Introduction to Control Systems

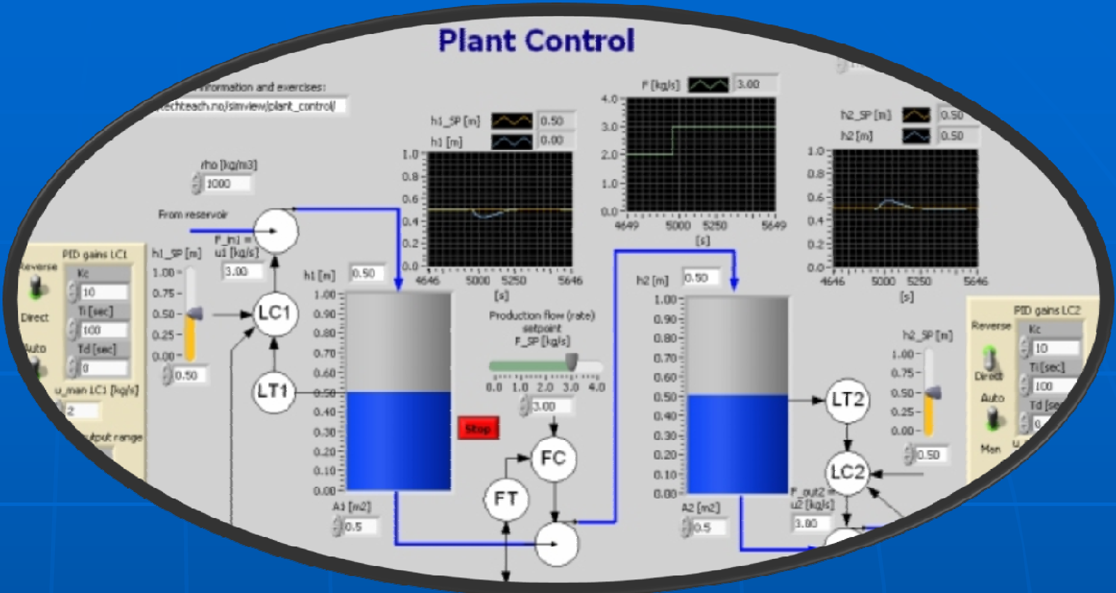
OBJECTIVES

After studying this chapter, you should be able to:

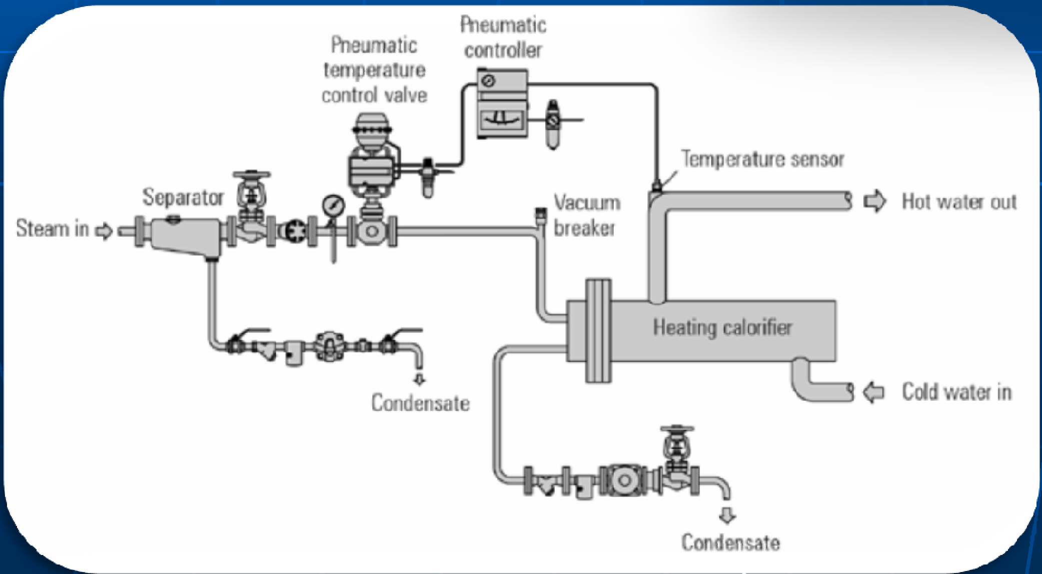
- Distinguish between open-loop and closed-loop control systems.
- Understand control system block diagrams.
- Explain transfer functions.
- Differentiate between analog and digital control systems.
- Know how process control systems work.
- Know how servomechanisms work.

ชนิดของระบบควบคุม

regulator system



การควบคุมระดับ ,อัตราการไหลในกระบวนการผลิต



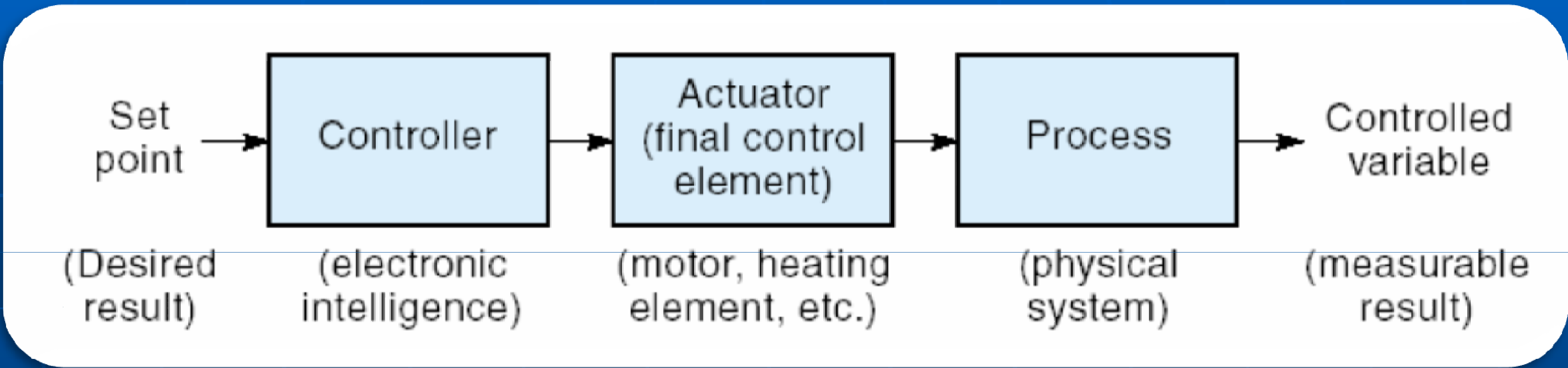
การควบคุมอุณหภูมิอุปกรณ์แลกเปลี่ยนความร้อน

follow-up system

ระบบติดตามดวงอาทิตย์แผงโซลาร์เซล

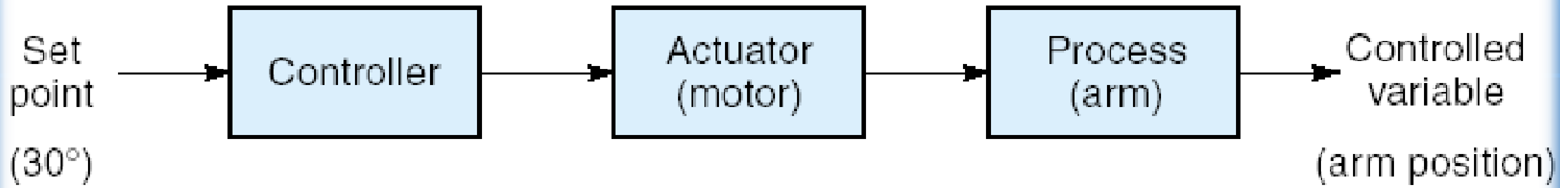
แขนกลหุ่นยนต์เชื่อมงานโลหะ

ส่วนประกอบระบบควบคุม(control system)

