Introduction to Control System

CEH3K3

Randy E. Saputra, ST. MT.

Objectives

- Distinguish between open-loop and closed-loop control systems
- Understand control system block diagrams
- Explain transfer functions
- Differentiate between analog and digital control systems
- Know how process control systems work
- Know how servomechanisms work

Introduction

- A control system is…

  Collection of components working together under the direction of some machine intelligence.

- Electronic circuits provide the intelligence
- Electromechanical components (sensors and motors) provide the interface to the physical world

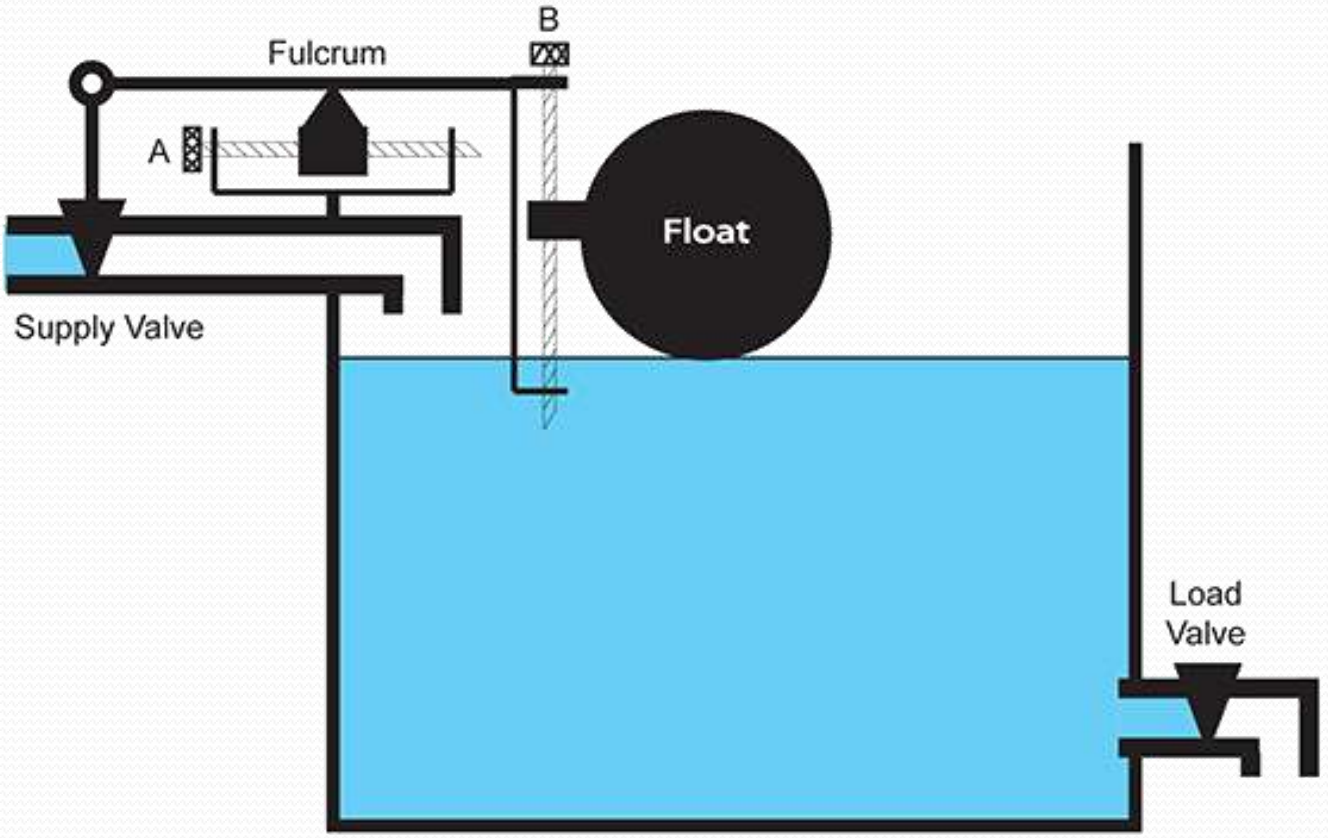
Natural Control System

Example : Human body

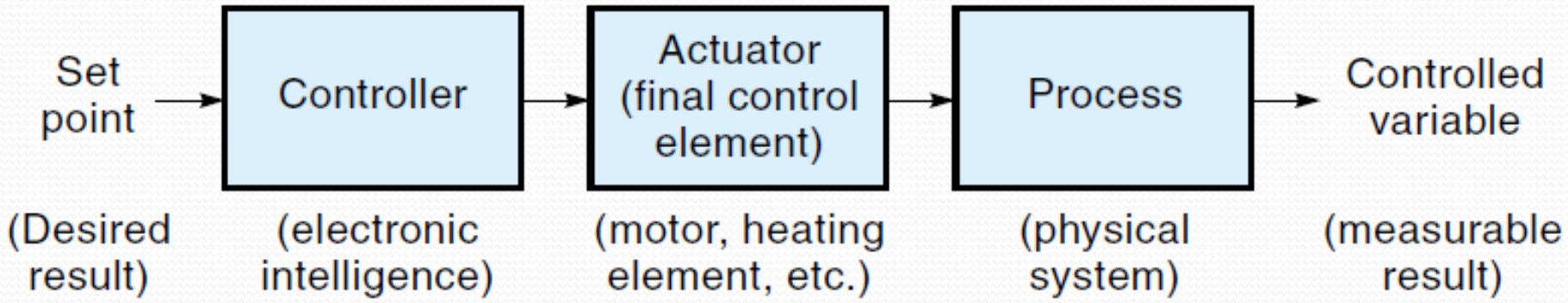
- If the body need to heat itself, food calories are converted to produce heat
- If temperature sensors in the body notice a drop in temperature, they signal the body to burn more fuel
- If the sensors indicate too high temperature, they signal the body to sweat

Man-made Control System

Example : Toilet

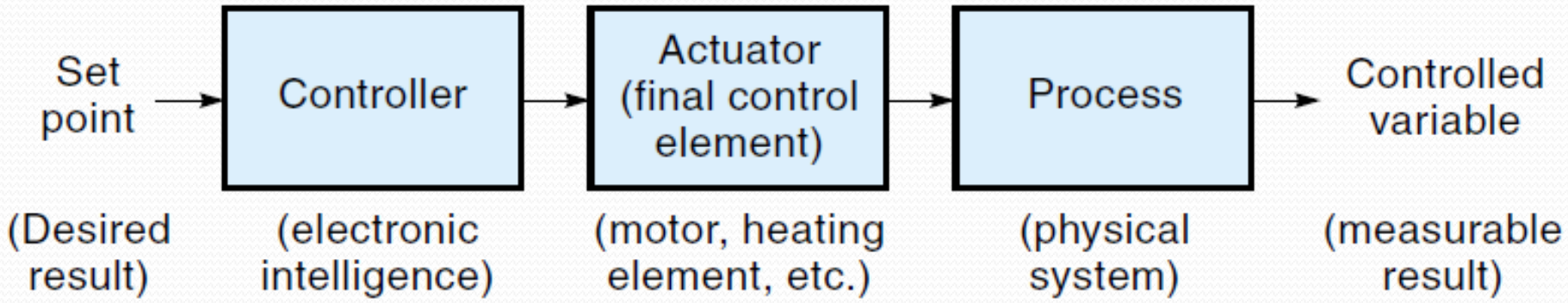


Block Diagram



- Set point : signal representing the desired output
- Actuator, example : electric motor, electric valve, heating element

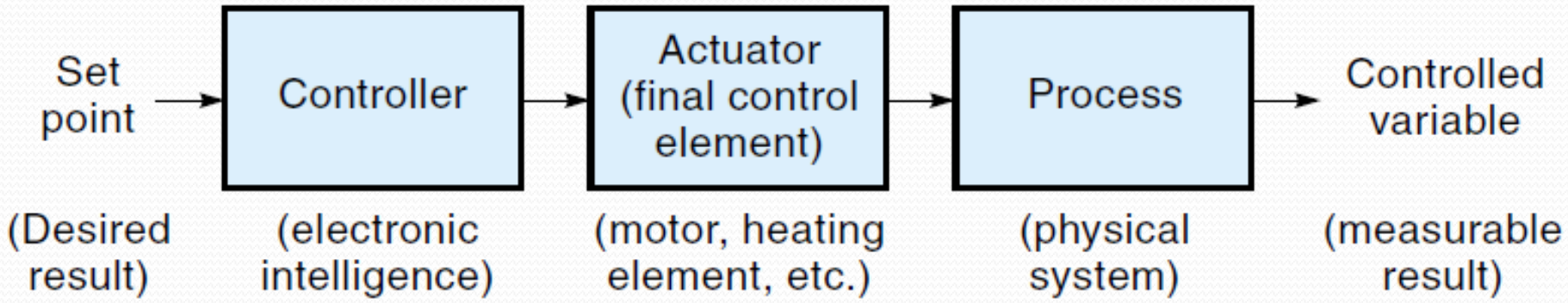
Block Diagram



If the actuator is an electric heating element :

