Automatic Control

By

Dr. Ayman Yousef

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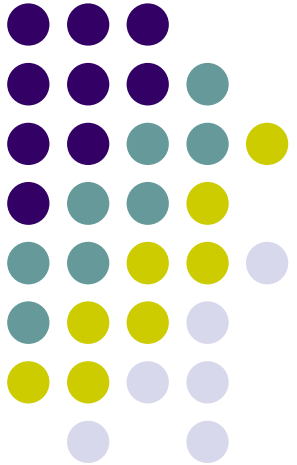

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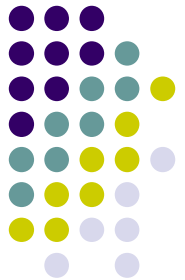
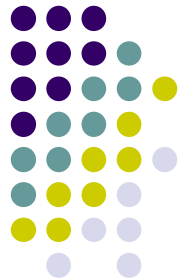


- ***CH1**: Introduction to control systems*
- ***CH2**: Laplace Transformation*
- ***CH3**: Block diagrams & Signal flow graphs*
- ***CH4**: Modeling of control systems*
- ***CH5**: Time domain analysis*
- ***CH6**: Stability of control systems*
- ***CH7**: Digital control sytems*

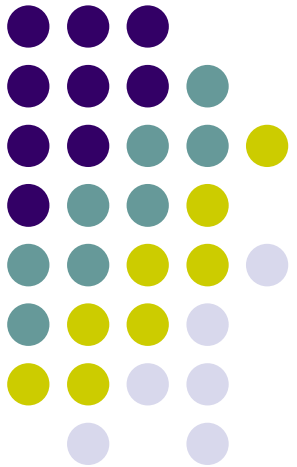
References



- Bengamin C. Kuo, **“Automatic Control Systems”**, 9th Edition
- Katsuhiko Ogata, **“Modern *Control* Engineering”**, 5th Edition.

Chapter 1

Introduction to control systems



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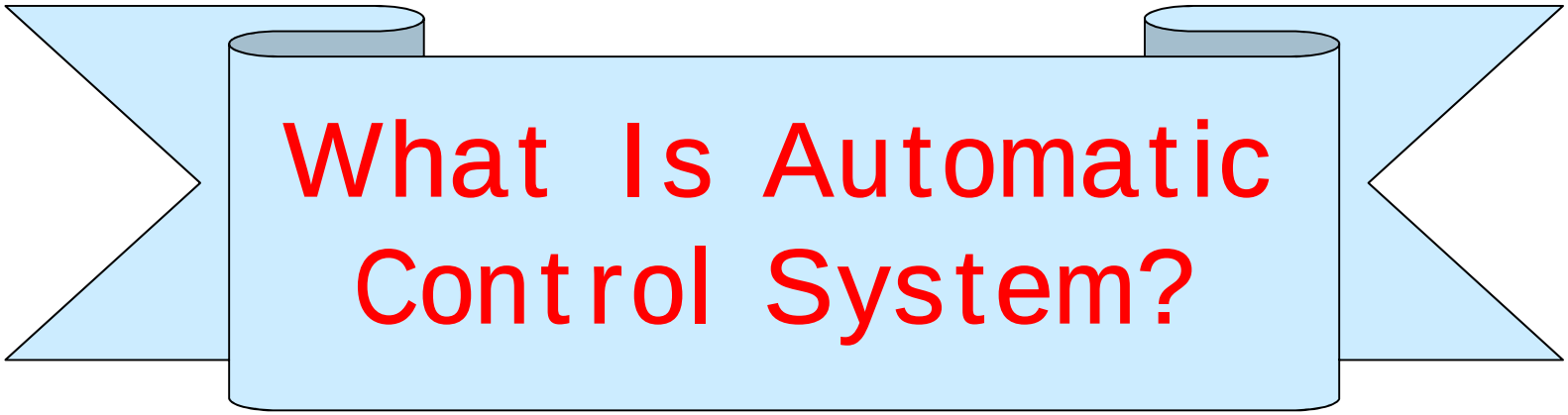
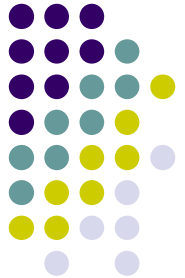

What Is Automatic Control System?

Automatic Control System ...



A process in which the output is kept at desired level by using feedback from the output to control the input.

The control system …

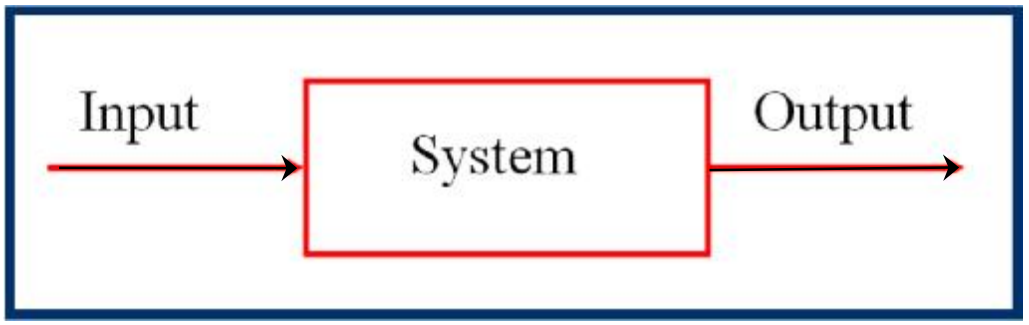
The control system is interconnection of several components all working together to perform a certain Function. This function needs Signal to be performed.

Function means control of the speed, temp, position, voltage, pressure...etc.

Signal is the actuating signal. يل إثدوالظ تشغ

System To Be Controlled !!!!

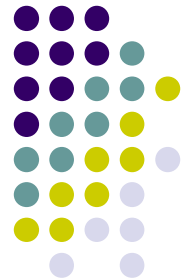
A System is a device or process that takes a given input "Signal" and produces some output "Function":



DC motor takes as input a voltage … "Signal" and produces as output rotary motion … "Function".


Why We Need
a Control System?

When we must need a control system?



We need a control system when a large amount of energy or power wanted to be controlled with a smaller amount of energy or power.

Examples:

* The aircraft has a weight of 158000 kg: control system is used to climb the aircraft to 6 km.
* Turning a key in the automobile: can start 300 hp engine.
* The air conditioner: controlling the room temperature by turning a knob on the air conditioner.
* Antenna-rotor system: the direction of the antenna on the roof can be controlled using simple dial adjustment on top of the TV.


Basic Components of
a Control System?