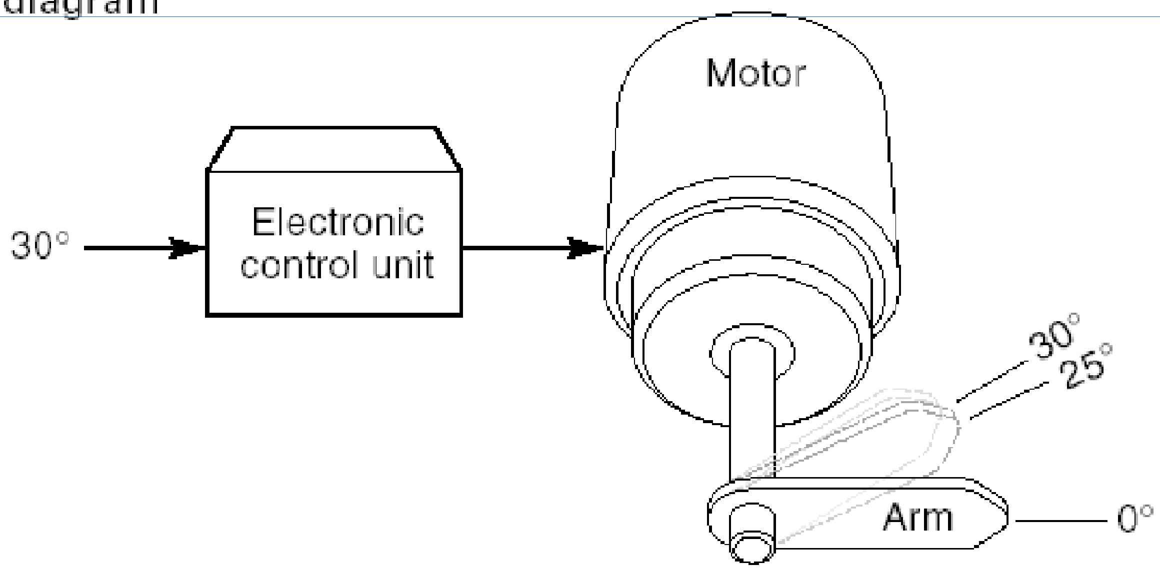


Block diagram of a control system

Open-Loop Control Systems

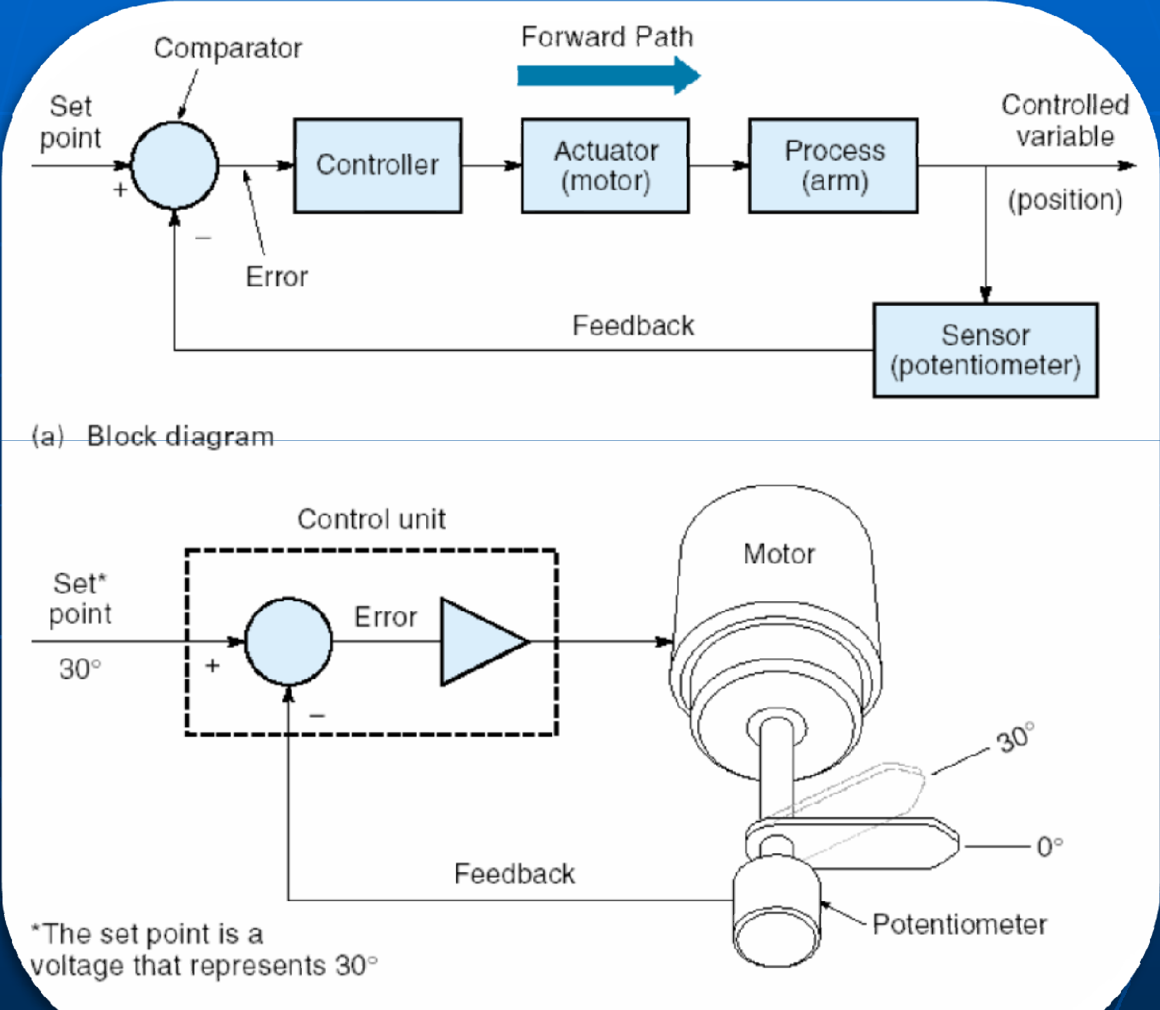


(a) Block diagram



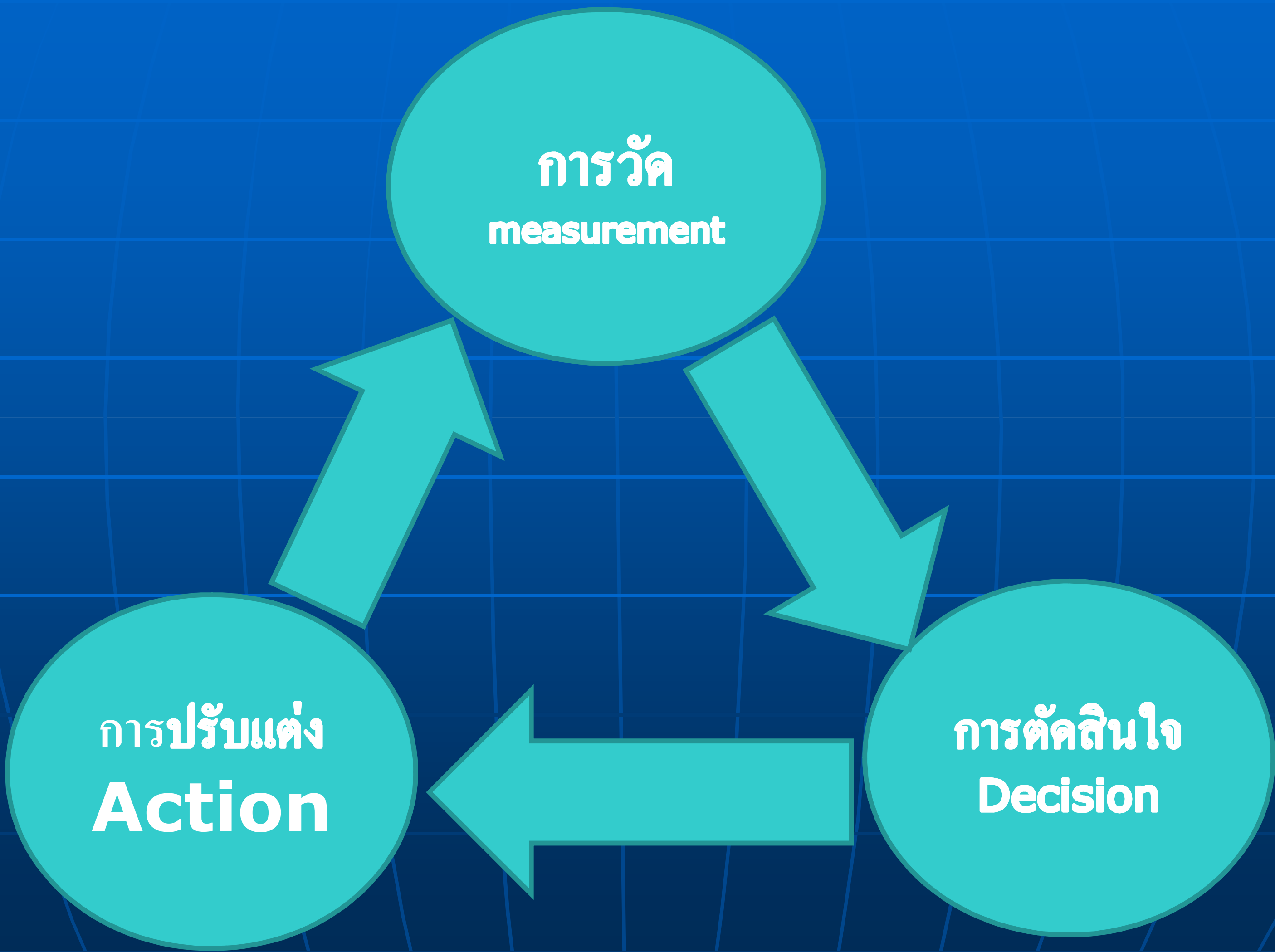
(b) A simple open-loop position system (Example 1.1)