- Process is "heating the furnace"
- Controlled variable is the temperature in the furnace

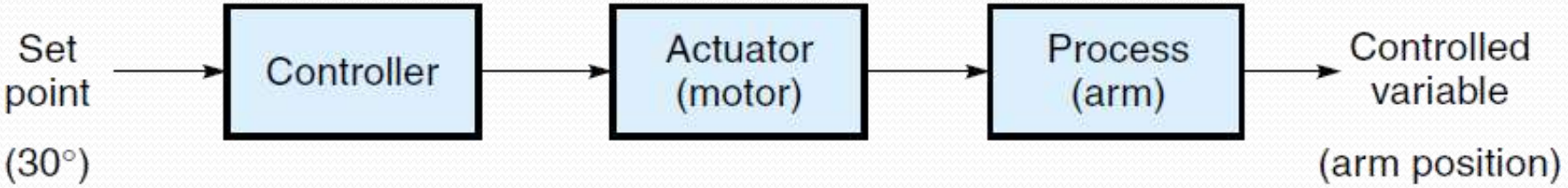
Block Diagram



If the actuator is electric motor that rotates an antenna :

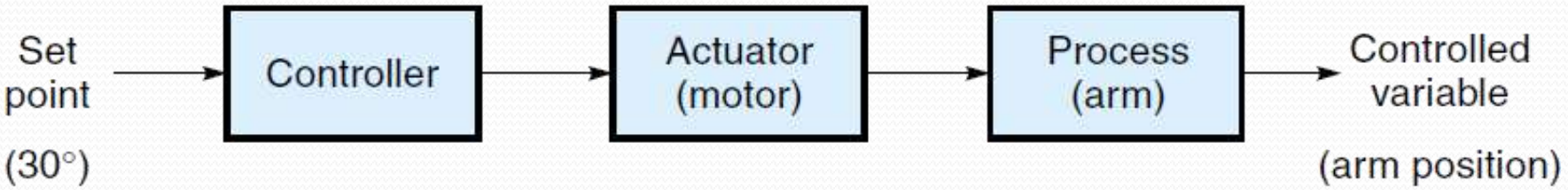
- Process is "rotating the antenna"
- Controlled variable is the angular position of the antenna

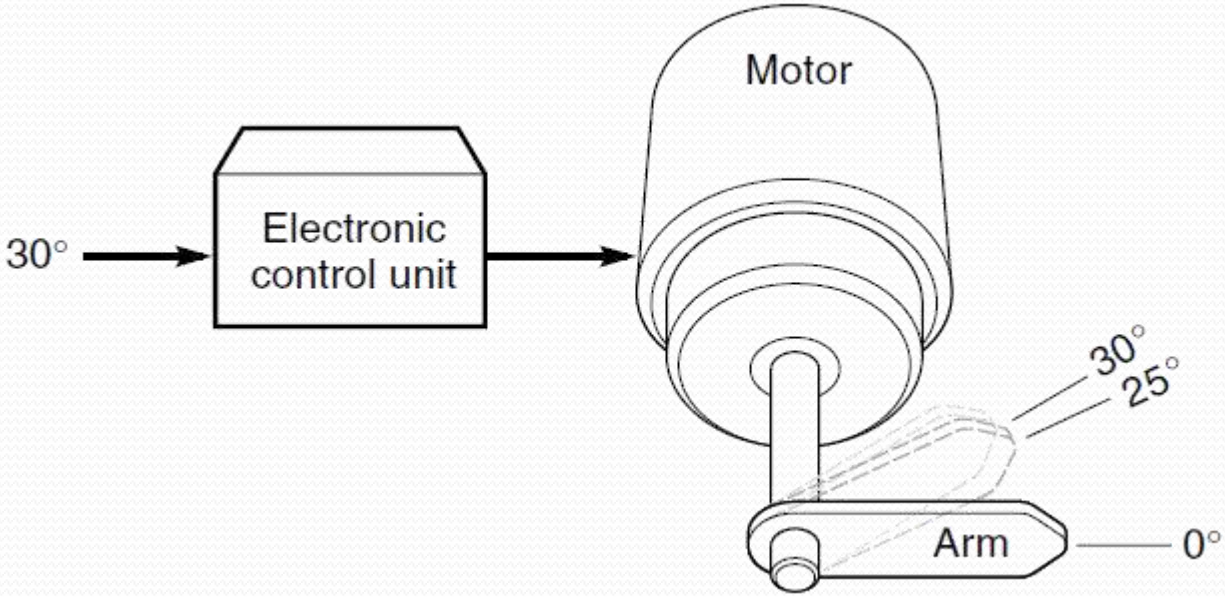
Open-Loop Control System



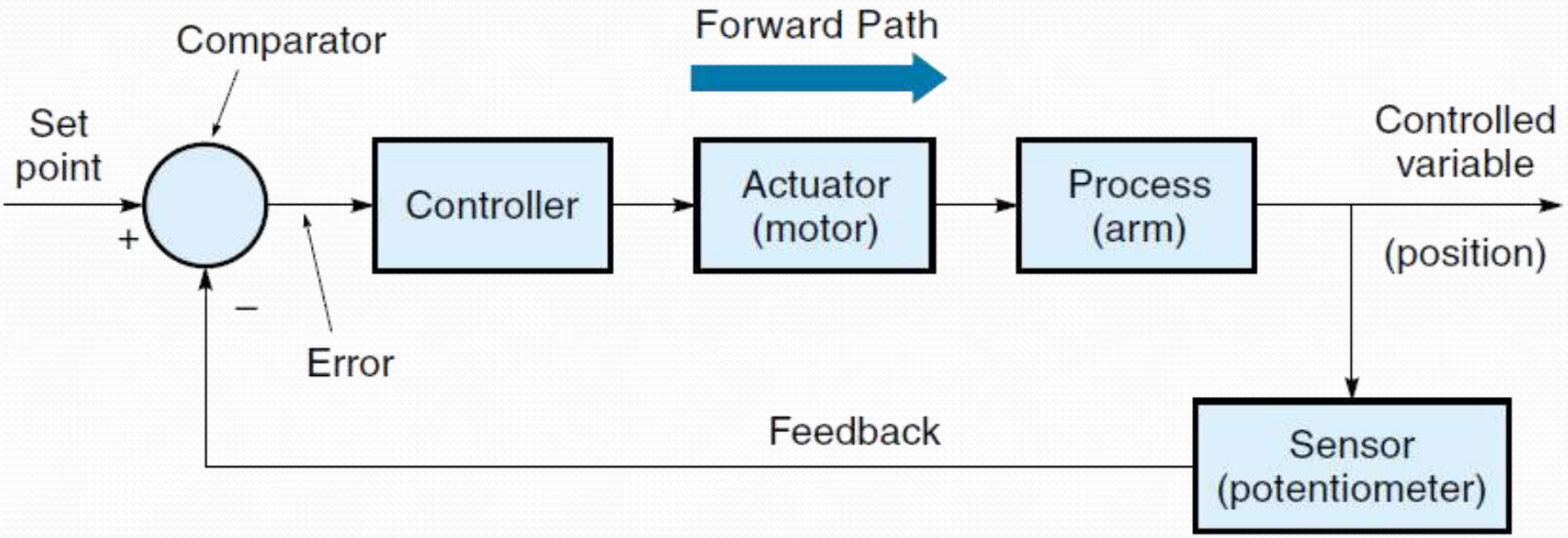
- Controller independently calculates exact voltage or current needed by the actuator to do the job
- No feedback

