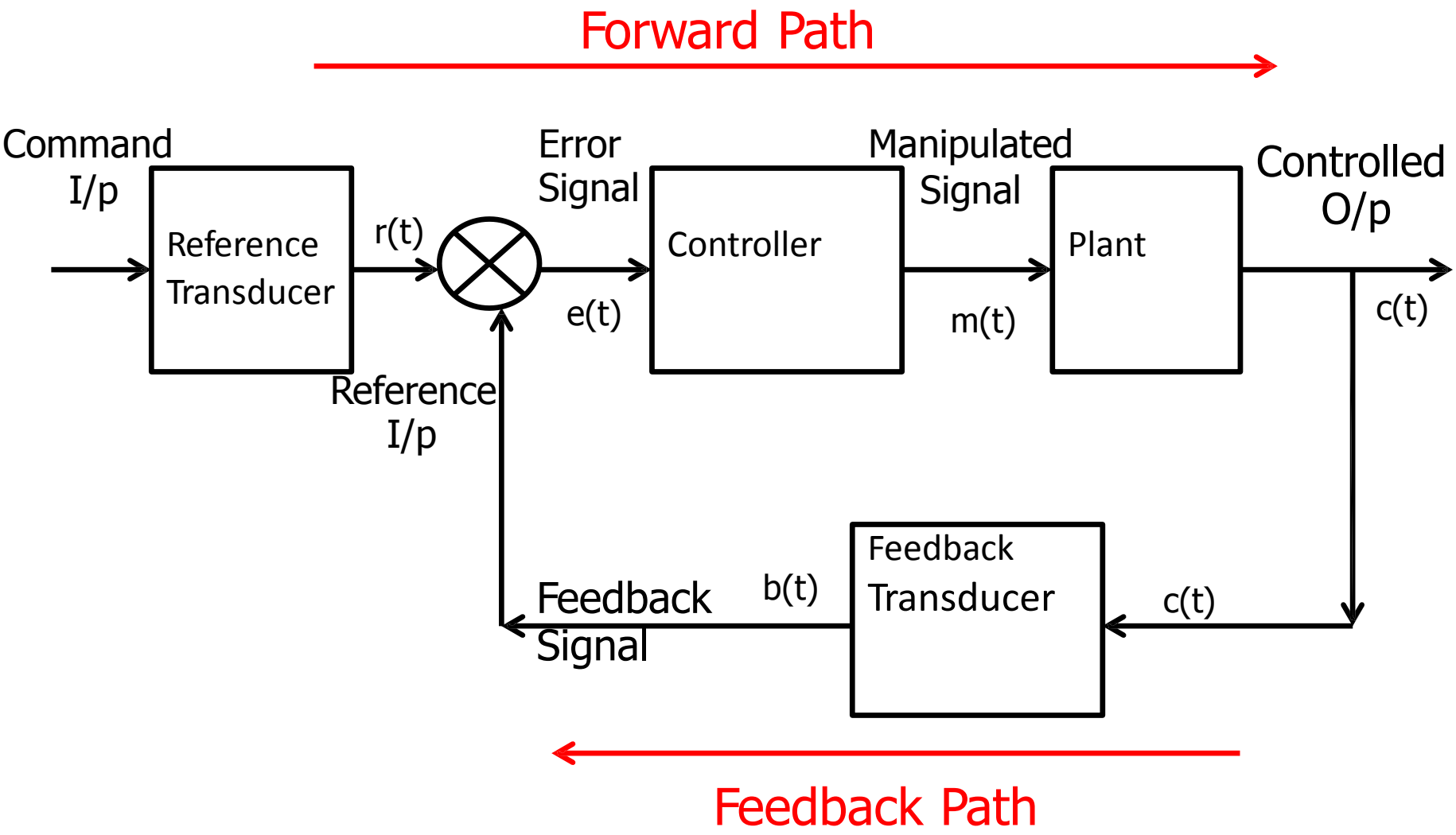
- They are inaccurate
- They are unreliable
- Any change in output cannot be corrected automatically.

Closed Loop System

Definition:

"A system in which the control action is somehow dependent on the output is called as closed loop system"

Block Diagram of CLCS



CLCS Examples

- **<u>Servo voltage stabilizer</u>** – Voltage controller operates depending upon output voltage of the system.