Basic Components of a Control System

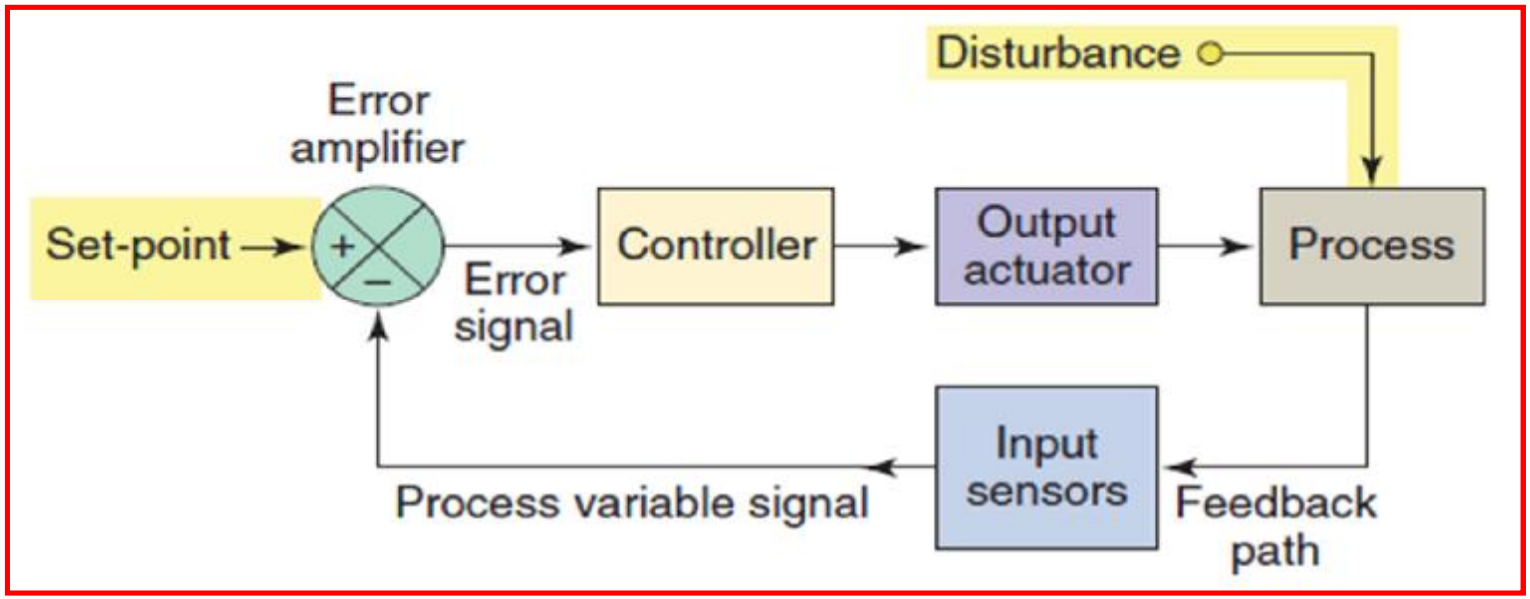


Figure illustrates an example of a closed-loop control system. The actual output is sensed and fed back to be subtracted from the set-point input that indicates what output is desired. If a difference occurs, a signal to the controller causes it to take action to change the actual output until the difference is 0.

System Components

- **Set-point** — The input that determines the desired operating point for the process.
- **Process Variable** — Refers to the feedback signal that contains information about the current process status.
- **Error Amplifier** — Determines whether the process operation matches the set-point. The magnitude and polarity of the error signal will determine how the process will be brought back under control.

System Components

- **Controller** — Produces the appropriate corrective output signal based on the error signal input.
- **Output Actuator** — The component that directly affects a process change. Examples are motors, heaters, fans, and solenoids.
- **Process** — The action that obtained, may be Motion or Heating or Filling … etc.
- **Sensor** — A device for used for detecting, and often measuring, the magnitude of something. They convert mechanical, magnetic, thermal, optical, and chemical variations into electric voltages and currents.

Actuating devices

Actuator produces an action: converts an electrical signal into mechanical movement

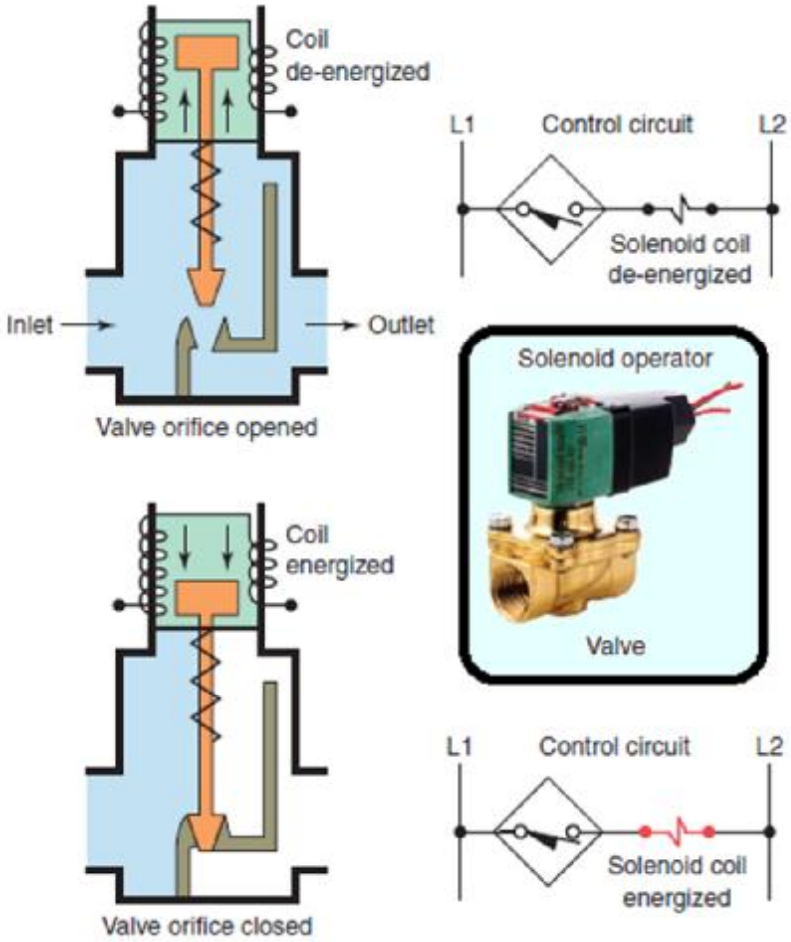


Figure 6-40 Solenoid valve construction and operation.
Source: Photo courtesy ASCO Valve Inc., **www.ascovalve.com**.

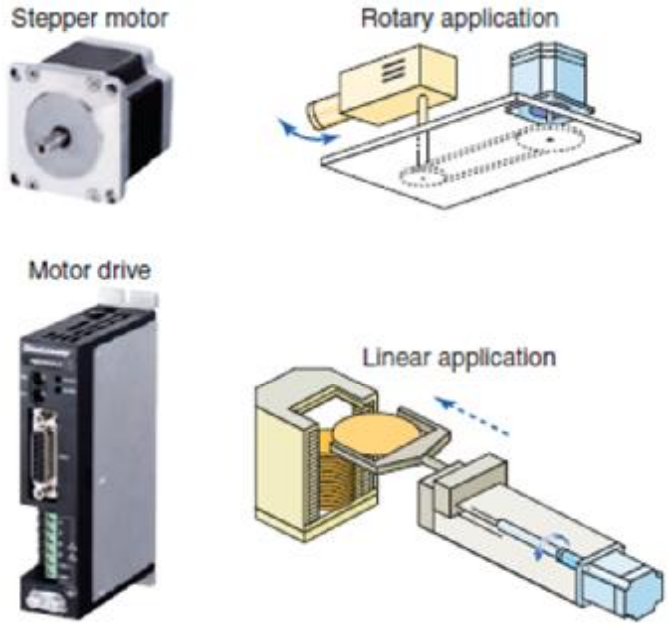


Figure 6-41 Stepper motor/drive unit.
Source: Photos courtesy Oriental Motor, **www.orientalmotor.com**.

Sensing device

A device for used for detecting, and often measuring, the magnitude of something. They convert mechanical, magnetic, thermal, optical, and chemical variations into electric voltages and currents.

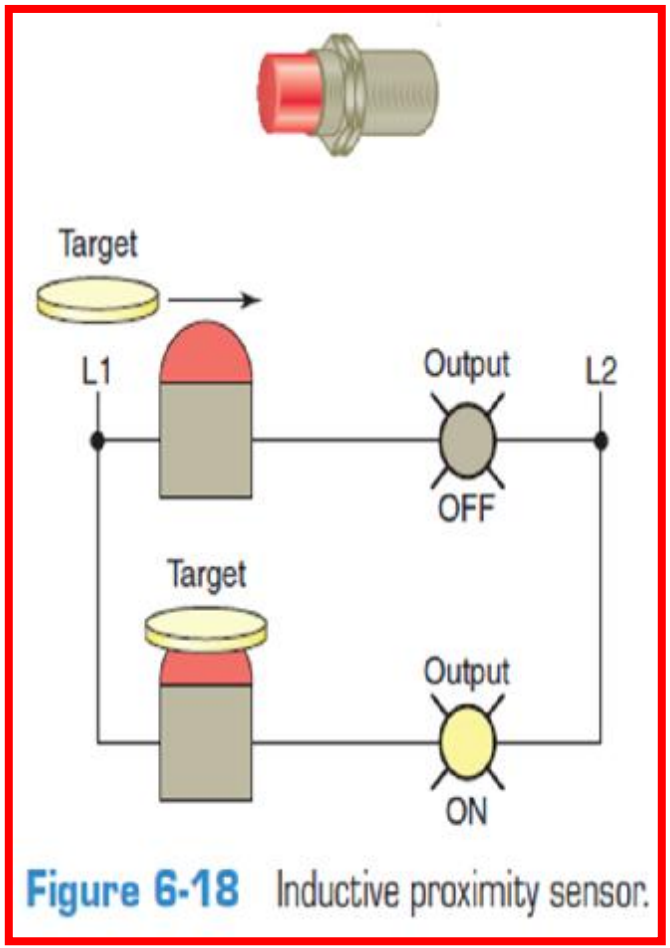


Figure 6-18 Inductive proximity sensor.