Open-Loop Control System



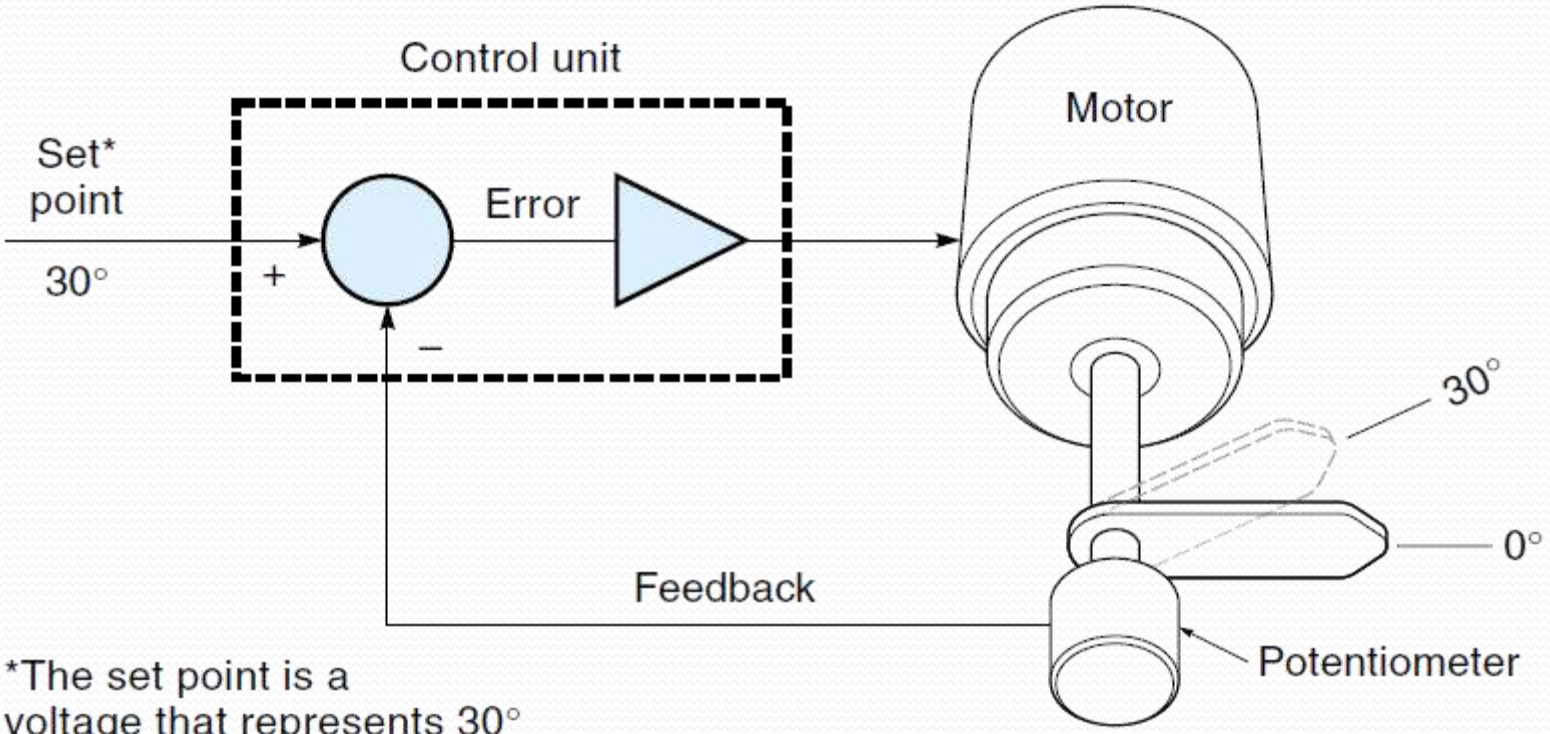


Closed-Loop Control System



- Output of the process (controlled variable) is constantly monitored by a sensor
- Receive a feedback

Closed-Loop Control System



Transfer Function

Background :

- Control system is a collection of components and circuits connected together
- Each component in the system converts energy from one form to another

  Example :

  - Temperature sensor converting degrees to volts
  - Motor converting volts to revolutions per minute

Transfer Function

- Transfer function is…

  Mathematical relationship between the input and output of a control system component,

$$\text{TF} = \frac{\text{output}}{\text{input}}$$

  Or if we consider only steady-state values for the transfer function,

$$\text{TF}_{\text{steady-state}} = \text{gain} = \frac{\text{steady} - \text{state output}}{\text{steady} - \text{state input}}$$

Example

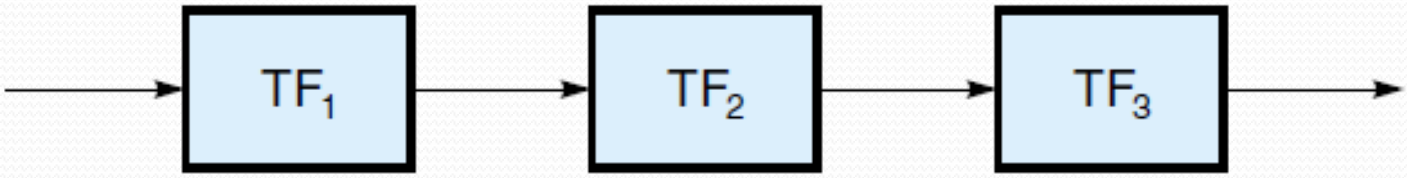
- A potentiometer is used as a position sensor. The pot is configured in such a way that 0° of rotation yields 0 V and 300° yields 10 V. Find transfer function of the pot.

Solution

The transfer function is output divided by input. In this case, the input to the pot is "position in degrees," and output is volt.

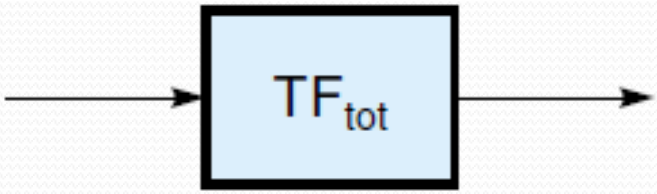
$$\mathrm{TF} = \frac{\text{output}}{\text{input}} = \frac{10\ \text{volt}}{300^\circ} = 0{,}0333\ \text{V/deg}$$