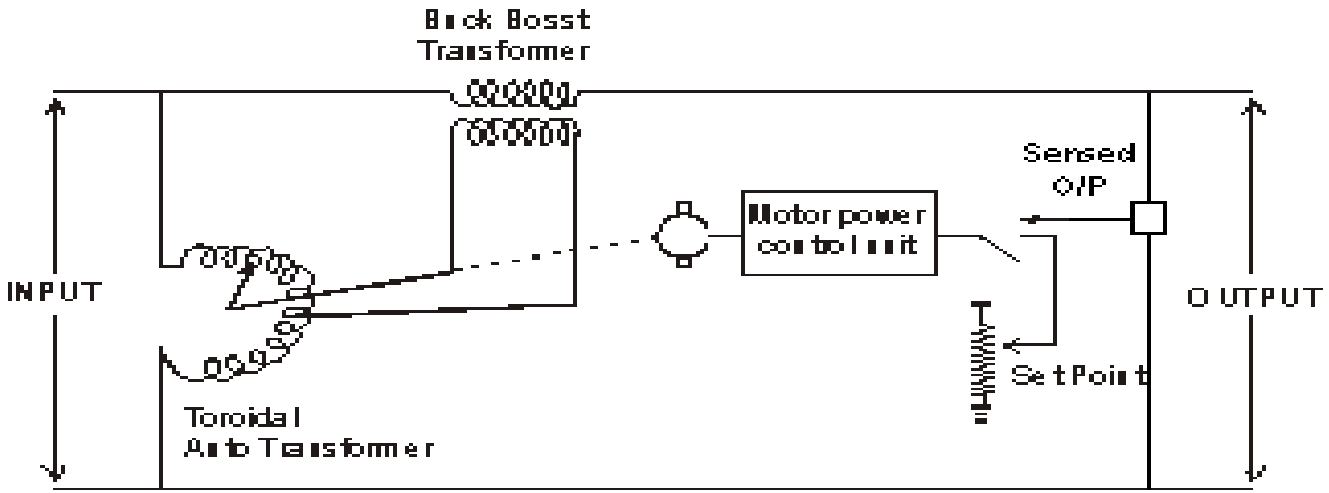


Fig. 5.6 Servo Voltage Stabilizer

Temperature Control

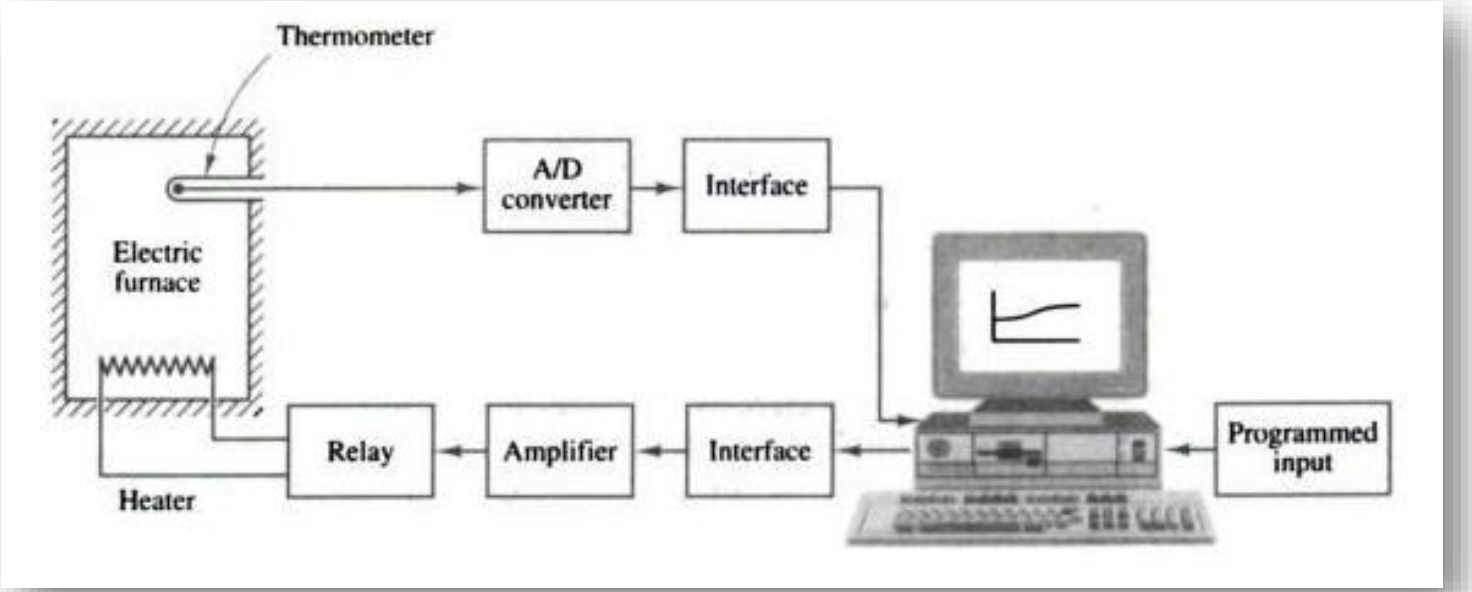
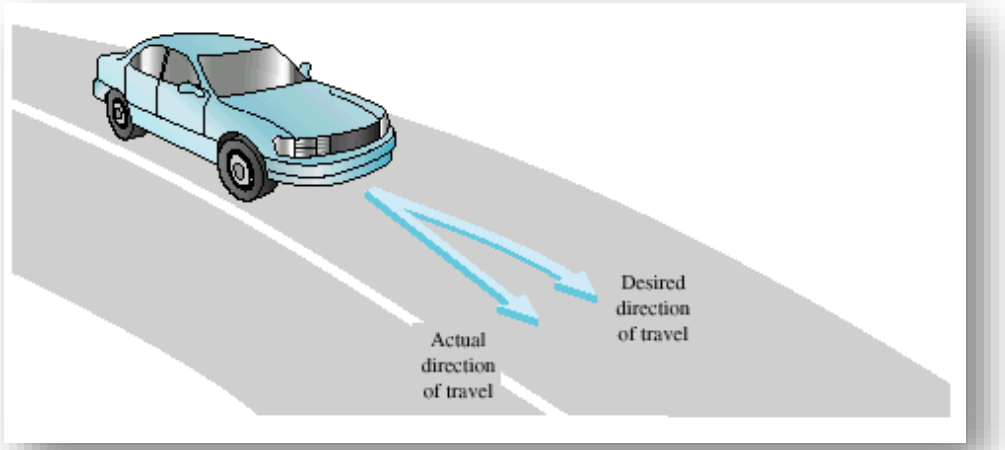


Figure shows a schematic diagram of temperature control of an electric furnace. The temperature in the electric furnace is measured by a thermometer, which is analog device. The analog temperature is converted to a digital temperature by an A/D converter. The digital temperature is fed to a controller