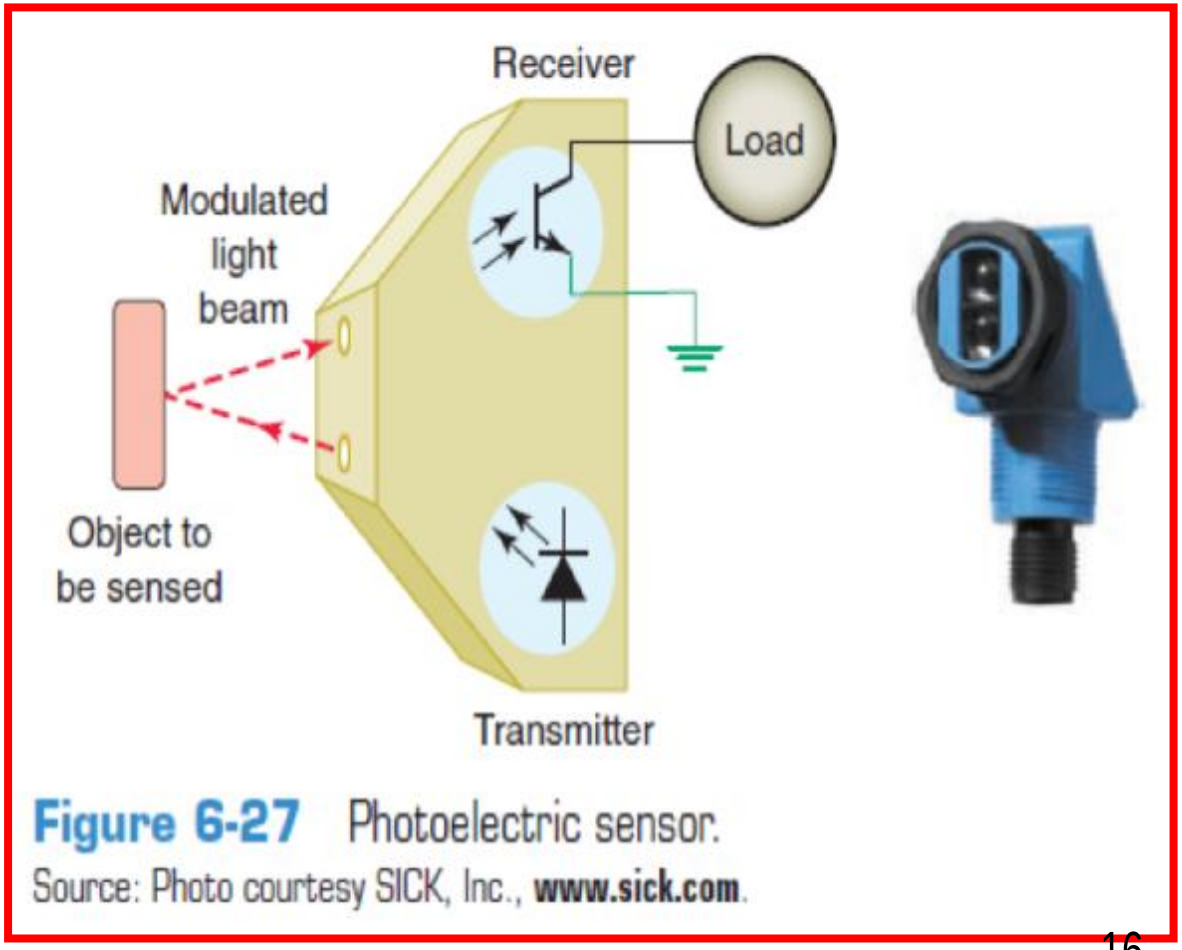


Figure 6-27 Photoelectric sensor.
Source: Photo courtesy SICK, Inc., **www.sick.com**.

Sensing device

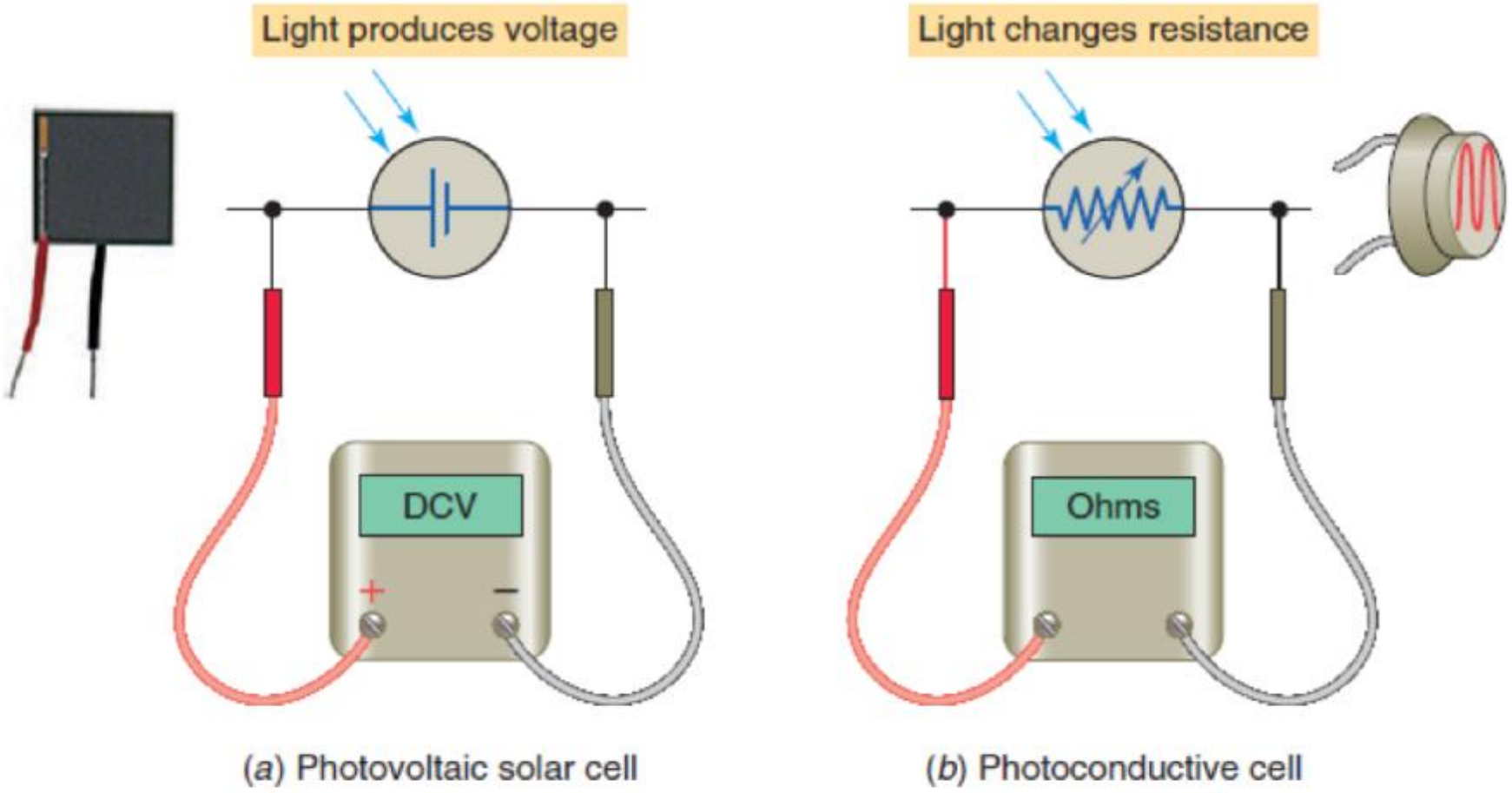


Figure 6-26 Photovoltaic and photoconductive light cells.

