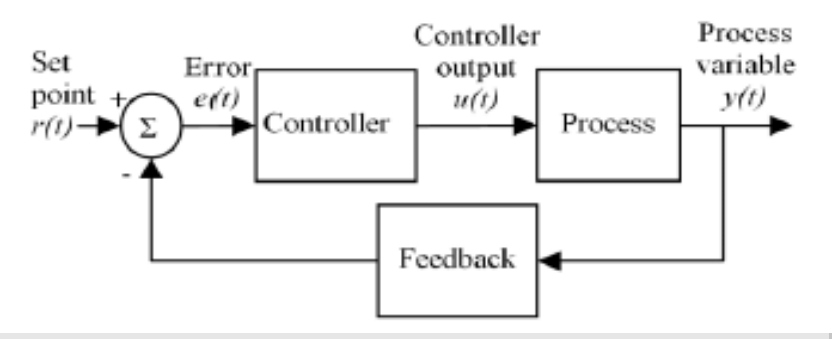


Control Systems
Lecture /1/

Mechatronics Department
Assistant Professor Isam Asaad

Objectives

- In this lecture, we lead you through a study of the basics of control systems.
- After completing the chapter, you should be able to
  - Understand the principles and purpose of control engineering
  - Examine examples of control systems

What is “Control”?

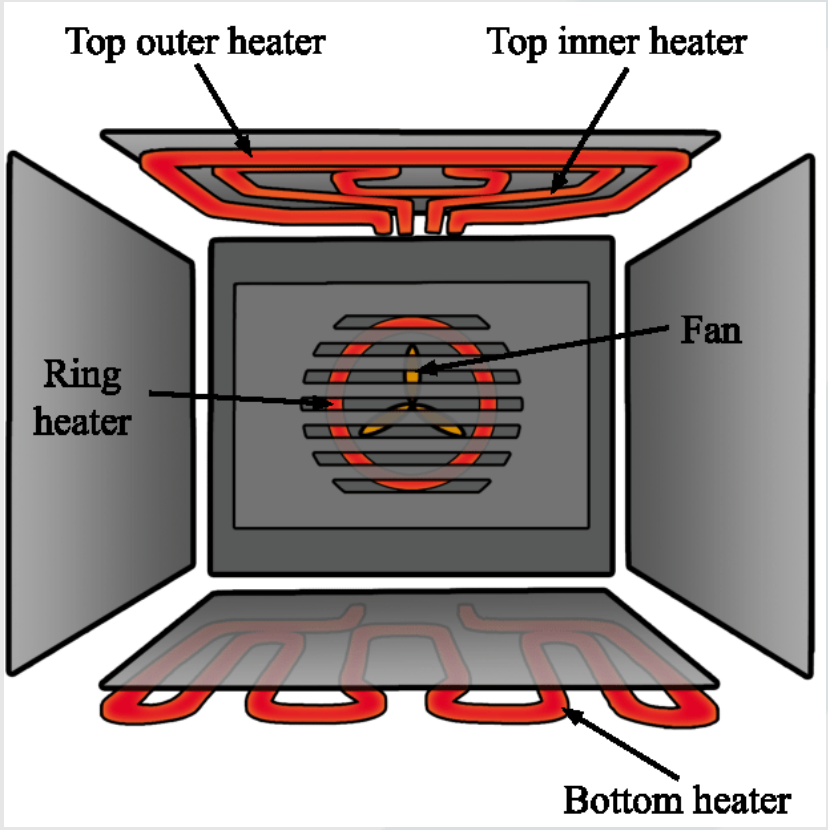
- Make some object (called ***system, or plant)*** behave as we desire.
- Imagine “control” around you!
  - Room temperature control
  - Car driving
  - Voice volume control
  - Balance of bank account
  - Epidemics control
  - “Control” (move) the position of the PC mouse pointer
  - etc.