through an interface. This digital temperature is compared with the programmed input temperature, and if there is any error , the controller sends out a signal to the heater, through an interface, amplifier and relay to bring the furnace temperature to a desired value.

Transportation

Car and Driver



Objective: To control direction and speed of car

Outputs: Actual direction and speed of car

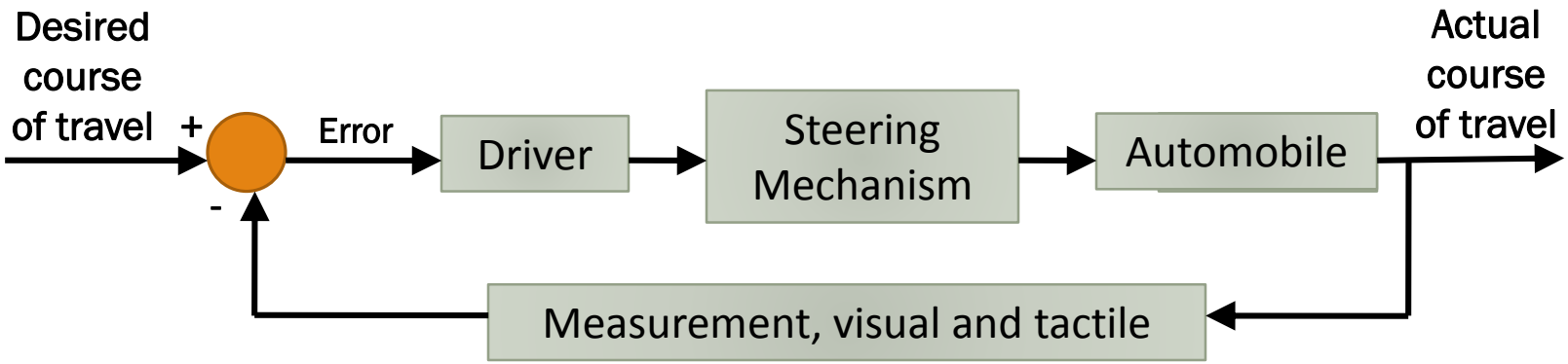
Control inputs: Road markings and speed signs