Sensing device

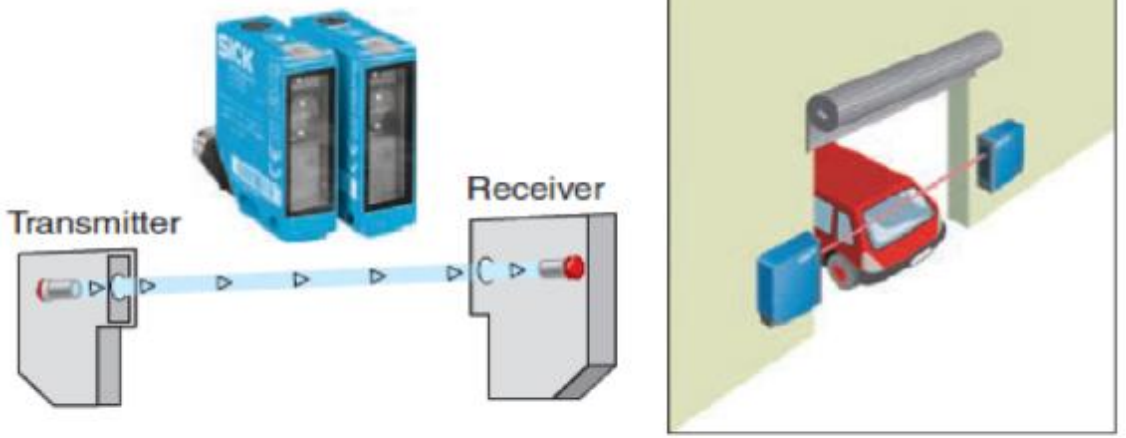


Figure 6-28 Through-beam scan.
Source: Photo courtesy SICK, Inc., **www.sick.com**.

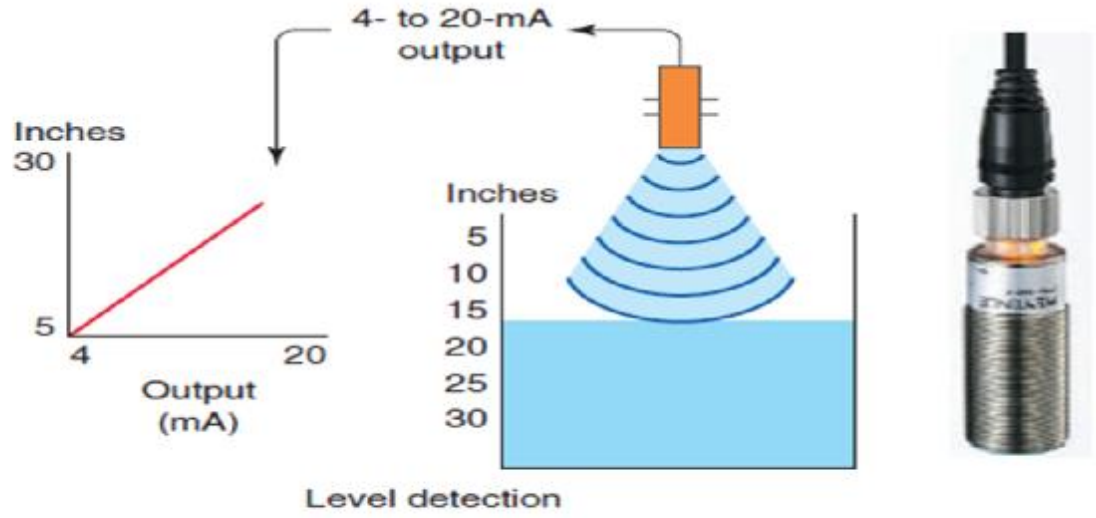


Figure 6-32 Ultrasonic sensor.
Source: Courtesy Keyence Canada, Inc.

Sensing device

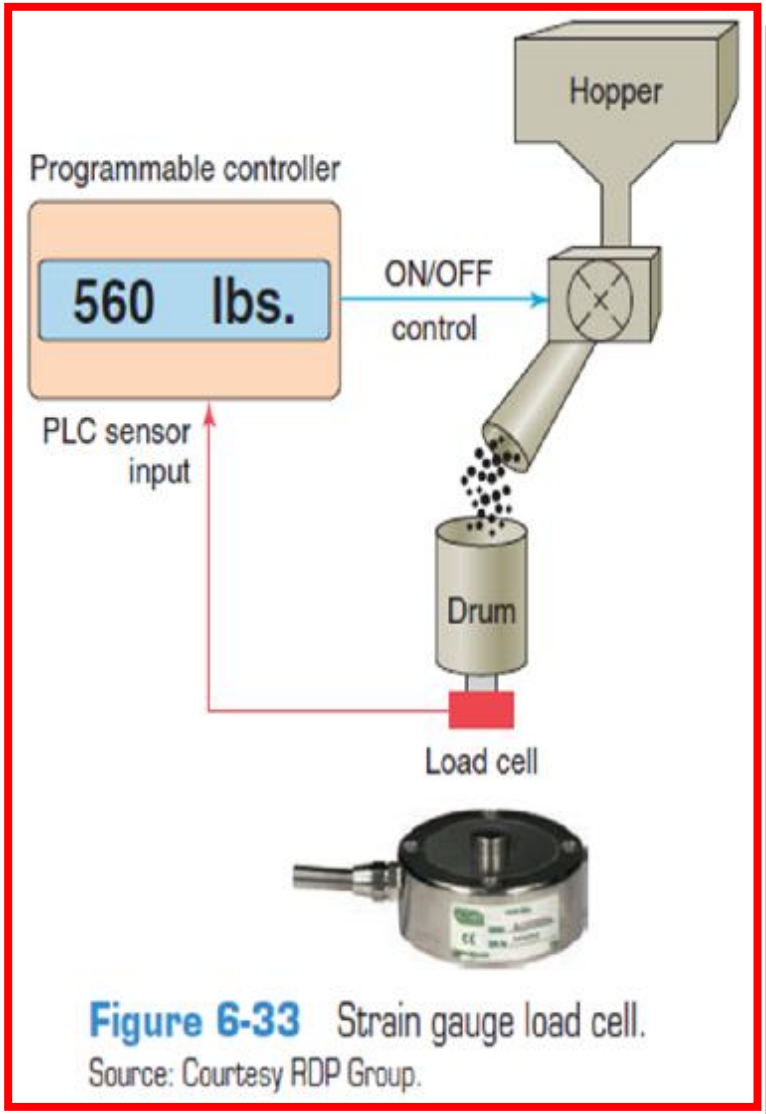


Figure 6-33 Strain gauge load cell.
Source: Courtesy RDP Group.