Combined Transfer Function



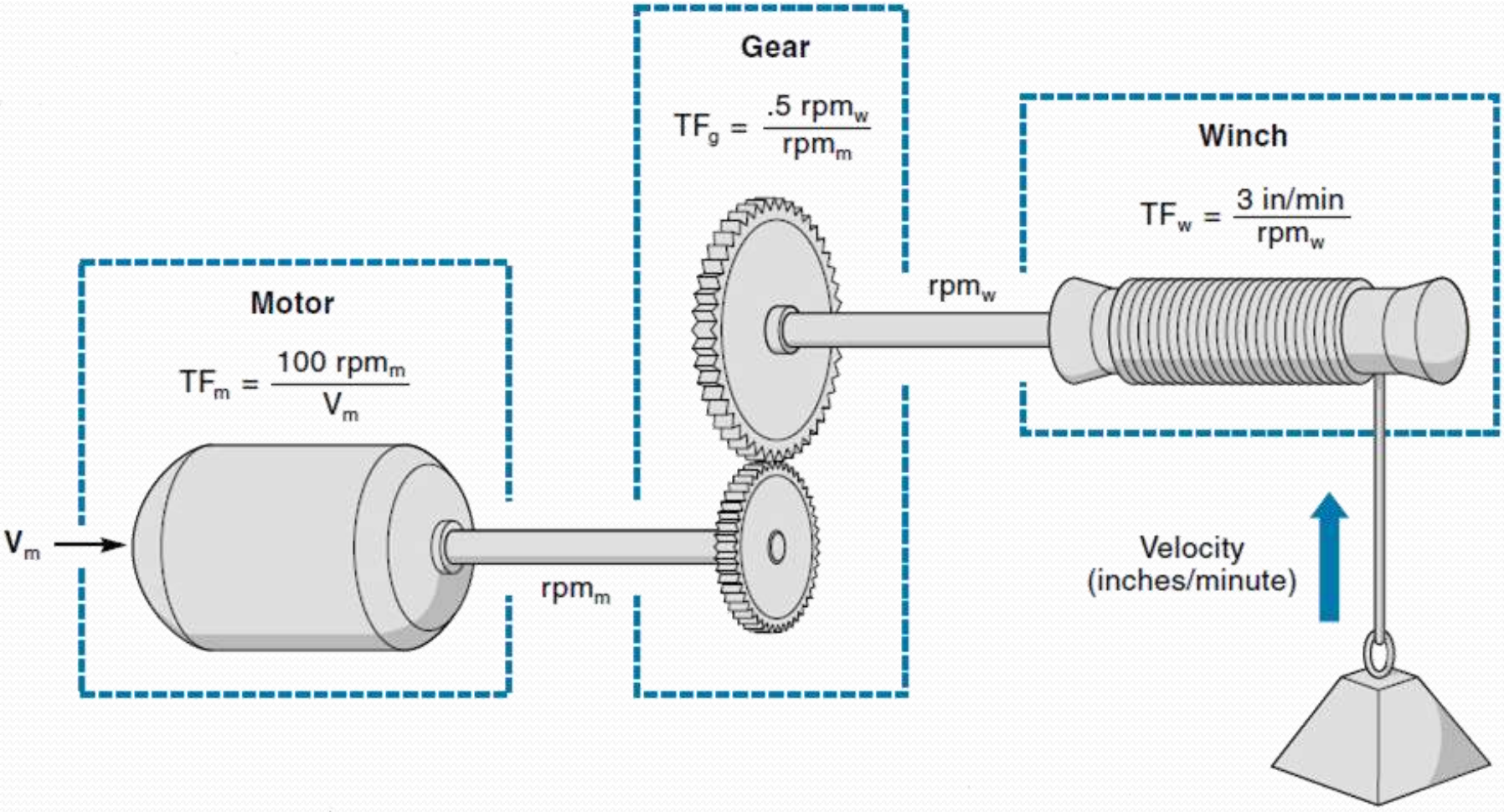
(a) Individual transfer functions

$$TF_{tot} = TF_1 \times TF_2 \times TF_3$$



(b) Combined transfer function

Example


Gear
$TF_g = \frac{.5\ rpm_w}{rpm_m}$
Winch
$TF_w = \frac{3\ in/min}{rpm_w}$
Motor
$TF_m = \frac{100\ rpm_m}{V_m}$
V_m
rpm_m
rpm_w
Velocity
(inches/minute)

Example

- Consider the system shown in Figure above. It consists of an electric motor driving a gear train, which is driving a winch. Each component has its own characteristics: The motor (under these conditions) turns at 100 rpm_m for each volt (V_m) supplied; the output shaft of the gear train rotates at one-half of the motor speed; the winch (with a 3-inch shaft circumference) converts the rotary motion (rpm_w) to linear speed. The individual transfer functions are given as follows :

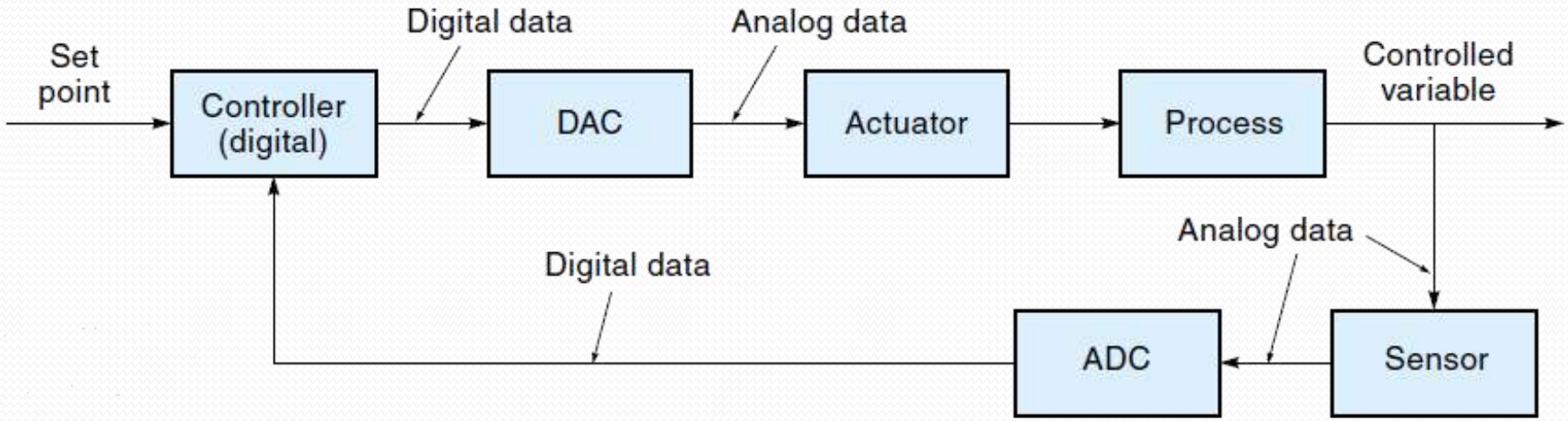
Example

- Motor : $TF_m = \frac{output}{input} = \frac{100\,rpm_m}{1\,V_m} = 100\,rpm_m/V_m$
- Gear train : $TF_g = \frac{output}{input} = \frac{1\,rpm_w}{2\,rpm_m} = 0{,}5\,rpm_w/rpm_m$
- Winch : $TF_m = \frac{output}{input} = \frac{3\,in./min}{1\,rpm_w} = 3\,in./min/rpm_w$

Analog & Digital Control System

- Physical world is basically an "analog place"
- Natural events take time to happen, and they move in a continuous fashion from one position to the next
- Digital control system must first convert real-world analog input data into digital form before it can be used in calculation
- Output from the digital controller must be converted from digital form back into analog form

Analog & Digital Control System



Classification of Control System

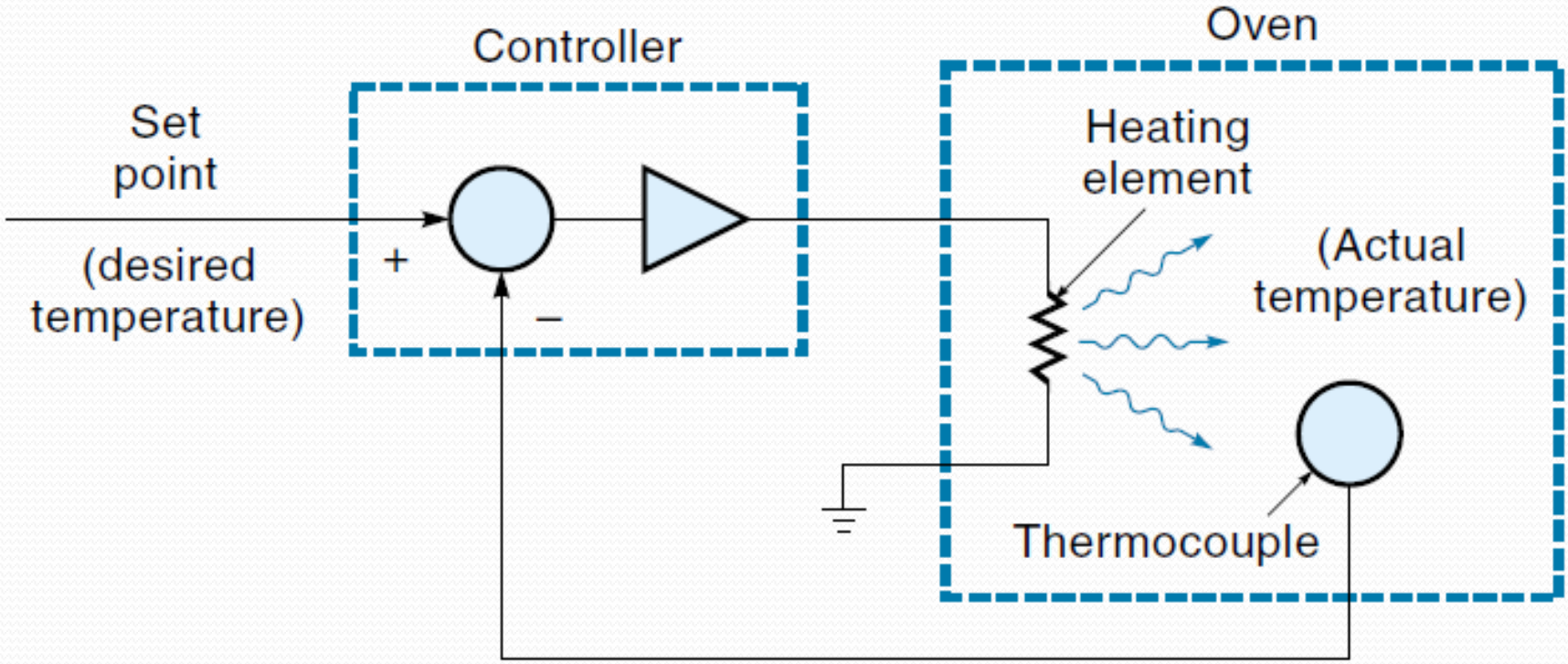
Process Control :