Disturbances: Road surface and grade, wind, obstacles

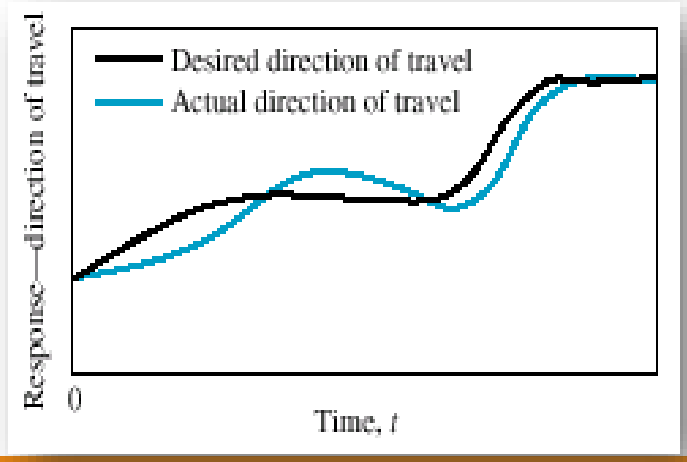
Possible subsystems: The car alone, power steering system, breaking system

Transportation

Functional block diagram:



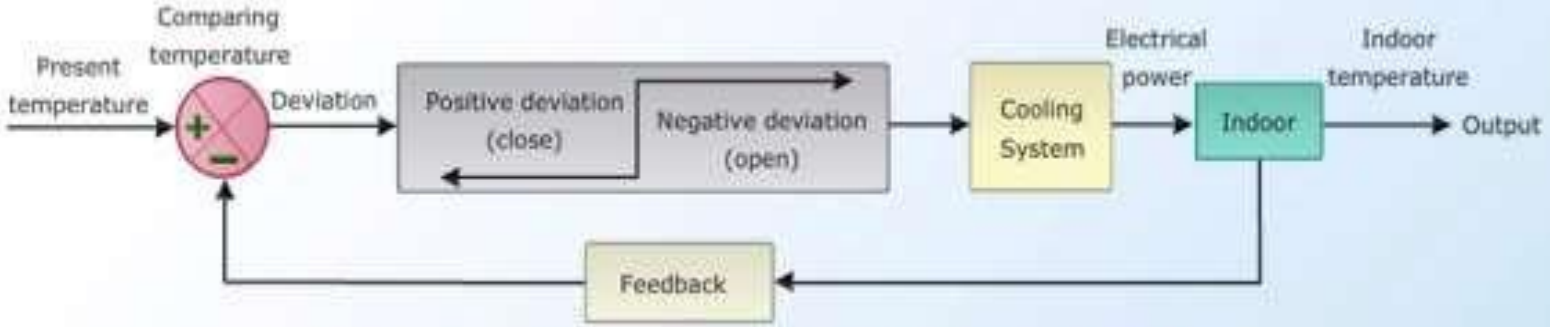
Time response:



Closed-loop Control Systems

Air Conditioner

- Most modern appliances and machinery are equipped with "closed-loop" control systems
- An air conditioner uses a thermostat to detect the temperature and controls the operation of its electrical parts to keep the room temperature at a preset constant



Block diagram of Closed-loop Control System (Air Conditioner)

Advantages of CLCS

- Closed loop control systems are more accurate even in the presence of non-linearity.
- Highly accurate as any error arising is corrected due to presence of feedback signal.
- Bandwidth range is large.
- Facilitates automation.
- The sensitivity of system may be made small to make system more stable.
- This system is less affected by noise.

Disadvantages of CLCS

- They are costlier.
- They are complicated to design.
- Required more maintenance.
- Feedback leads to oscillatory response.
- Overall gain is reduced due to presence of feedback.
- Stability is the major problem and more care is needed to design a stable closed loop system.