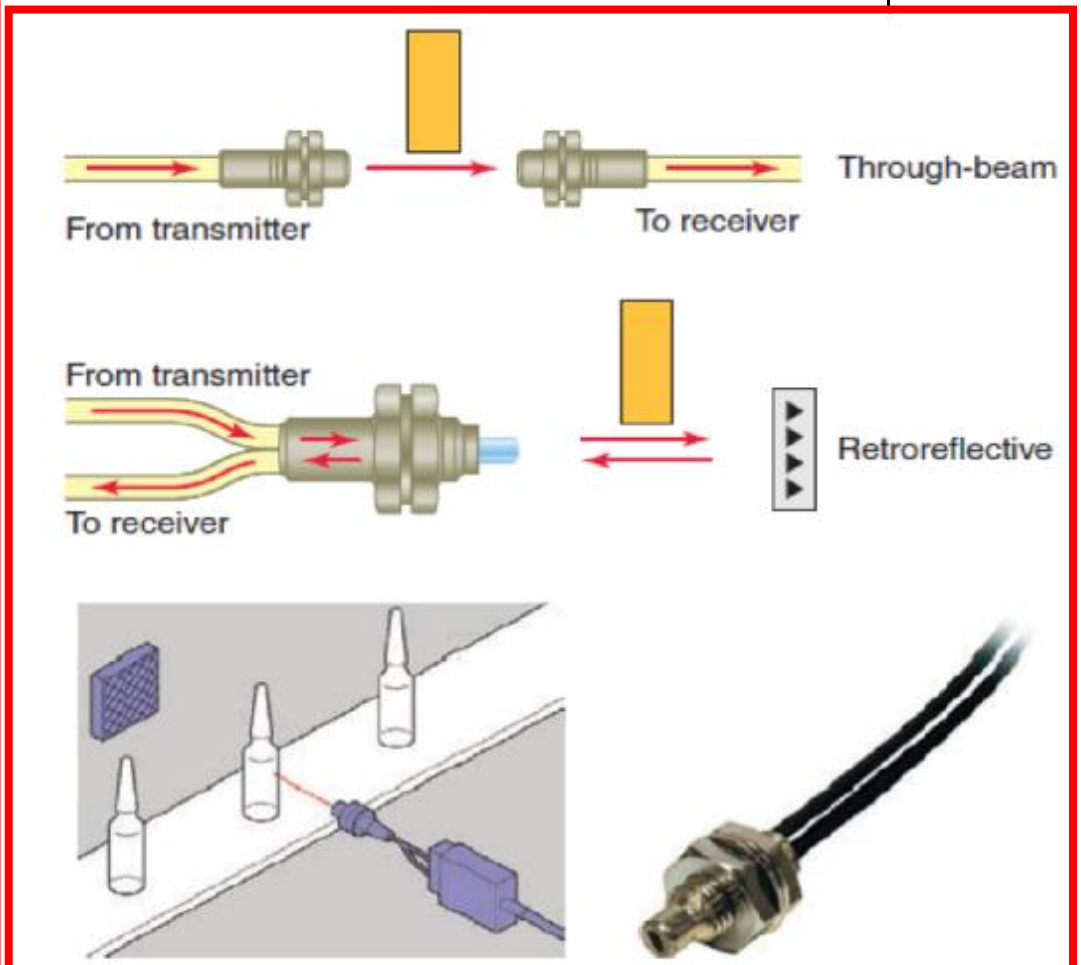
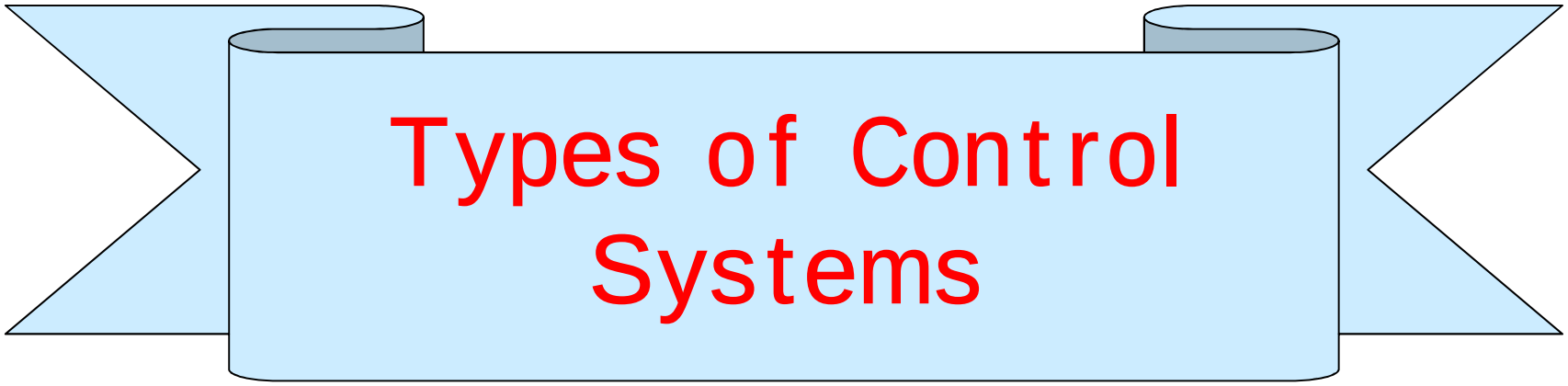
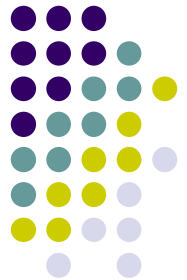


Figure 6-30 Fiber optic sensors.
Source: Photo courtesy Omron Industrial Automation, **www.ia.omron.com**

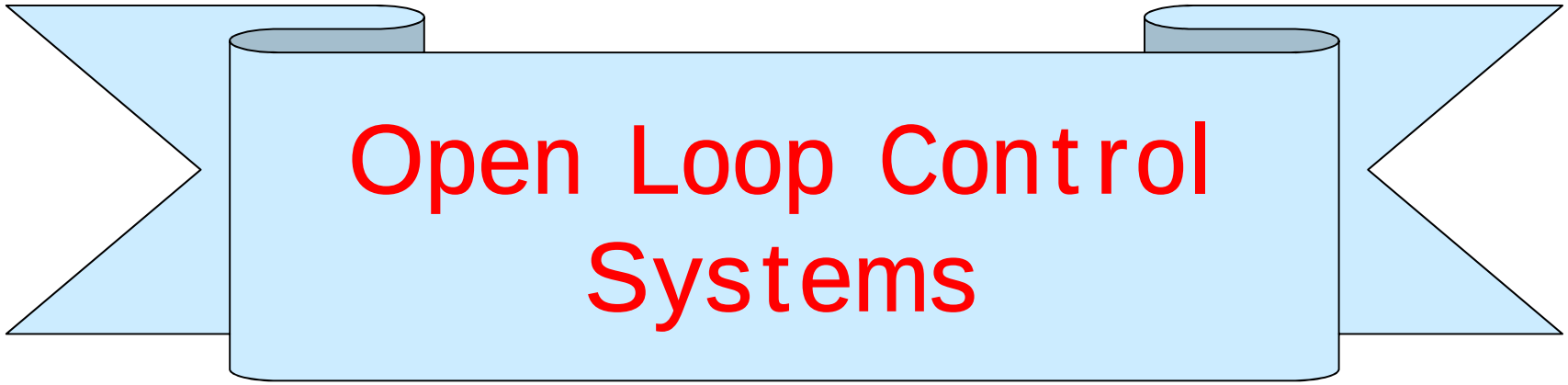

Types of Control Systems

Types of Control Systems

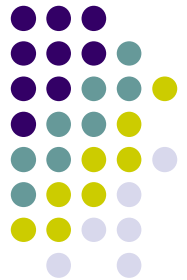


Control Systems can be classified as :

- **Open loop system** (No feedback System)
- **Closed loop system** (Feedback System).


Open Loop Control Systems

Open Loop Control Systems

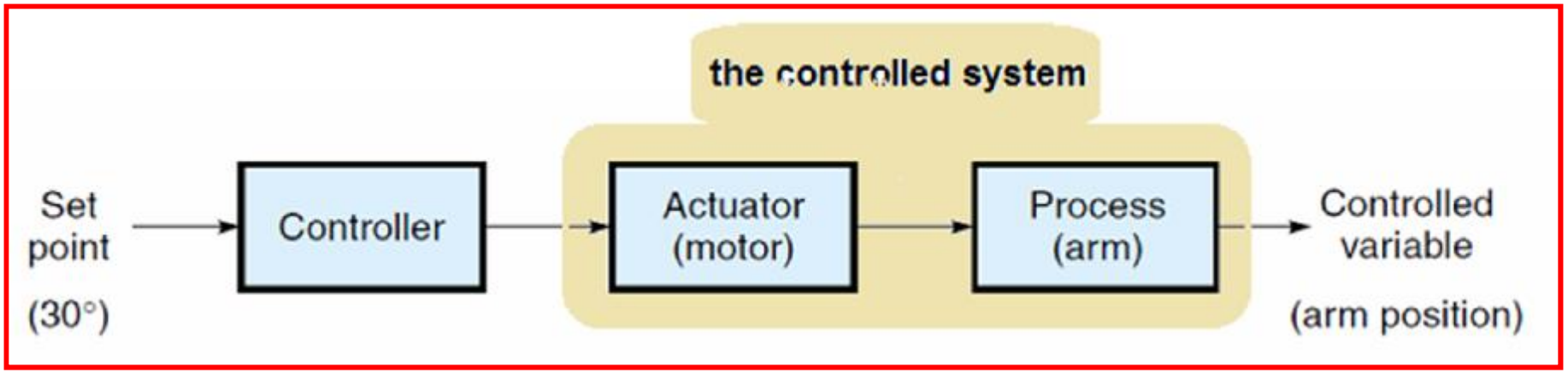


The system can be controlled in which the outputs are controlled only by using the inputs.