- Control system that oversees some industrial process so that a uniform, correct output is maintained
- Monitoring and adjusting the control parameters (such as temperature or flow rate) to ensure that the output product remains as it should

  Example :

  - Closed-loop system maintaining a specified temperature in an electric oven

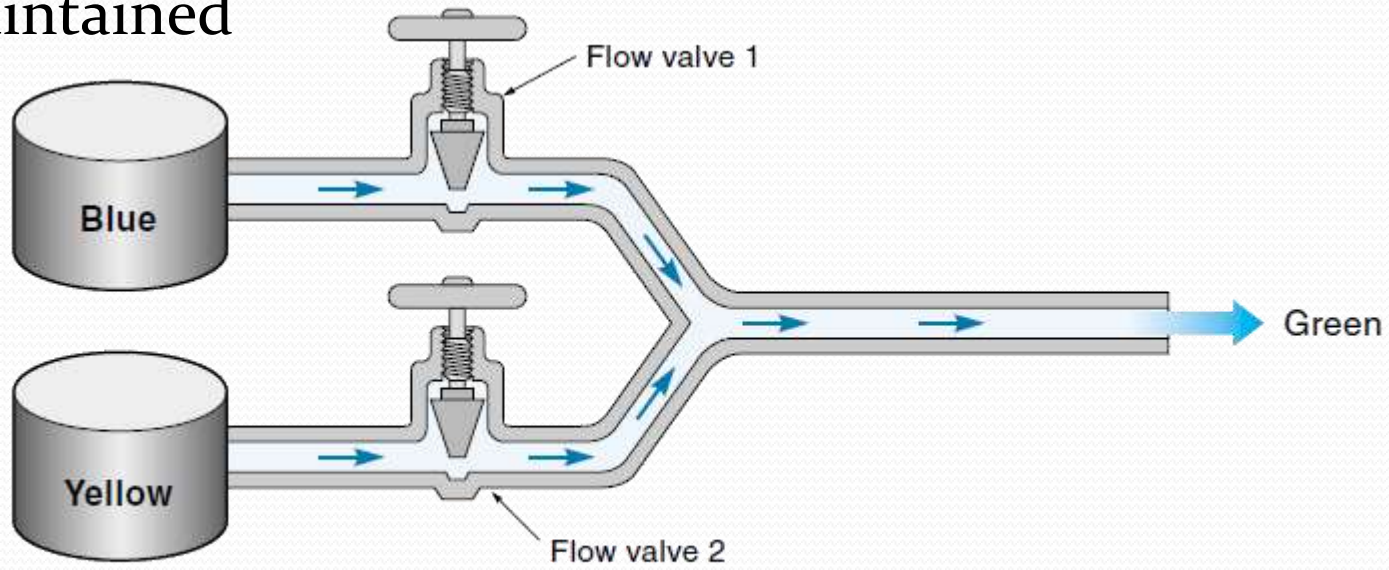
Classification of Control System



Classification of Control System

Example :

- Paint factory in which two colors, blue and yellow, are mixed to produce green. To keep the output color constant, the exact proportions of blue and yellow must be maintained

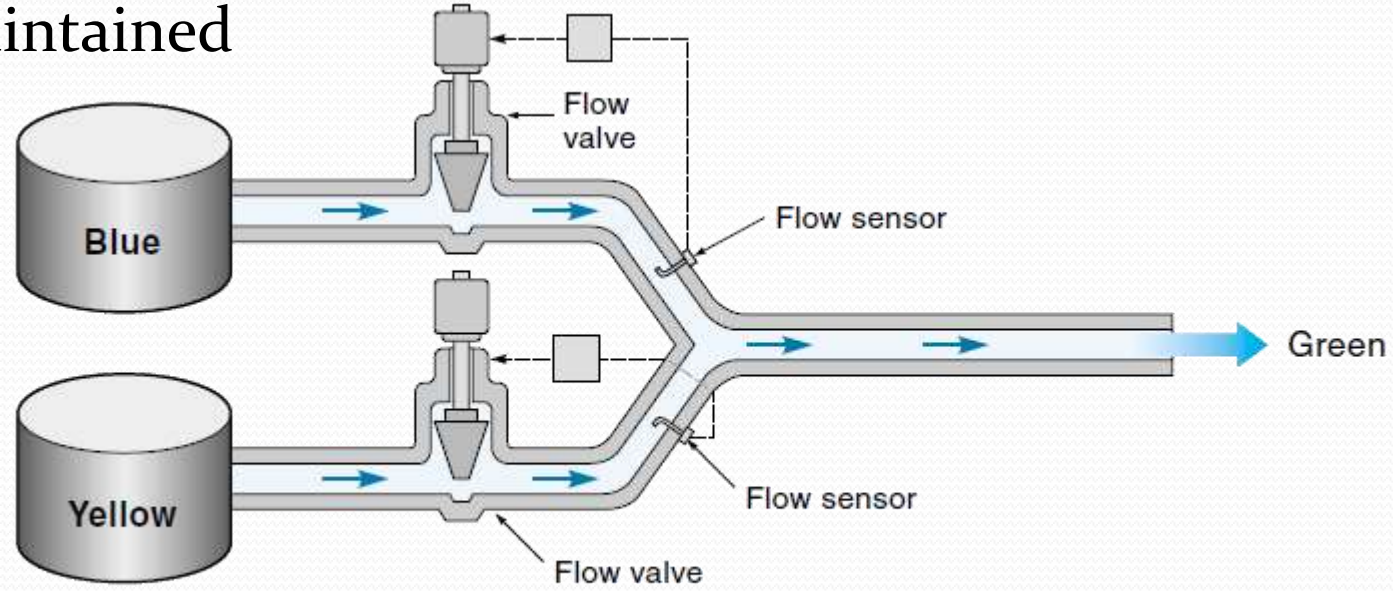


(a) Manual control

Classification of Control System

Example :

- Paint factory in which two colors, blue and yellow, are mixed to produce green. To keep the output color constant, the exact proportions of blue and yellow must be maintained

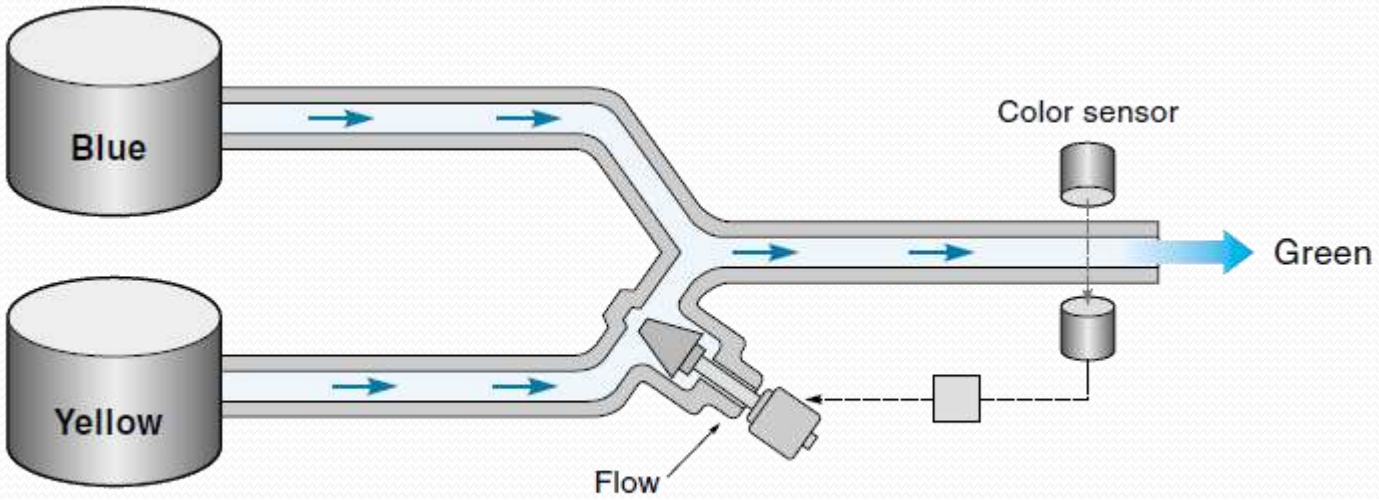


(b) Automatic flow control

Classification of Control System

Example :