Closed-Loop Control Systems



A simple closed-loop position system (Example 1.2)

การทำงานลูปปิดทำงานอย่างไร



Open Vs. Closed Loop Systems

- OPEN LOOP
  - Simple Design
  - Accuracy dependant on calibration
  - Unlikely to become unstable
- Closed Loop
  - More accurate
  - Less sensitive to changes in environment
  - Smooth response
  - Can become unstable

Advantages of a Closed-Loop Feedback System

- **Increased Accuracy**
  - Increased ability to reproduce output with varied input.
- **Reduced Sensitivity to Disturbance**
  - Self-correcting minimizes effects of system changes.
- **Smoothing and Filtering**
  - System induced noise and distortion are reduced.
- **Increased Bandwidth**
  - Produces sat. response to increased range of input changes.

Transfer Functions

- A **transfer function** (TF) is a mathematical relationship between the input and output of a control system component.

$$\mathrm{TF} = \frac{\text{output}}{\text{input}} \tag{1.1}$$

$$\mathrm{TF}_{\text{steady-state}} = \text{gain} = \frac{\text{steady-state output}}{\text{steady-state input}} \tag{1.2}$$

EXAMPLE 1.3

A potentiometer is used as a position sensor [see Figure 1.3(b)]. The pot is configured in such a way that 0° of rotation yields 0 V and 300° yields 10 V. Find the 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 volts:

$$\text{TF} = \frac{\text{output}}{\text{input}} = \frac{10\text{ V}}{300^\circ} = 0.0333\text{ V/deg}$$

The transfer function of a component is an extremely useful number. It allows you to calculate the output of a component if you know the input. The procedure is simply to multiply the transfer function by the input, as shown in Example 1.4.

EXAMPLE 1.4

For a temperature-measuring sensor, the input is temperature, and the output is voltage. The sensor transfer function is given as 0.01 V/deg. Find the sensor-output voltage if the temperature is 600°F.

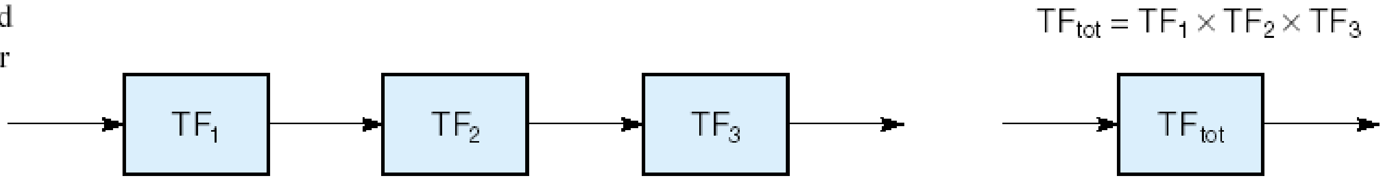
SOLUTION

If $TF = \frac{\text{output}}{\text{input}}$, then

$$\text{Output} = \text{input} \times TF$$

$$= \frac{600^\circ \times 0.01\ \text{V}}{\text{deg}} = 6\ \text{V}$$

Figure 1.4
A series of transfer functions reduced to a single tranfer function.



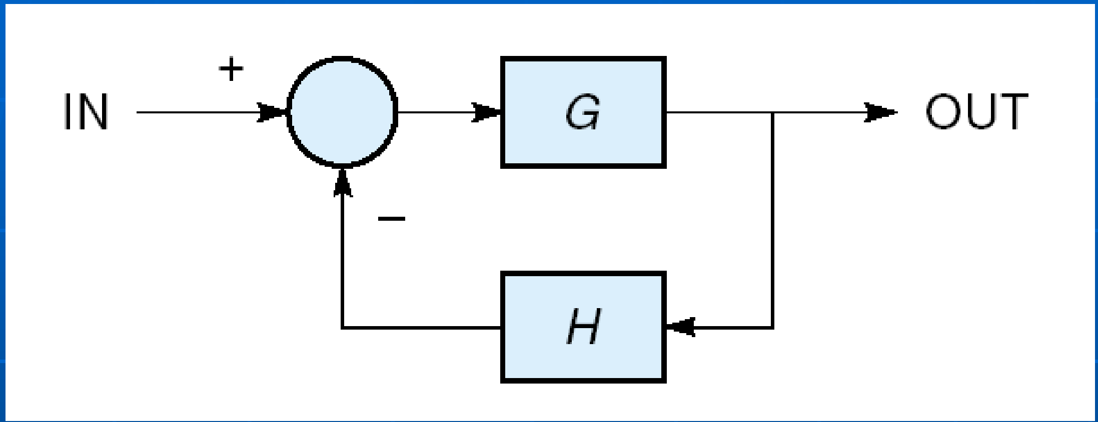
(a) Individual transfer functions (b) Combined transfer function

$$TF_{tot} = \text{system gain} = TF_1 \times TF_2 \times TF_3 \times \ldots \quad (1.3)$$

where

TF_{tot} = total steady-state transfer function for the entire (open-loop) system