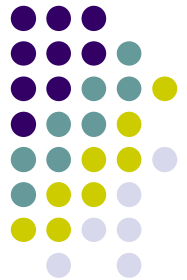
If there are any disturbances, the output changes.

Open-Loop Control Systems (No feedback Systems)

The elements of an open-loop control system can usually be divided into two parts: the controller and the controlled system, as shown by the block diagram



Open-loop control systems



Advantages:

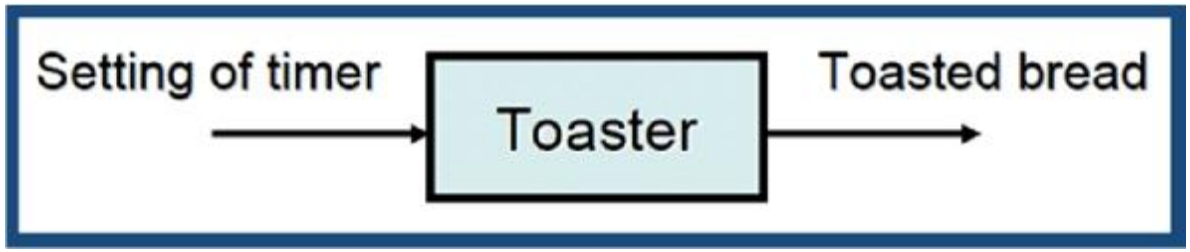
- Simple construction and easy of maintenance.
- There is no stability.
- Cheap.

Disadvantages:

- Internal or external disturbances cause errors the output may be different from what is desired.
- Recalibration is necessary from time to time.

Example 1: Toaster

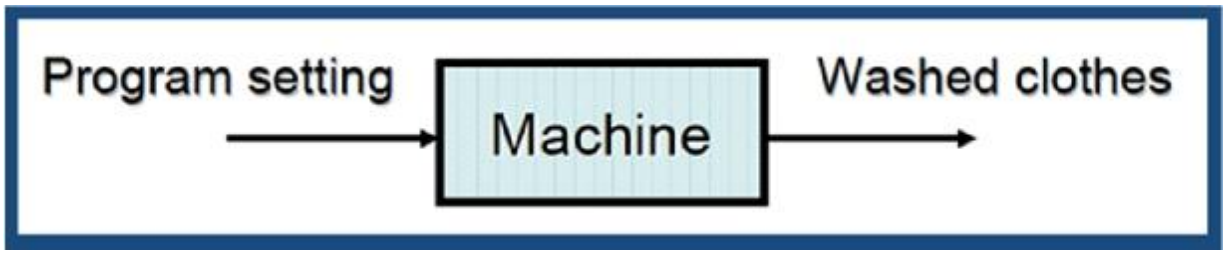
- A toaster toasts bread, by setting timer.



- A toaster does not measure the color of bread during the toasting process.
- What will happen if your setting is wrong....
- However, a toaster would be more expensive with sensors to measure the color and actuators to adjust the timer based on the measured color.

Example 2: Laundry machine

- A laundry machine washes clothes, by setting a program.



- A laundry machine does not measure how clean the clothes become.

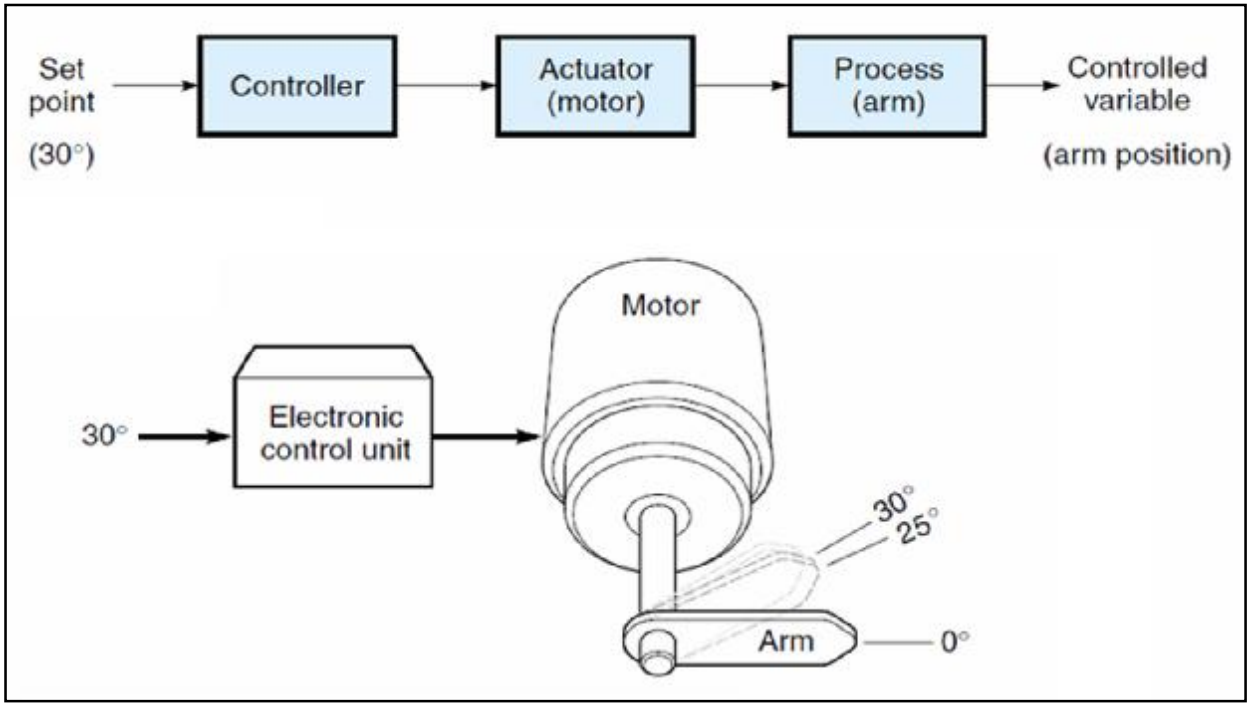
- Control without measuring devices (sensors) are called ***open-loop control***.

Example 3: Rotating motor shaft

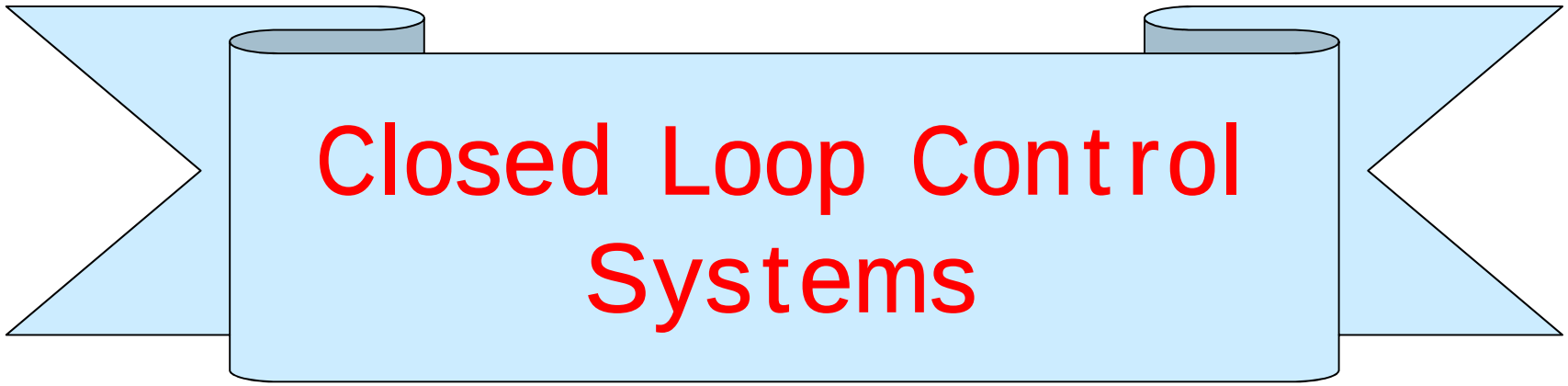
At rated voltage:

* control pulse of 1 sec. causes motion 5°.