- Paint factory in which two colors, blue and yellow, are mixed to produce green. To keep the output color constant, the exact proportions of blue and yellow must be maintained



(c) Automatic color control

Classification of Control System

Process Control can be classified into :

- Continuous process

  There is a continuous flow of material or product

  Example, paint-mixing machine

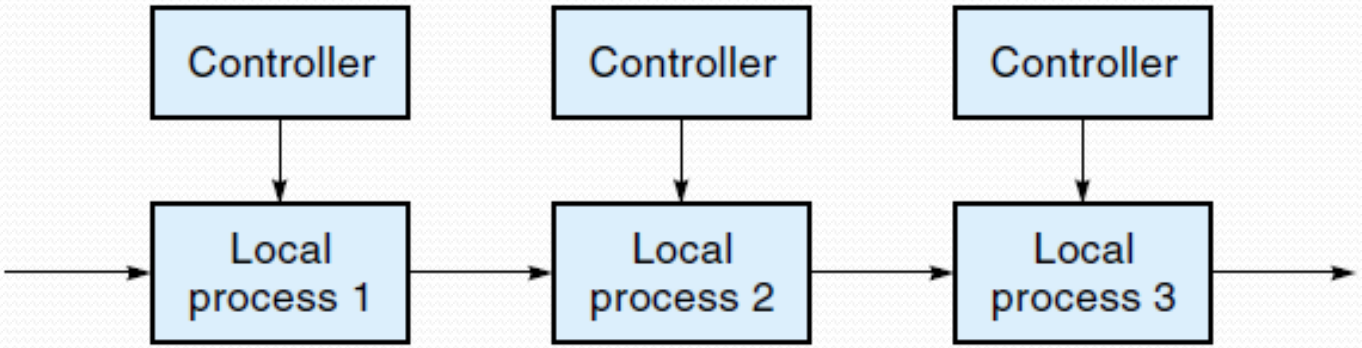
- Batch process

  There is a beginning and an end (which is usually performed over and over)

  Example, mixing a batch of bread dough and loading boxes on a pallet

Classification of Control System

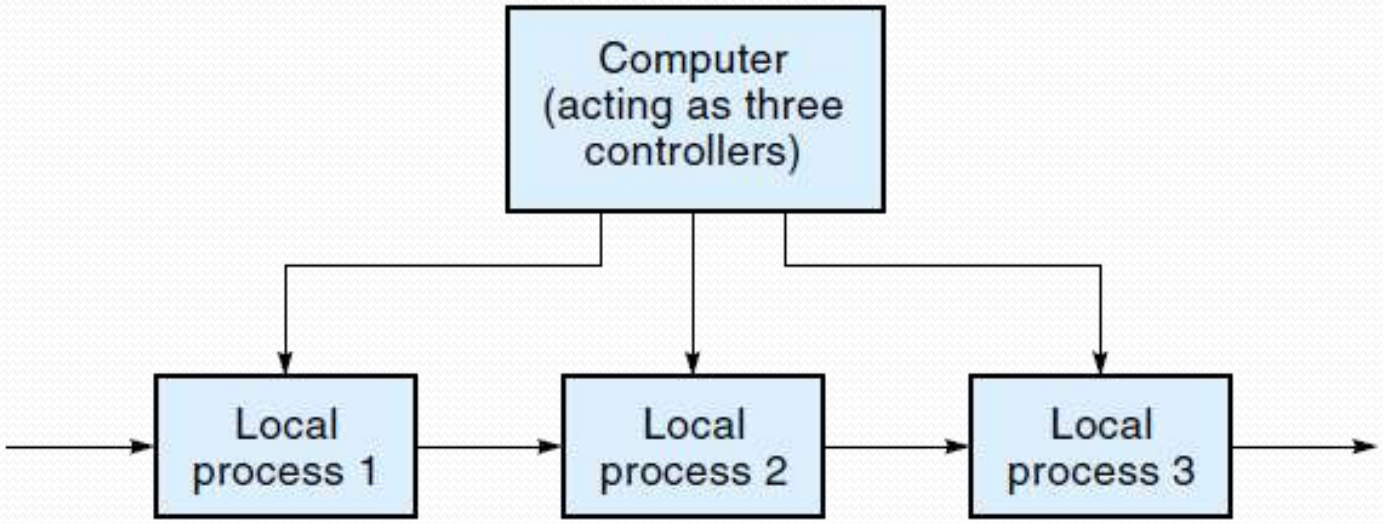
Multiprocess Control :



(a) Individual local controllers

Classification of Control System

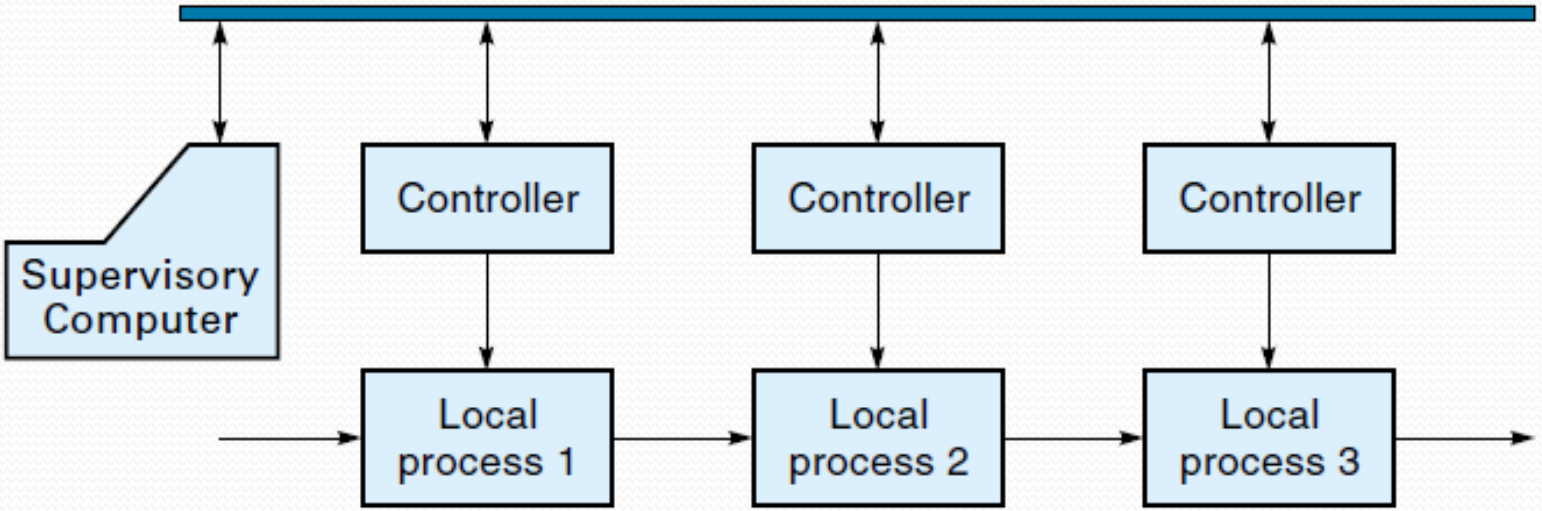
Multiprocess Control :



(b) Direct computer control of three processes

Classification of Control System

Multiprocess Control :



(c) Distributed computer control using local controllers

Classification of Control System

Sequentially Controlled System :

- Series of tasks to be performed—that is, a sequence of operations, one after the other

Based on its properties :