$TF_1, TF_2, \ldots$ = individual transfer functions

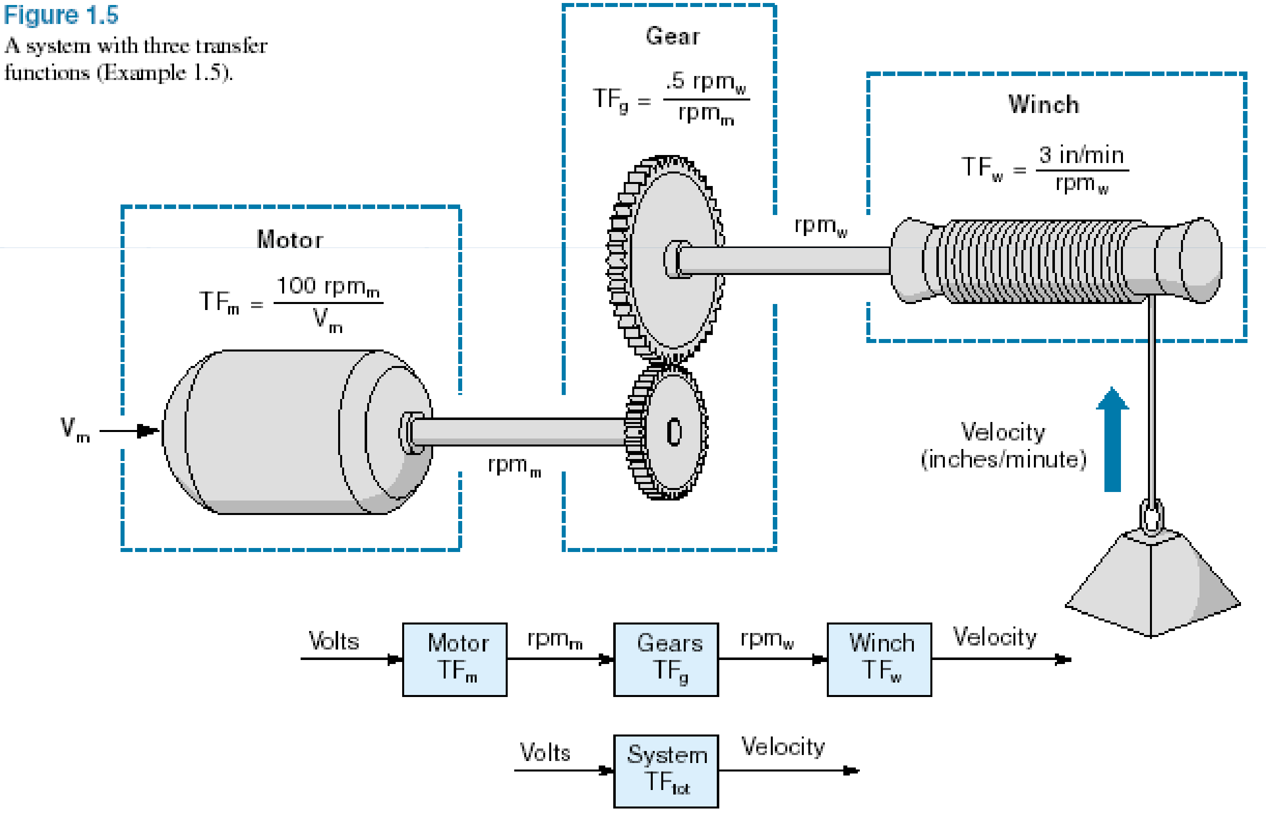


*Equation 1.3 is for open-loop systems only. If there is a feedback path (as shown in the accompanying diagram), then the overall system gain can be calculated as follows: $TF_{tot} = G/(1 + GH)$, where G is the total gain of the forward path and H is the total gain of the feedback path.

EXAMPLE 1.5

Consider the system shown in Figure 1.5. 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

Figure 1.5
A system with three transfer functions (Example 1.5).



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$$TF_{tot} = TF_m \times TF_g \times TF_w$$

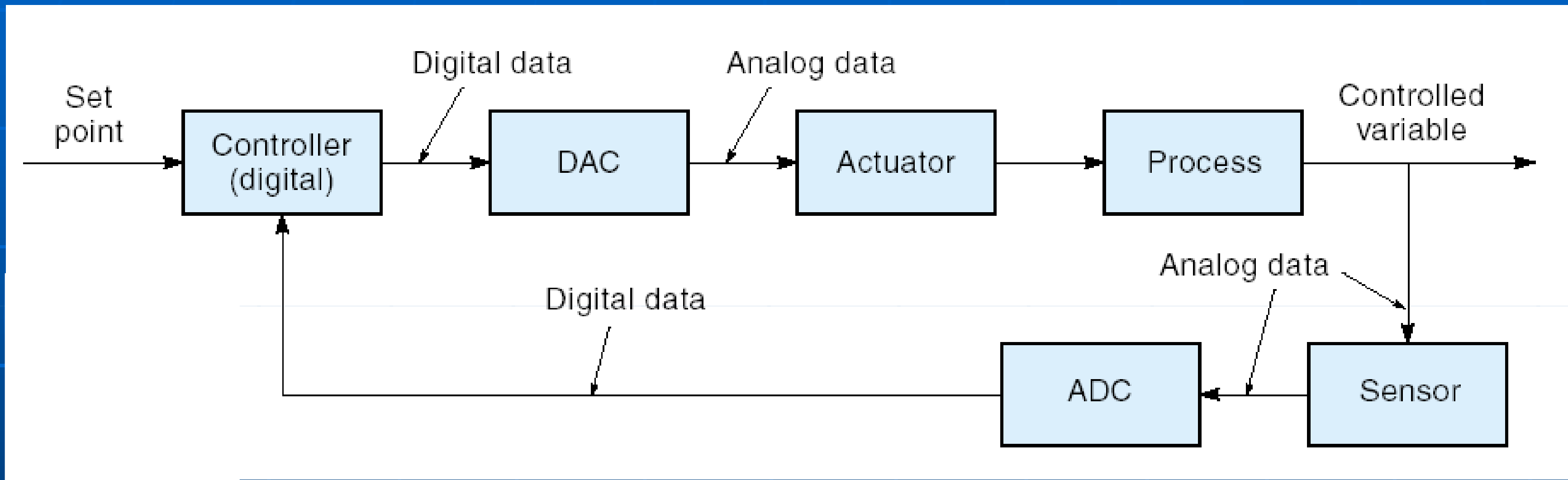
$$= \frac{100 \text{ rpm}_m}{1 \text{ V}_m} \times \frac{0.5 \text{ rpm}_w}{1 \text{ rpm}_m} \times \frac{3 \text{ in./min}}{1 \text{ rpm}_w}$$

$$= 150 \text{ in./min/V}_m$$

We have shown that the transfer function of the complete system is 150 in./min/V_m. *Knowing this value, we can calculate the system output for any system input.* For example, if the input to the this system is 12 V (to the motor), the output speed of the winch is calculated as follows:

$$\text{Output} = \text{input} \times \text{TF} = \frac{12 \text{ V} \times 150 \text{ in./min}}{1 \text{ V}_m} = 1800 \text{ in./min}$$