* control pulse of 6 sec. causes motion 30°.

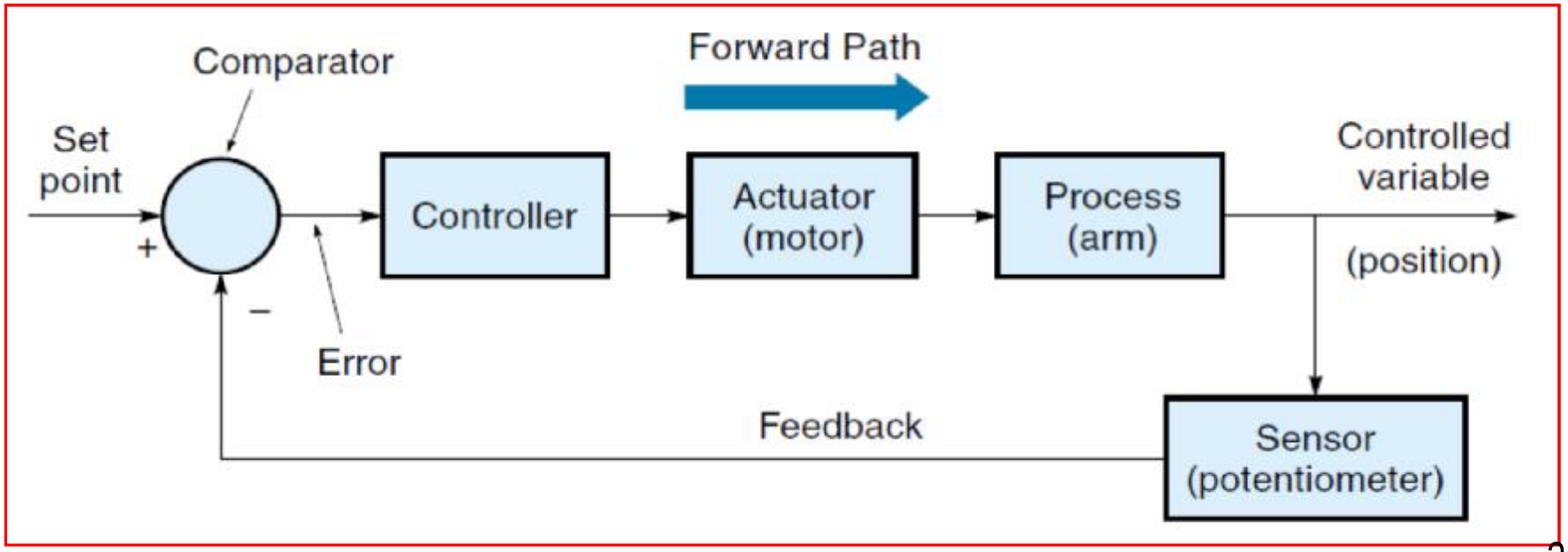


If error of 5° occurs; the controller has no way of knowing the error and does nothing to correct it.


Closed Loop Control Systems

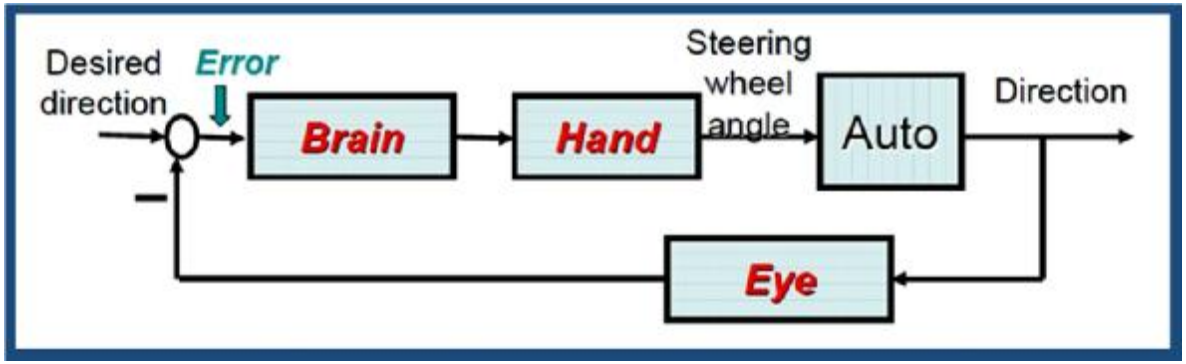
Closed-Loop Control Systems (Feedback Control Systems)

- The system has feedback to reduce the error between the reference input and the system output.
- To obtain more accurate control, the controlled signal (output) should be fed back and compared with the reference input.



Example: Car Direction Control

- Change the direction of the automobile.

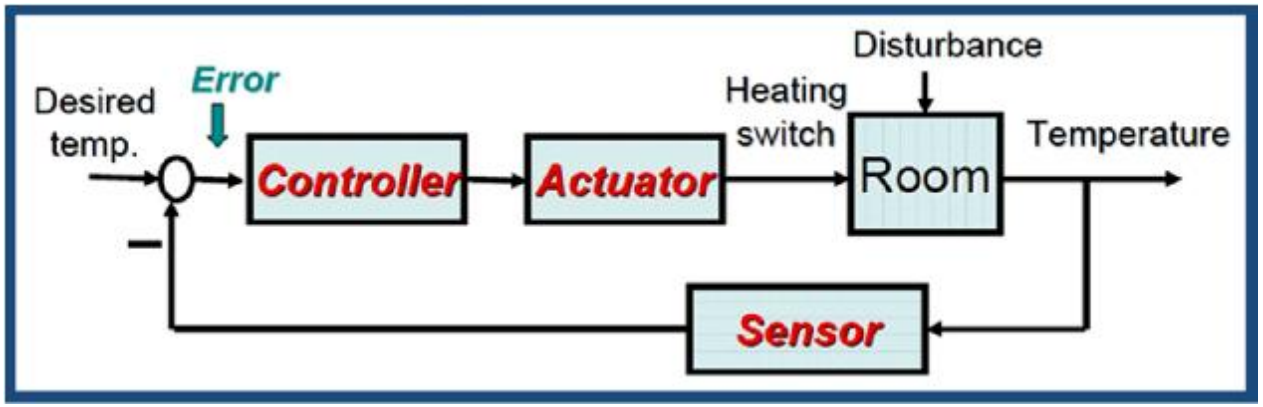


- Manual closed-loop (***feedback***) control.

- Although the controlled system is "Automobile", the ***input*** and the ***output*** of the system can be different, depending on ***control objectives***!

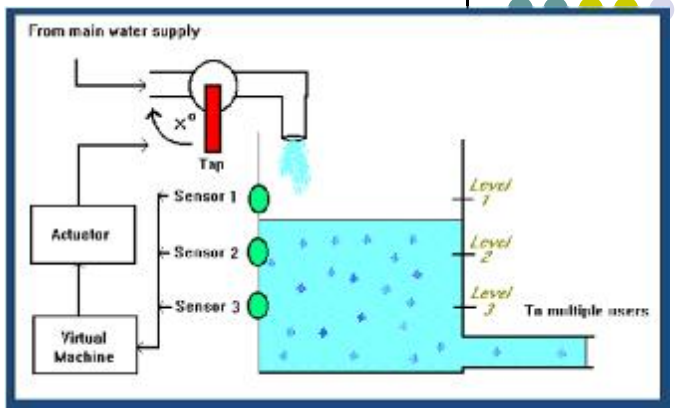
Example: Room Temperature Control

- Maintain the temperature in a room.