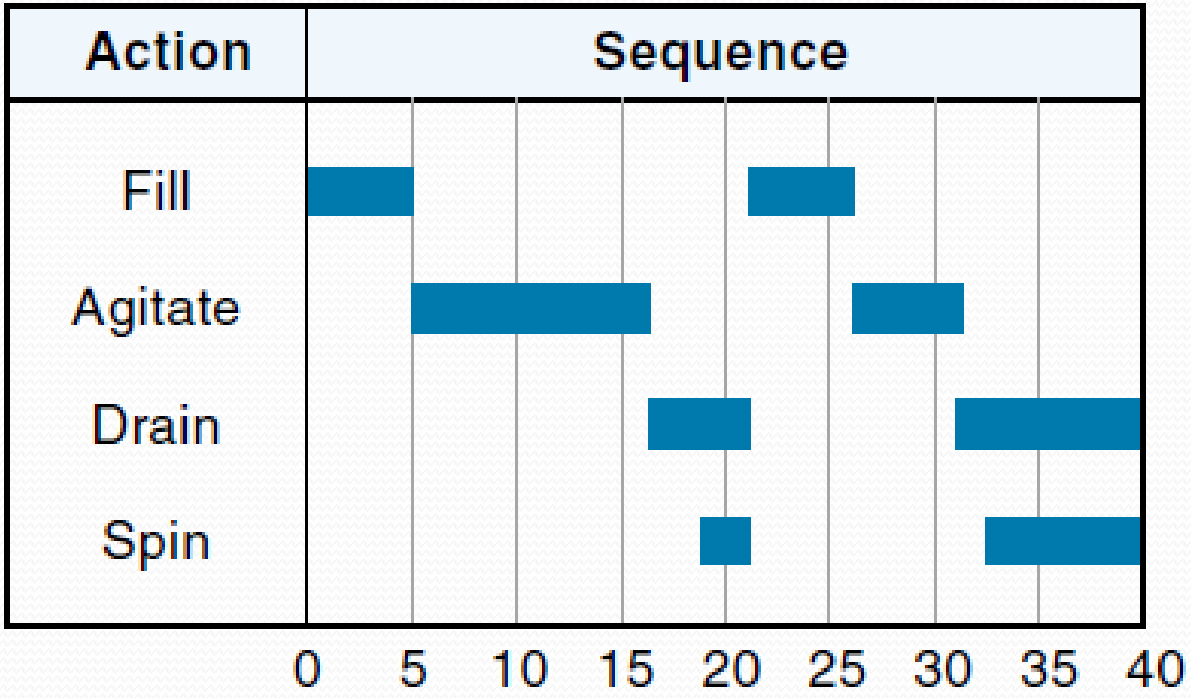
- Time-driven (open-loop)

  Do it for a certain amount of time. Example, traffic light
- Event-driven (closed-loop)

  Do it until the task is finished. Example, automatic washing machine

Classification of Control System

Automatic washing machine timing diagram

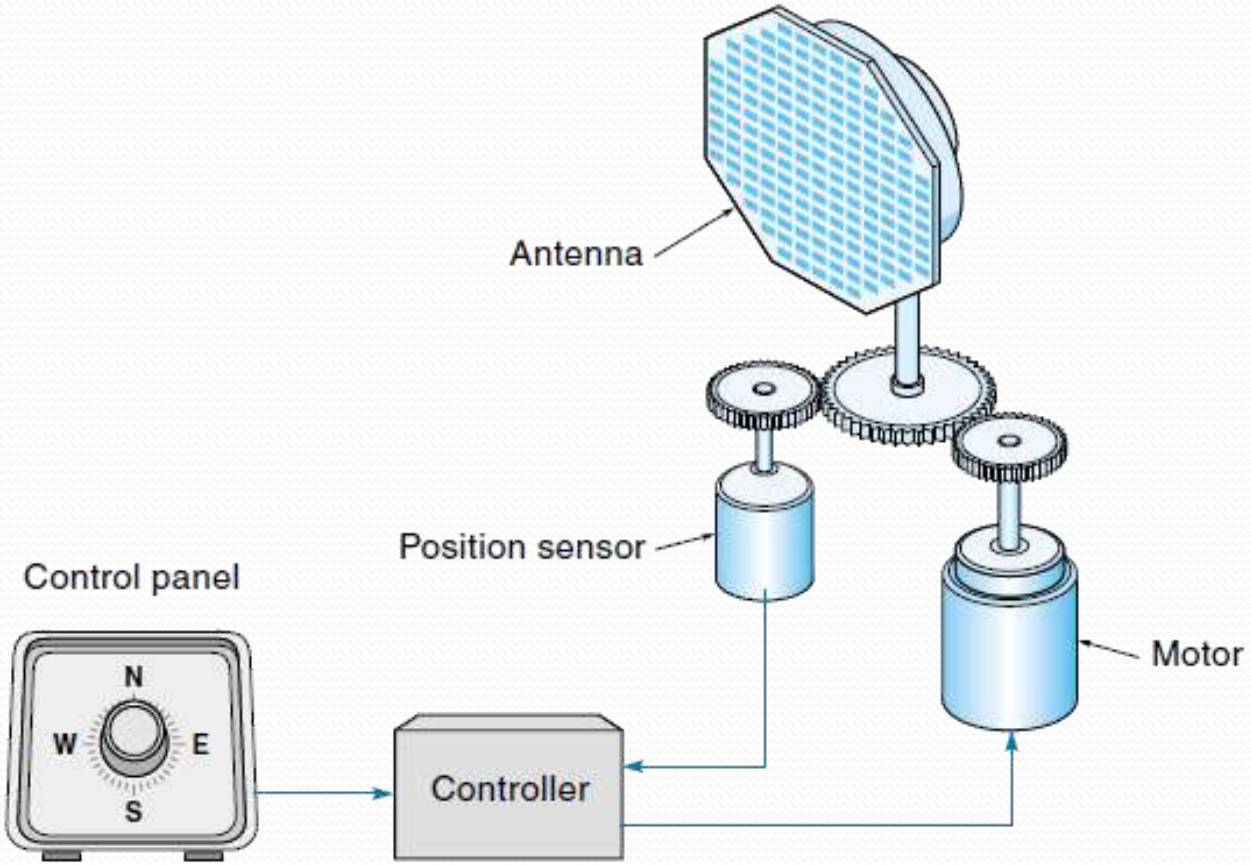


Classification of Control System

Motion Control :

- Servomechanism
  - Closed-loop electromechanical control system that directs the precise movement of a physical object such as a radar antenna or robot arm
  - Typically, output position or the output velocity (or both) is controlled

Classification of Control System

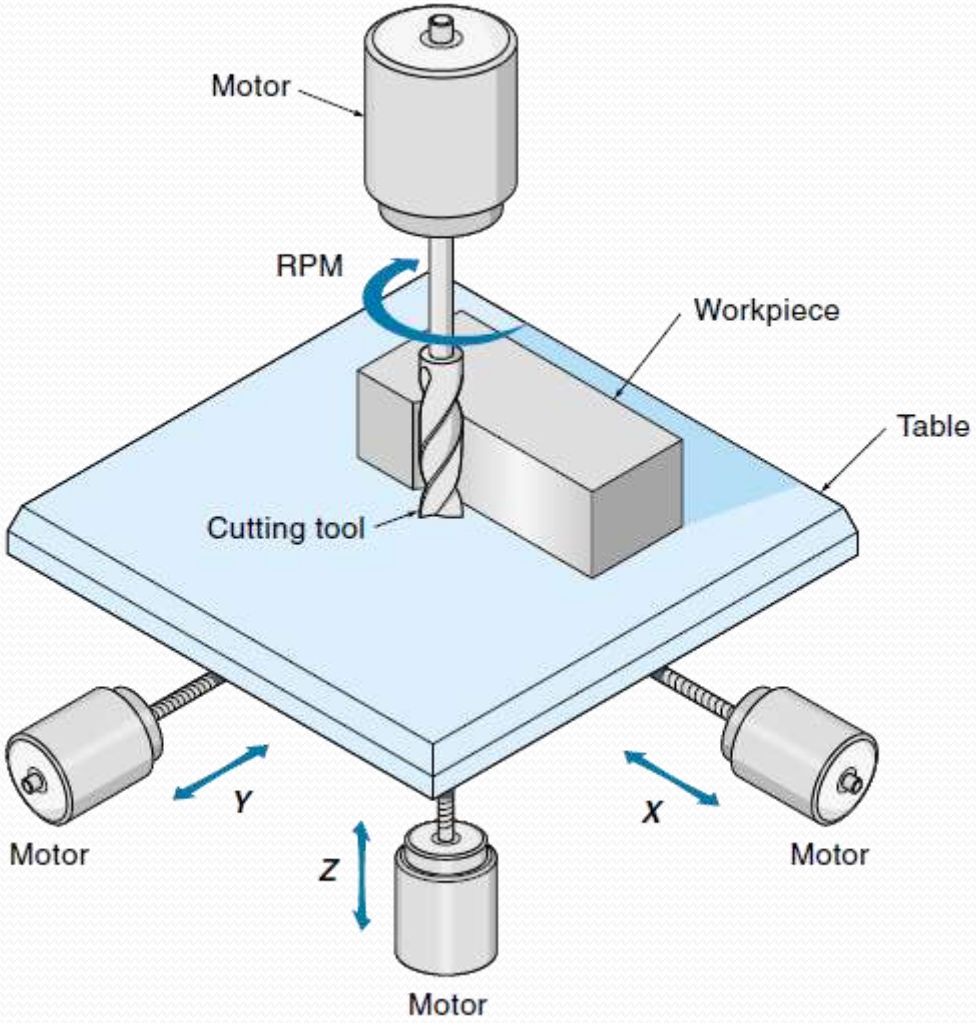


Classification of Control System

Motion Control :