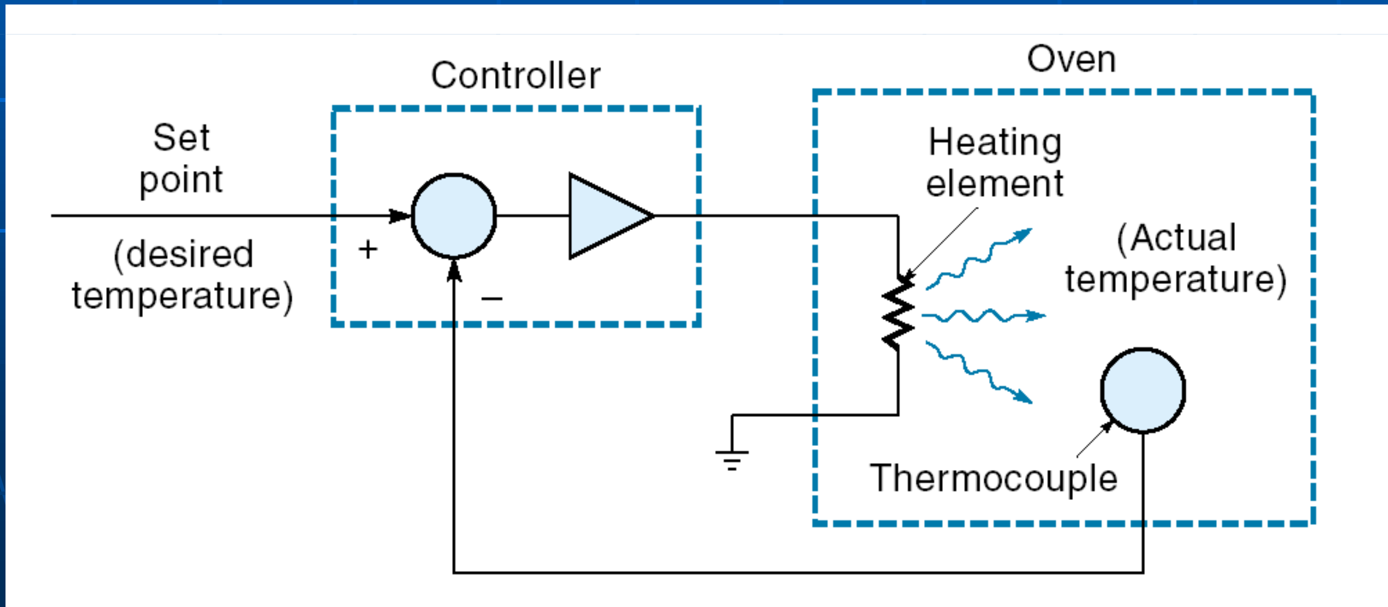
ANALOG AND DIGITAL CONTROL SYSTEMS



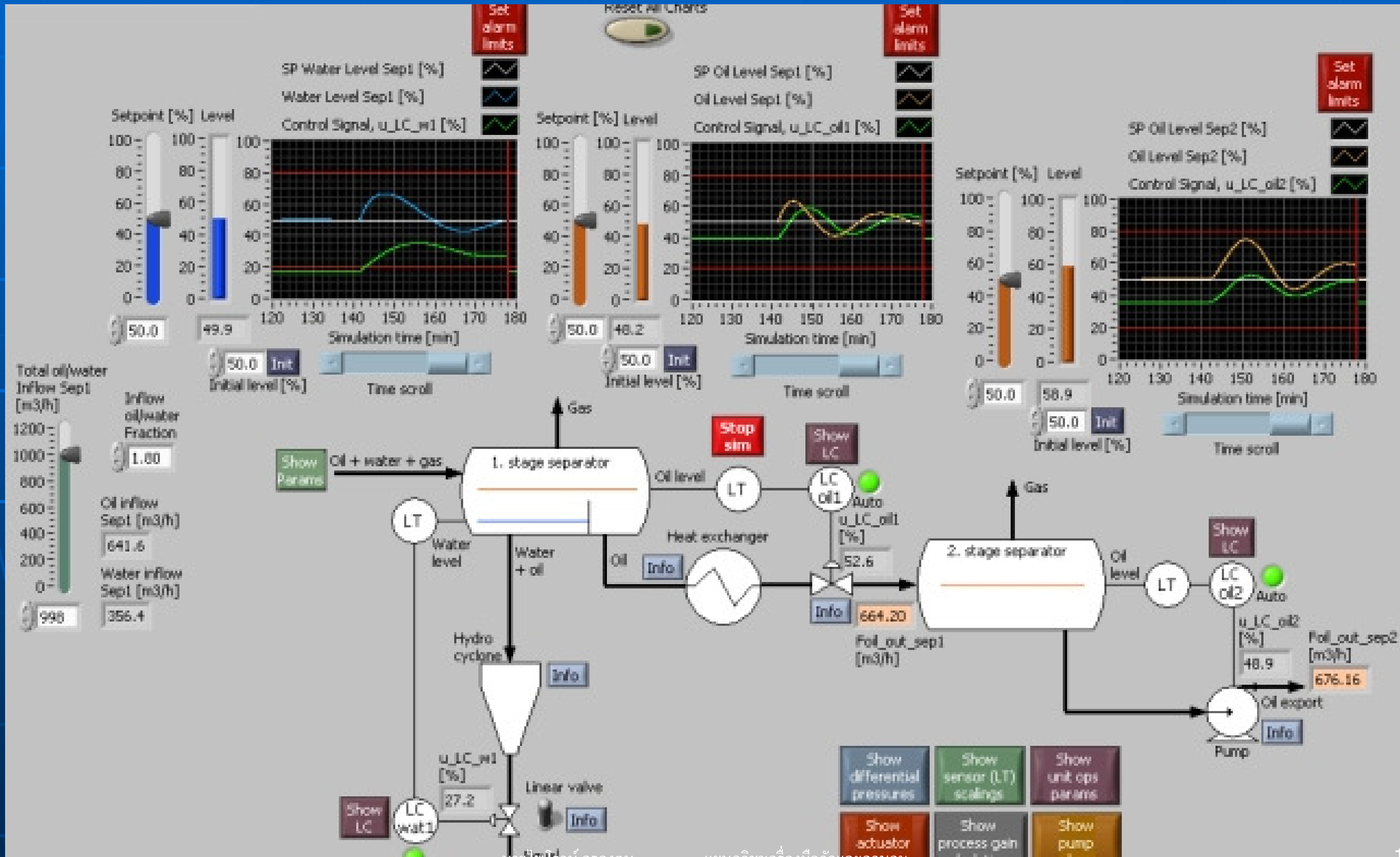
CLASSIFICATIONS OF CONTROL SYSTEMS

Process Control

- continuous process
- batch process

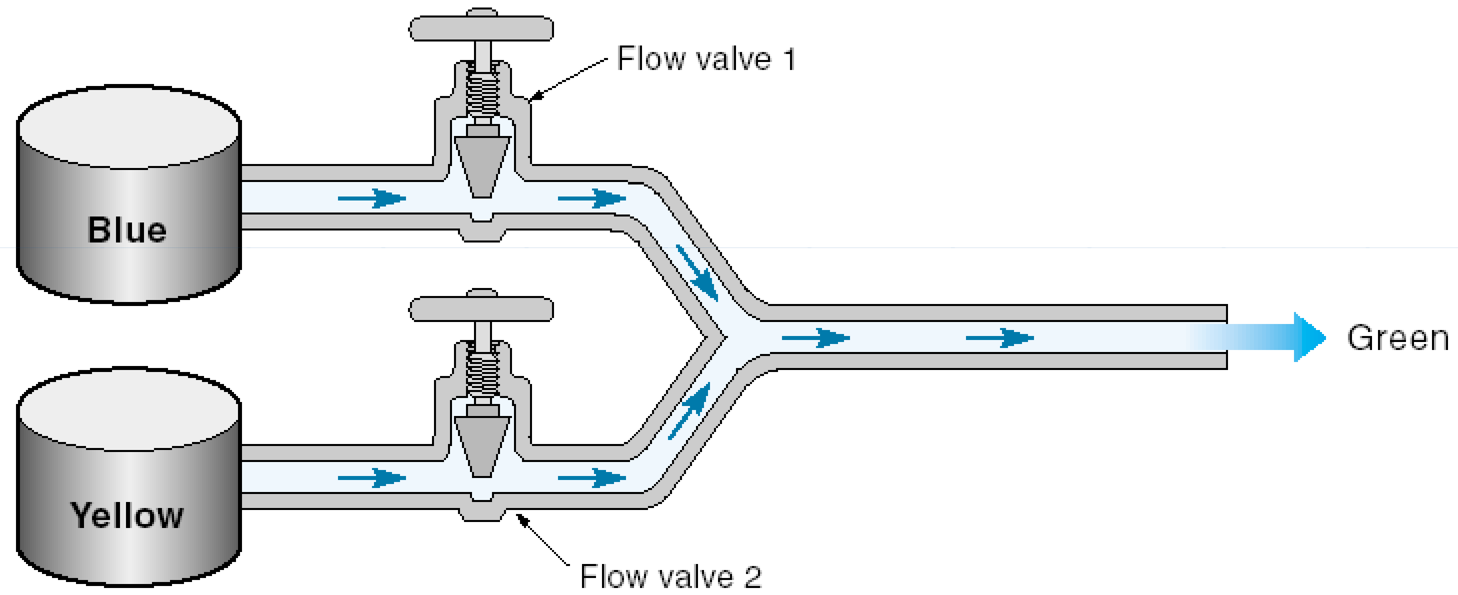


continuous process



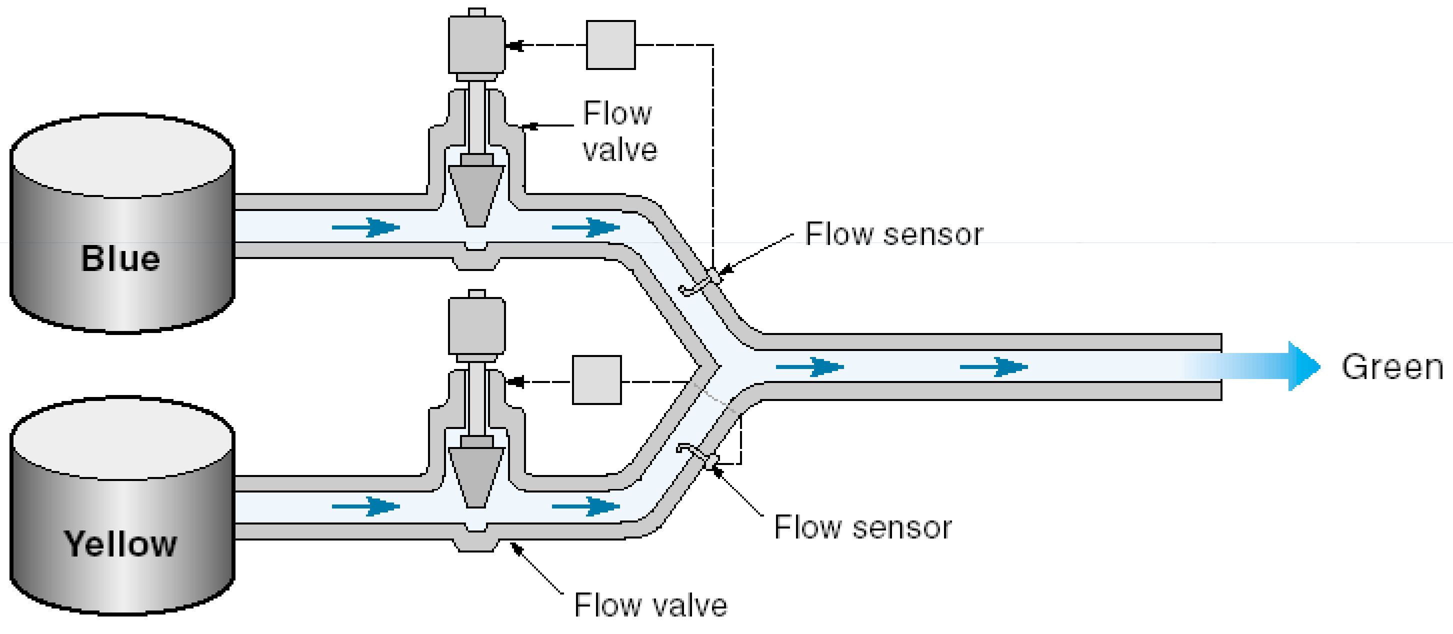