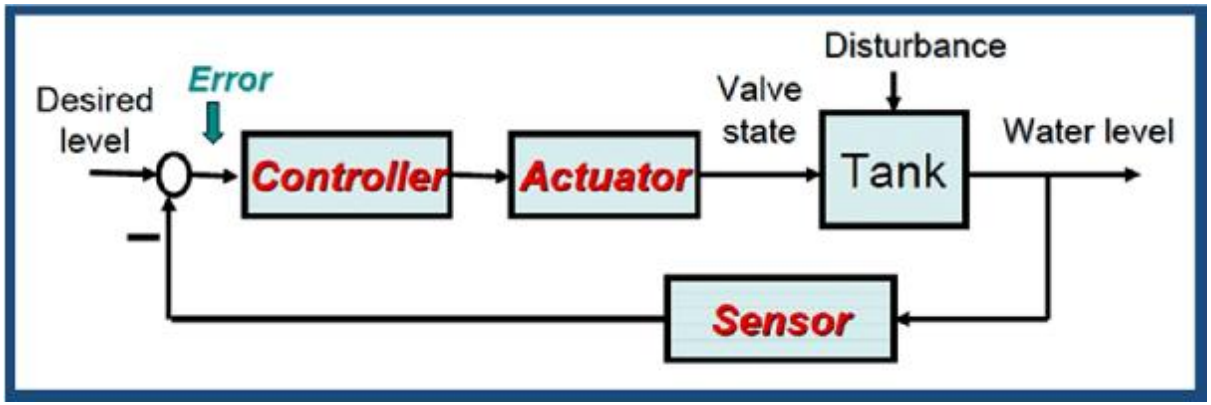


- Temperature control can be automatic.
- Note the similarity of the diagram above to the diagram in the previous slides!

Example: Water Level Control



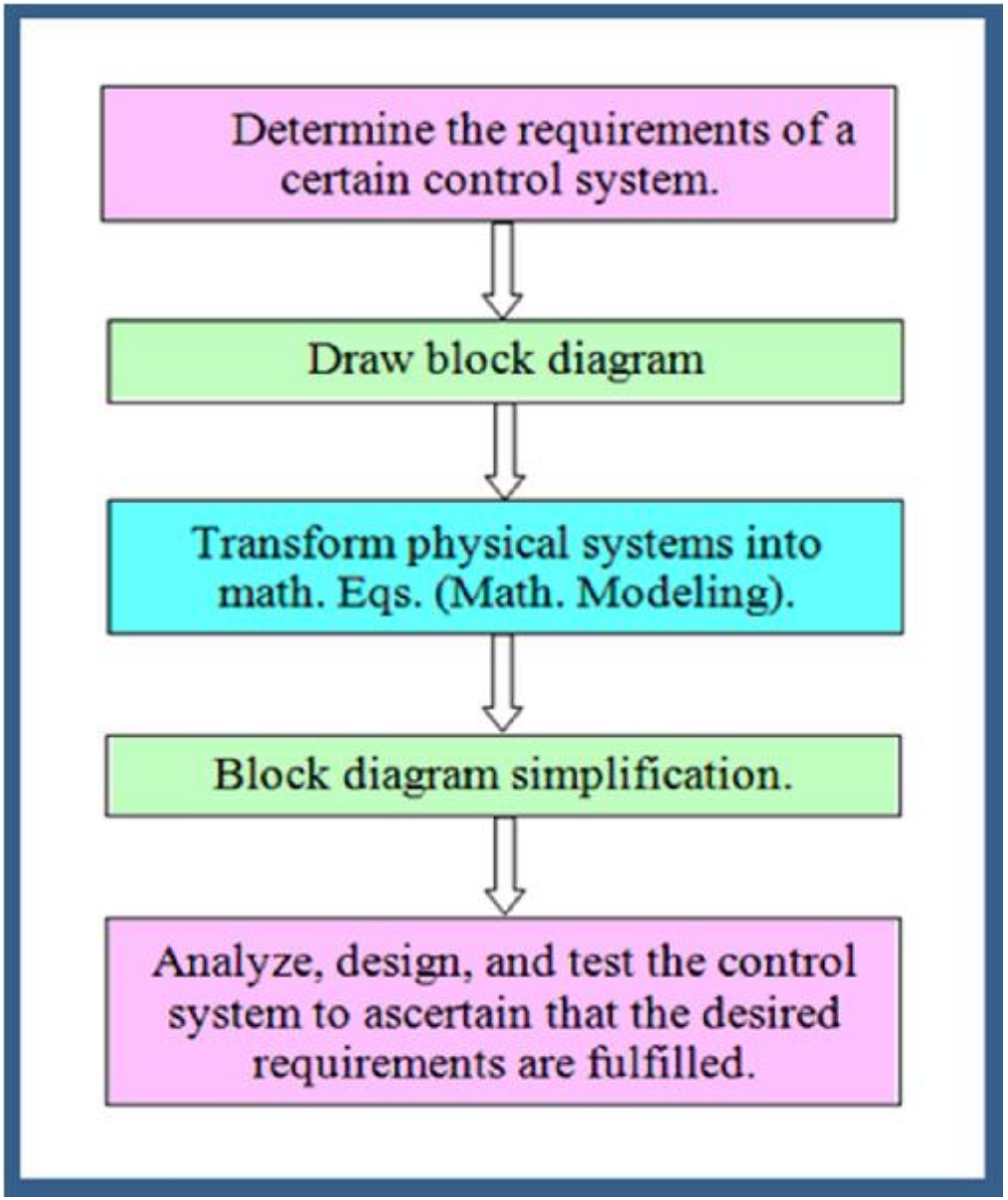
- Maintain the water level in a tank.



- Water level control can be automatic.

http://www.atp.rub.de/DynLAB/dynlabmodules/Examples/WhatIsControl/WaterLevel6.html

Controller design procedure



Examples : Washing Machine

- **System Requirements**
  - Understanding of load sizes
  - Receptacle to hold clothes
  - ‘Plumbing’
  - Ease of use, Reliability
  - Low Cost
- **Actuators**
  - AC or DC Motors
  - Water inlet/drain
- **Sensors**
  - Water level
  - Load speed/balance
- **Control**
  - Choice depends on design

Examples : The CD Player

- A CD player is an example of control system
- Requires
  - Accurate positioning of the laser read head
  - Precise control of media speed
  - Conversion of digital data to analogue signal

Examples : Hard Drive

- A computer disk drive is another example of a rotary control system
- **Requires**
  - Accurate positioning of the magnetic read head
  - Accurate control of media speed
  - Extraction of digital data from magnetic media

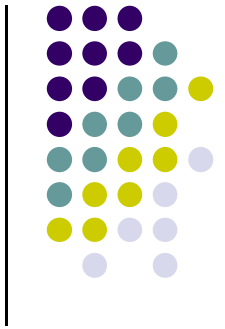
Examples : Modern Automobiles

Modern Automobiles are controlled by a number of computer components

Requires

- Control of automobile sub systems
  - Brakes and acceleration
  - Cruise control
  - ABS
  - Climate control
  - GPS
- Reliability
- Low cost
- Ease of use

The Control Problem



Generally a controller is required to filter the error signal in order that certain control criteria or specifications, be satisfied. These criteria may involve, but not be limited to:

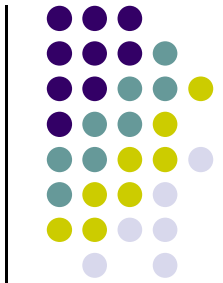
1- Disturbance rejection

2- Steady state errors

3- Transient response characteristics

4- Sensitivity to parameter changes in the plant

Solution of Control Problem



To Solve the control problem must must follow these steps ;

1- Choosing sensors to measure the plant output

2- Choosing actuators to drive the plant

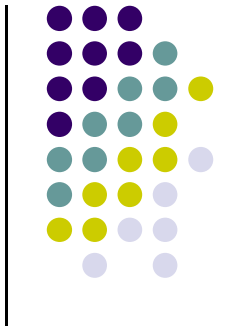
3- Developing the plant, actuator, and sensors equations

4- Designing the controller

5- Evaluating the design analytically by simulation, and finally by testing the physical system.

6- If the physical tests are unsatisfactory, repeating the above steps.

Summary



- Introduction:

Control essentiality

Open loop versus closed loop control systems

Examples of control systems

- Next Lecture:

Laplace Transformation and Transfer function