Difference Between OLCS & CLCS

Open Loop Control System	Closed Loop Control System
1. The open loop systems are simple & economical.	1. The closed loop systems are complex and costlier
2. They consume less power.	2. They consume more power.
3. The OL systems are easier to construct because of less number of components required.	3. The CL systems are not easy to construct because of more number of components required.
4. The open loop systems are inaccurate & unreliable	4. The closed loop systems are accurate & more reliable.

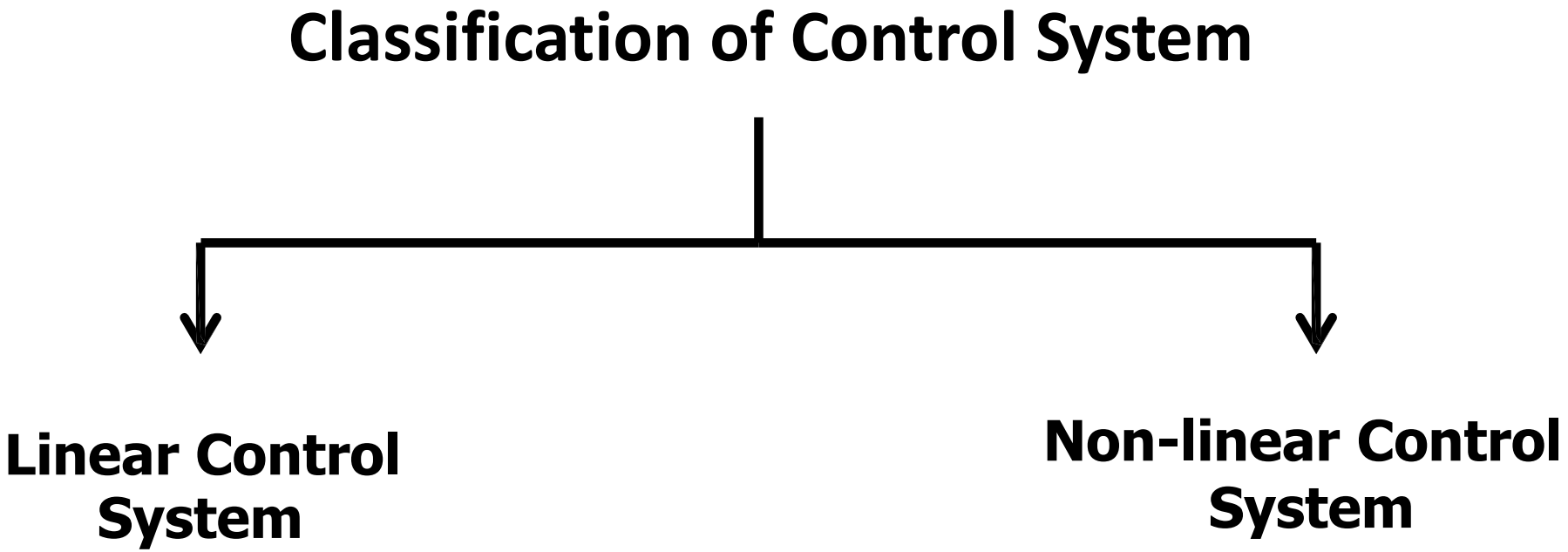
Difference Between OLCS & CLCS

Open Loop Control System	Closed Loop Control System
5. Stability is not a major problem in OL control systems. Generally OL systems are stable.	5. Stability is a major problem in closed loop systems & more care is needed to design a stable closed loop system.
6. Small bandwidth.	6. Large bandwidth.
7. Feedback element is absent.	7. Feedback element is present.
8. Output measurement is not necessary.	8. Output measurement is Necessary.

Difference Between OLCS & CLCS

Open Loop Control System	Closed Loop Control System
9. The changes in the output due to external disturbances are not corrected automatically. So they are more sensitive to noise and other disturbances.	9.The changes in the output due to external disturbances are corrected automatically. So they are less sensitive to noise and other disturbances.
10. Examples: Coffee Maker, Automatic Toaster, Hand Drier.	10. Examples: Guided Missile, Temp control of oven, Servo voltage stabilizer.

Classification of Control System



Linear Control System

- When an input X1 produces an output Y1 & an input X2 produces an output Y2, then any combination $\alpha X1+\beta X2$ should produce an output $\alpha Y1+\beta Y2$. In such case system is linear. Therefore, linear systems are those where the principles of superposition and proportionality are obeyed.