batch process

Process control in mixing paint



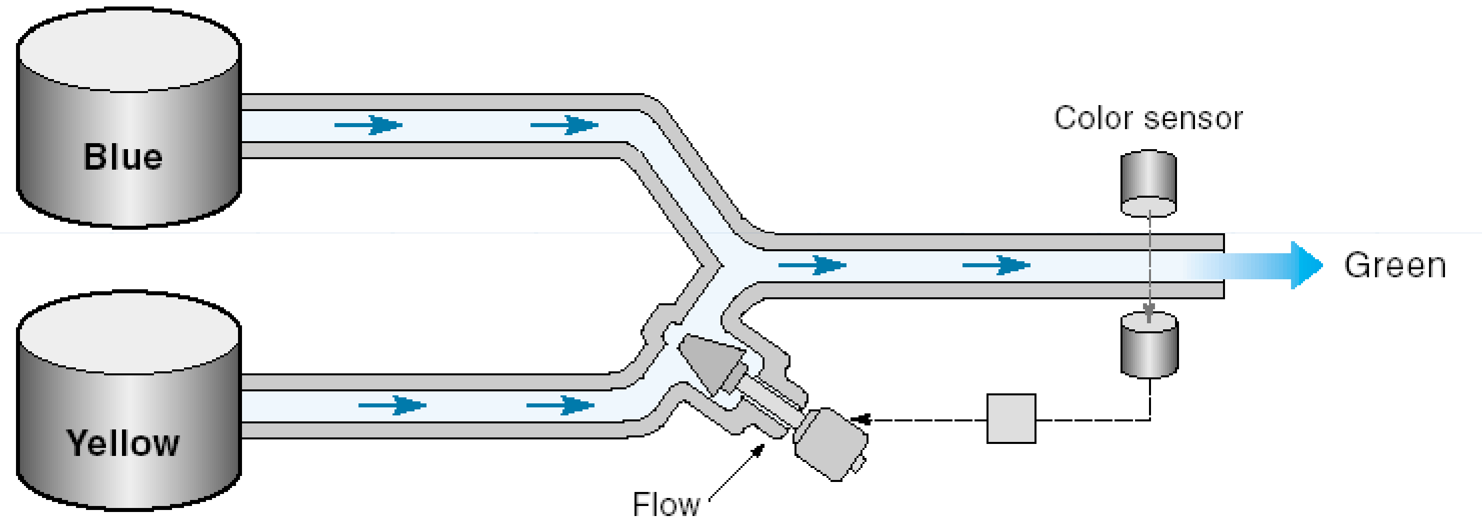
(a) Manual control

Process control in mixing paint



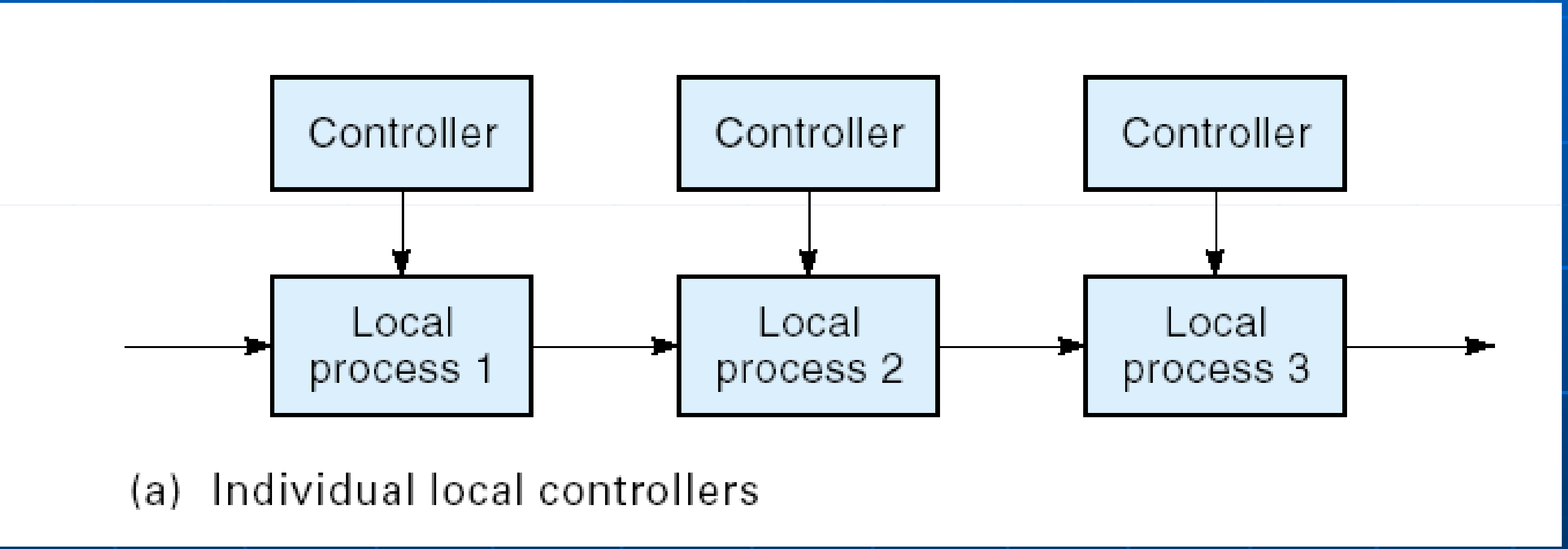
(b) Automatic flow control

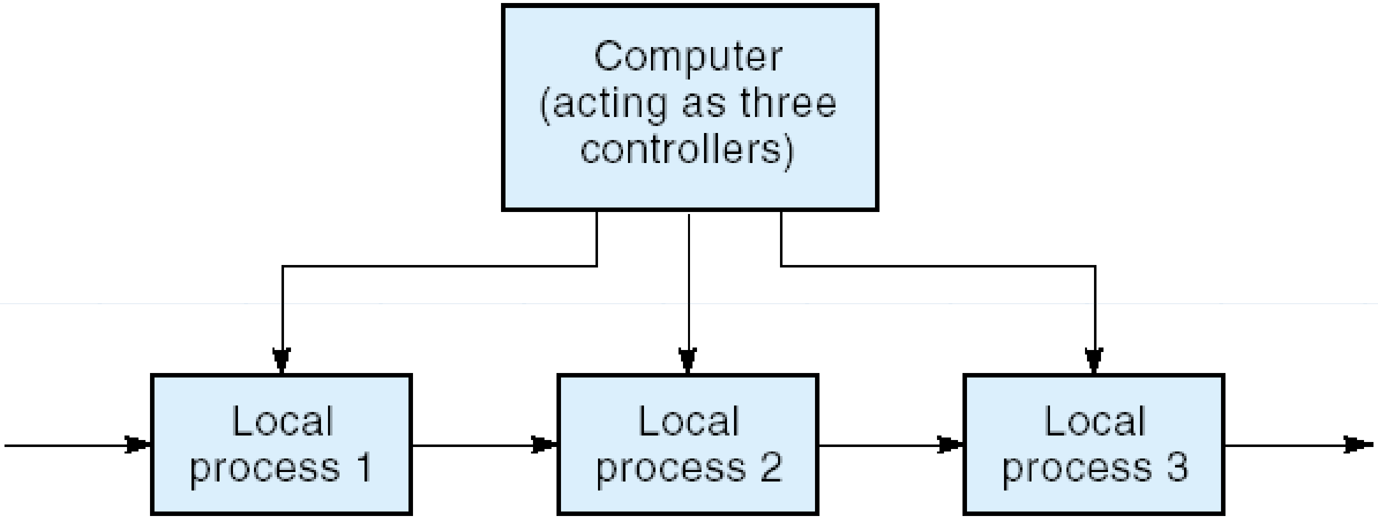
Process control in mixing paint