- Numerical control
  - Type of digital control used on machine tools such as lathes and milling machines
  - Each machine has its own set of axes or parameters that must be controlled
  - The controller takes as its input a series of numbers that completely describe how the part is to be made

Classification of Control System

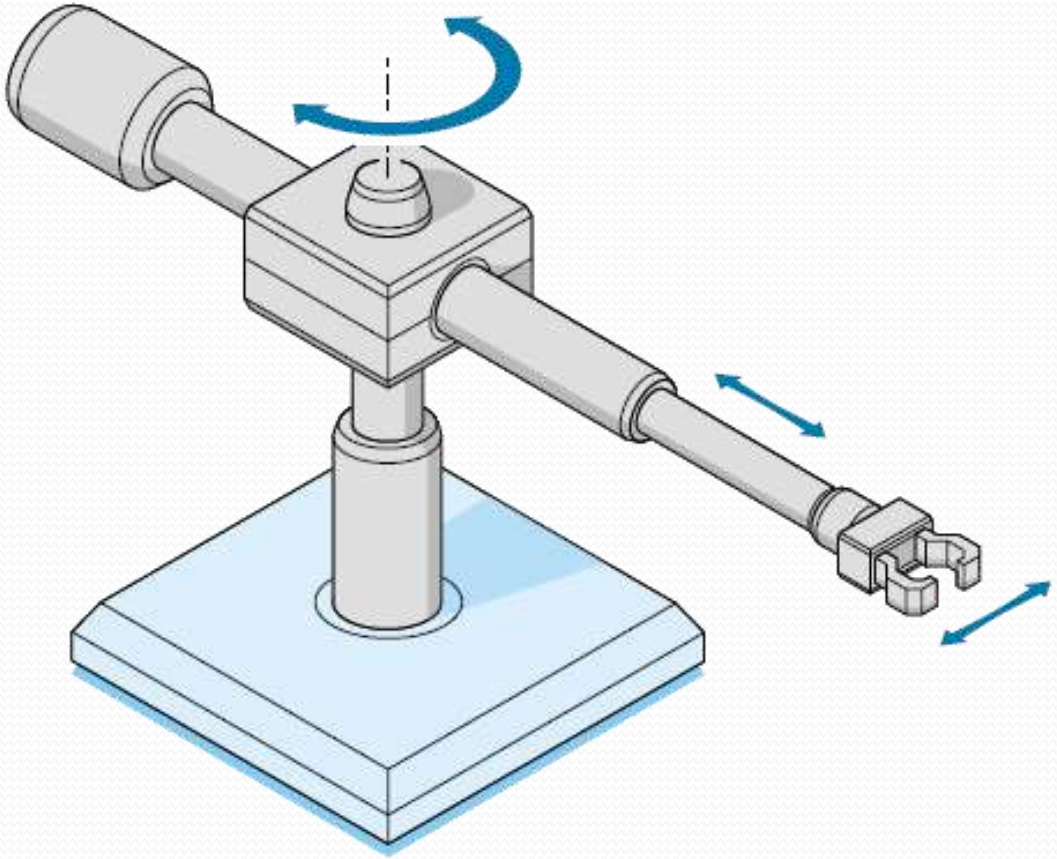


Classification of Control System

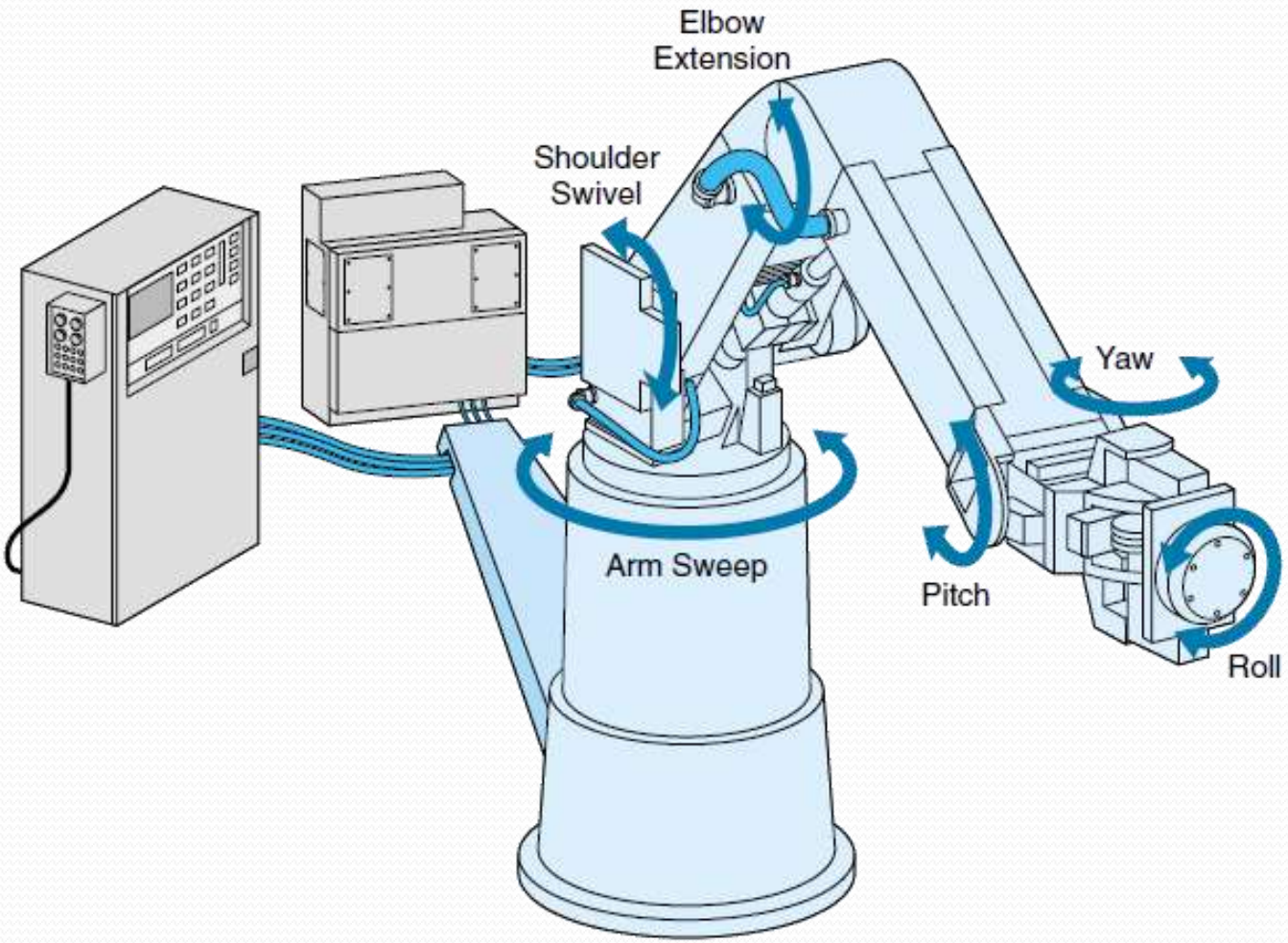
Motion Control :

- Robotics
  - Used to move parts from place to place, assemble parts, load and off-load NC machines
  - Pick-and-place robots (simplest type), run open-loop using mechanical stops or limit switches
  - Sophisticated robots use closed-loop position systems for all joints

Classification of Control System



Classification of Control System



Objectives Completed

- ✓ Distinguish between open-loop and closed-loop control systems
- ✓ Understand control system block diagrams
- ✓ Explain transfer functions
- ✓ Differentiate between analog and digital control systems
- ✓ Know how process control systems work
- ✓ Know how servomechanisms work