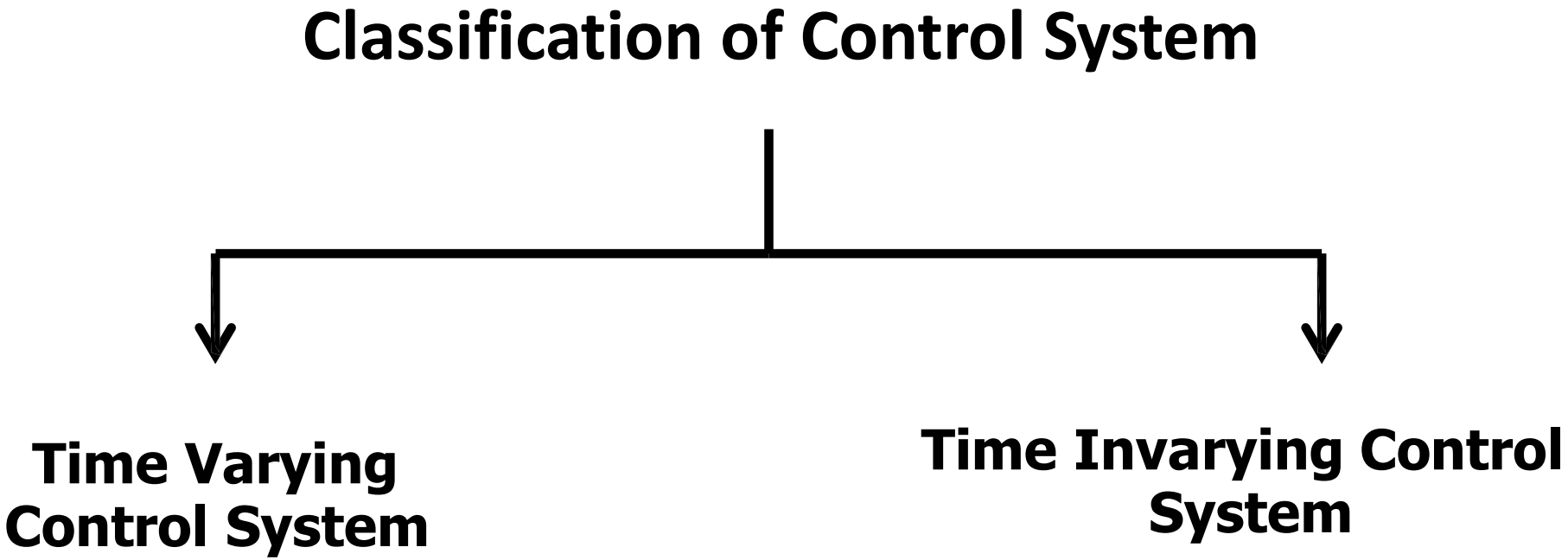
Non-linear Control System

- Non-linear systems do not obey law of superposition.
- The stability of non-linear systems depends on root location as well as initial conditions & type of input.
- Non-linear systems exhibit self sustained oscillations of fixed frequency.

Difference Between Linear & Non-linear System

Linear System	Non-linear System
1. Obey superposition.	1. Do not obey superposition
2. Can be analyzed by standard test signals	2. Cannot be analyzed by standard test signals
3. Stability depends only on root location	3. Stability depends on root locations, initial conditions & type of input
4. Do not exhibit limit cycles	4. Exhibits limit cycles
5. Do not exhibit hysteresis/ jump resonance	5. Exhibits hysteresis/ jump resonance
6. Can be analyzed by Laplace transform, z- transform	6. Cannot be analyzed by Laplace transform, z- transform

Classification of Control System



Time varying/In-varying Control System

- Systems whose parameters vary with time are called time varying control systems.
- When parameters do not vary with time are called Time Invariant control systems.

Time varying/In-varying Control System

- The mass of missile/rocket reduces as fuel is burnt and hence the parameter mass is time varying and the control system is time varying type.

Classifications of Control Systems

- Control Systems are classified as:
  - Time-variant System and Time-invariant System
  - Linear System and Non linear System
  - Continuous time System and Discrete time control System
  - SISO and MIMO Systems
  - Open-loop and Closed-loop Systems