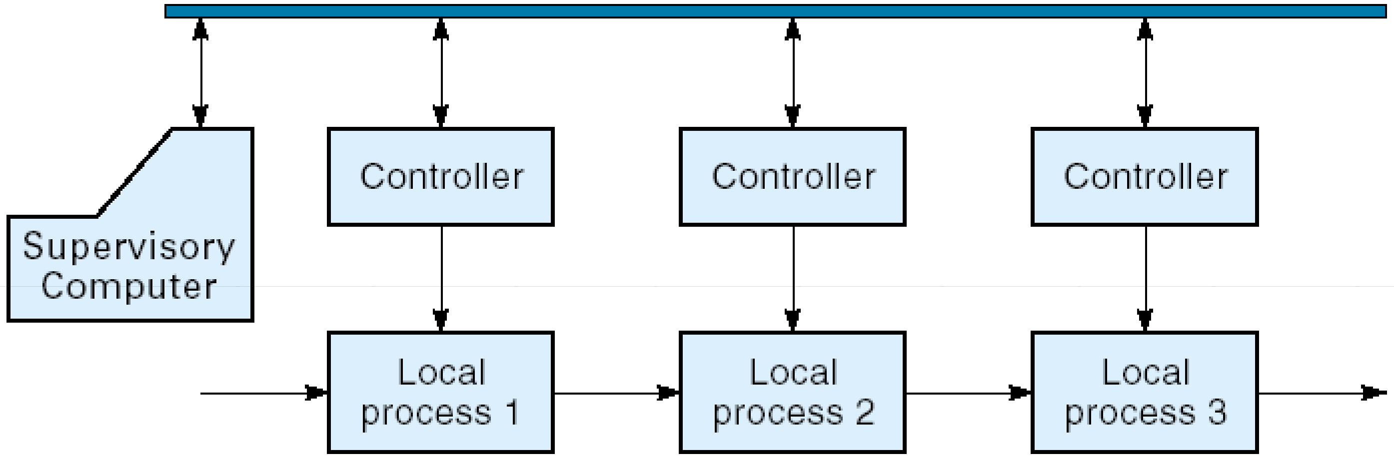
(c) Automatic color control

Approaches of multiprocess control





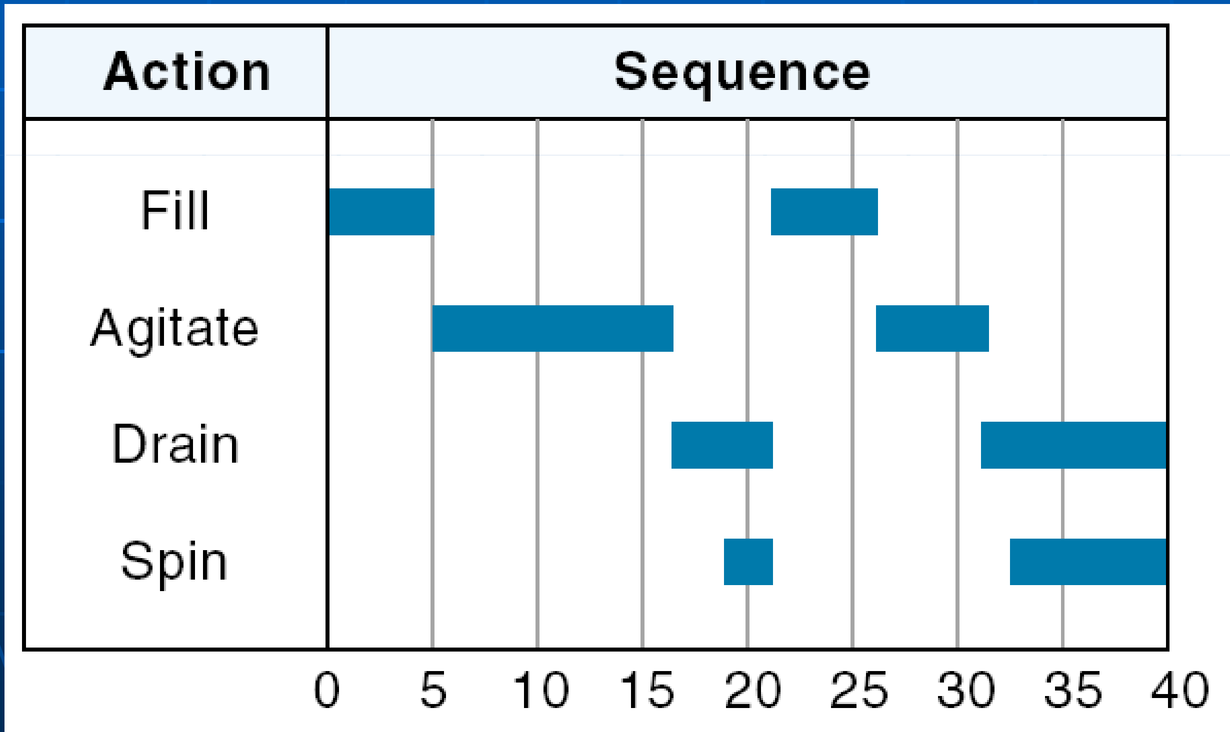
(b) Direct computer control of three processes



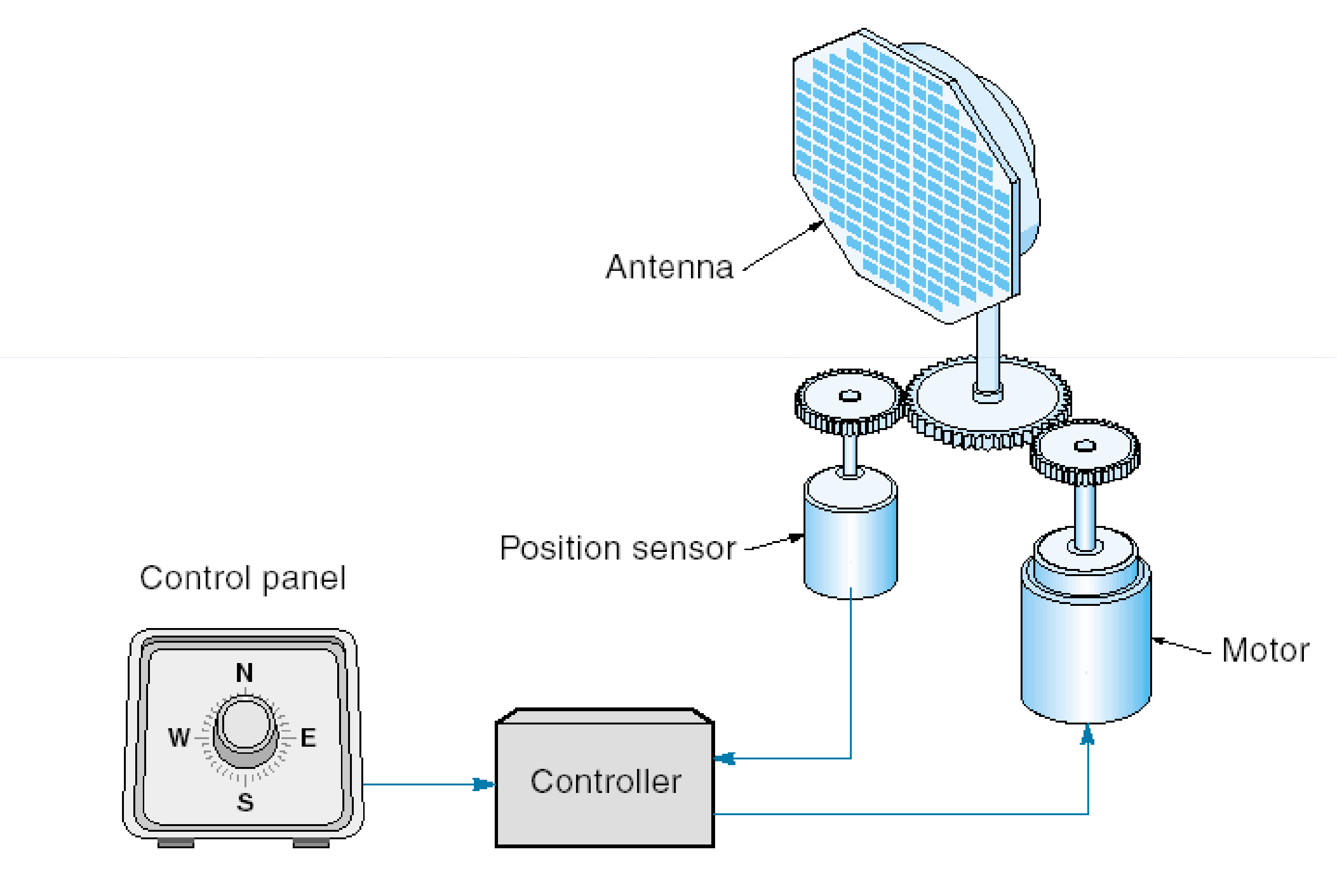
(c) Distributed computer control using local controllers

Sequentially Controlled Systems

- time-driven,
- event-driven.



Servomechanisms



Numerical control (NC)

computer-aided design (CAD),

computer-aided manufacturing(CAM).

computer-integrated manufacturing (CIM),

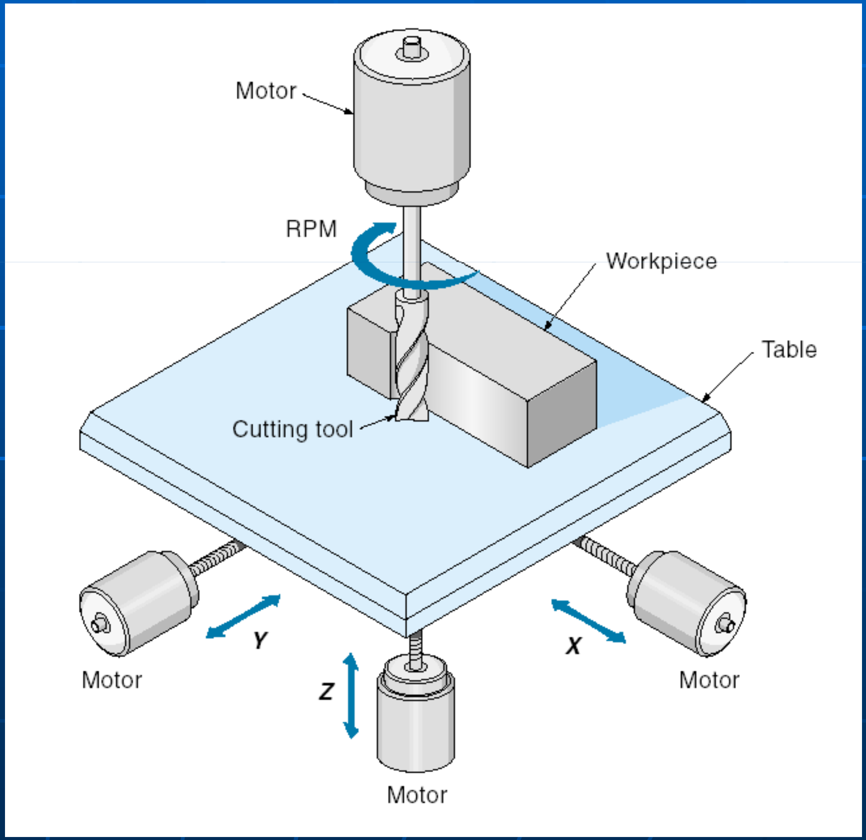
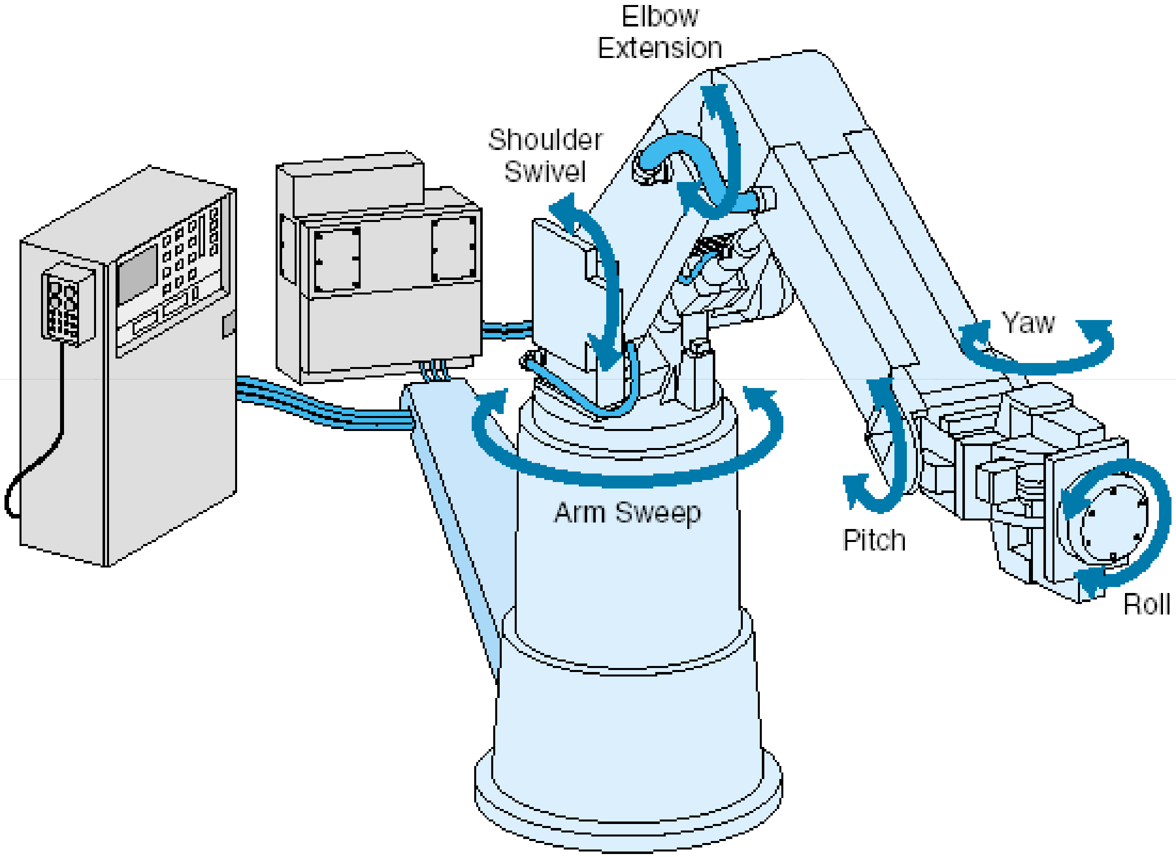


Figure 1.14
A large industrial robot.



Questions?

SUMMARY

- **GLOSSARY**
  - **actuator** The first component in the control system which generates physical movement, typically a motor. The actuator gets its instructions directly from the controller. Another name for the actuator is the *final control element*
  - **analog control system** A control system where the controller is based on analog electronic circuits, that is, linear amplifiers.
  - **batch process** A process that has a beginning and an end and is usually preformed over and over.
  - **CAD** See **computer-aided design.**
  - **CAM** See **computer-aided manufacturing.**

GLOSSARY

- **CIM** See **computer-integrated manufacturing.**
- **closed-loop control system** A control system that uses feedback. A sensor continually monitors the output of the system and sends a signal to the controller, whic makes adjustments to keep the output within specification.
- **comparator** Part of the control system that subtracts the feedback signal (as reported by the sensor) from the set point, to determine the error.
- **computer-aided design** A computer system that makes engineering drawings.
- **computer-aided manufacturing** A computer system that allows CAD drawings to be converted for use by a numerical control (NC) machine tool.
- **computer-integrated manufacturing** A computer system that oversees every step in the manufacturing process, from customer order to delivery of finished parts.
- **continuous process** A process wherein there is a continuous flow of product—for example, a steam boiler where water is continuously pumped in and steam continuously comes out.