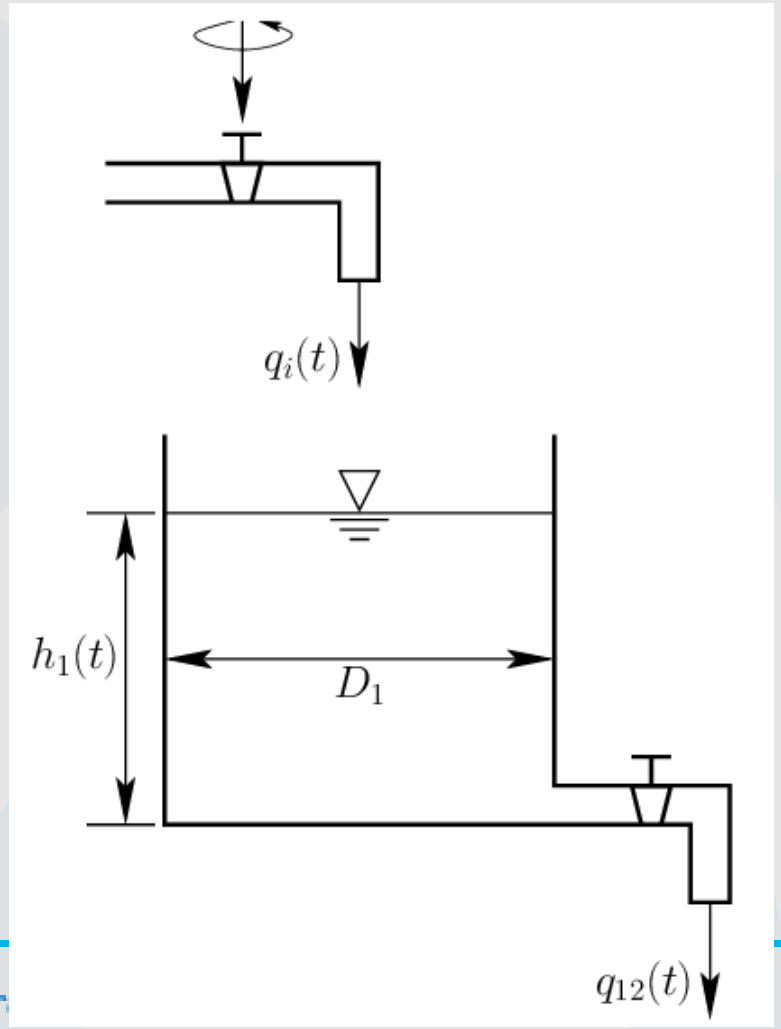
What is “Automatic Control”?

- Not manual!
- Why do we need automatic control?
  - Convenient (room temperature, laundry machine)
  - Dangerous (hot/cold places, space)
  - Impossible for human (nanometer scale precision positioning, work inside the small space that human cannot enter like ICs manufacturing process).
  - It exists in nature (human body temperature control)
  - High efficiency (engine control)
- Many examples of automatic control around us
- Applications:
  - Robotic systems, Medical tools, Aircraft, Industrial processes, Automobiles.

Definitions.

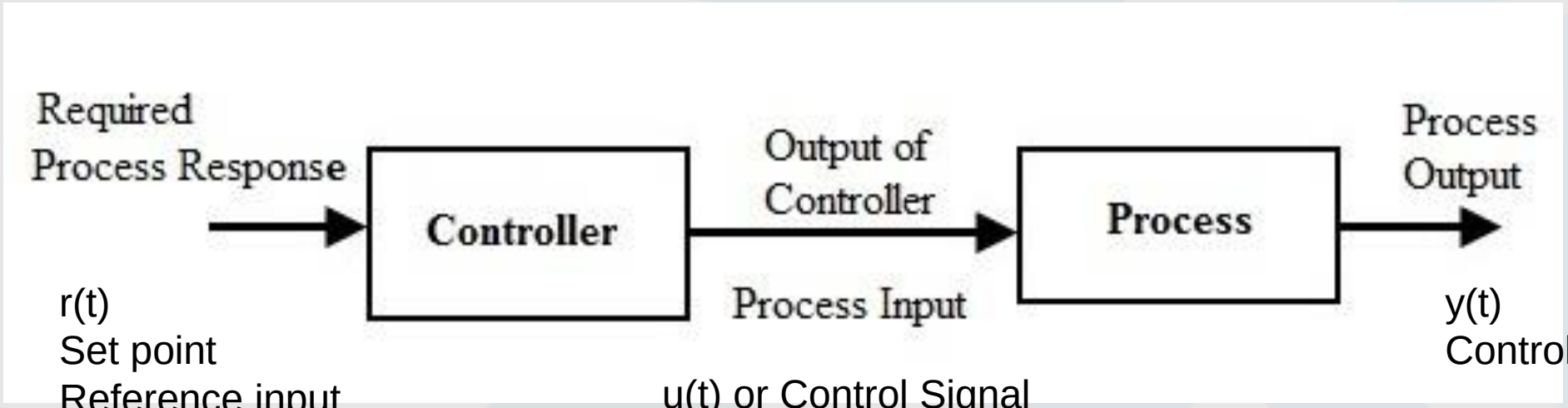
- System - A system is a combination of components (Hardware/Software) that act together and perform a certain objective.





Definitions.

- Control System – An interconnection of components forming a system configuration that will provide a **desired response**.



Definitions.

- Plant/Process – A plant may be a piece of equipment, perhaps just a set of machine parts functioning together, or the device, or system under control. The input and output relationship represents the cause-and-effect relationship of the process.

Definitions.

- Disturbance - A disturbance is a signal that tends to adversely affect the value of the output of a system. If a disturbance is generated within the system, it is called internal, while an external disturbance is generated outside the system and it is treated as an input.

- Controlled Variable – is the quantity or condition that is measured and controlled. the controlled variable is the output of the system.

- Actuator – Final control element that receives the control signal u(t) and gives an output (manipulated variable) to the process's input.

- The Manipulated Variable – is the quantity or condition that is varied by the Actuator so as to affect the value of the controlled variable.

Definitions.

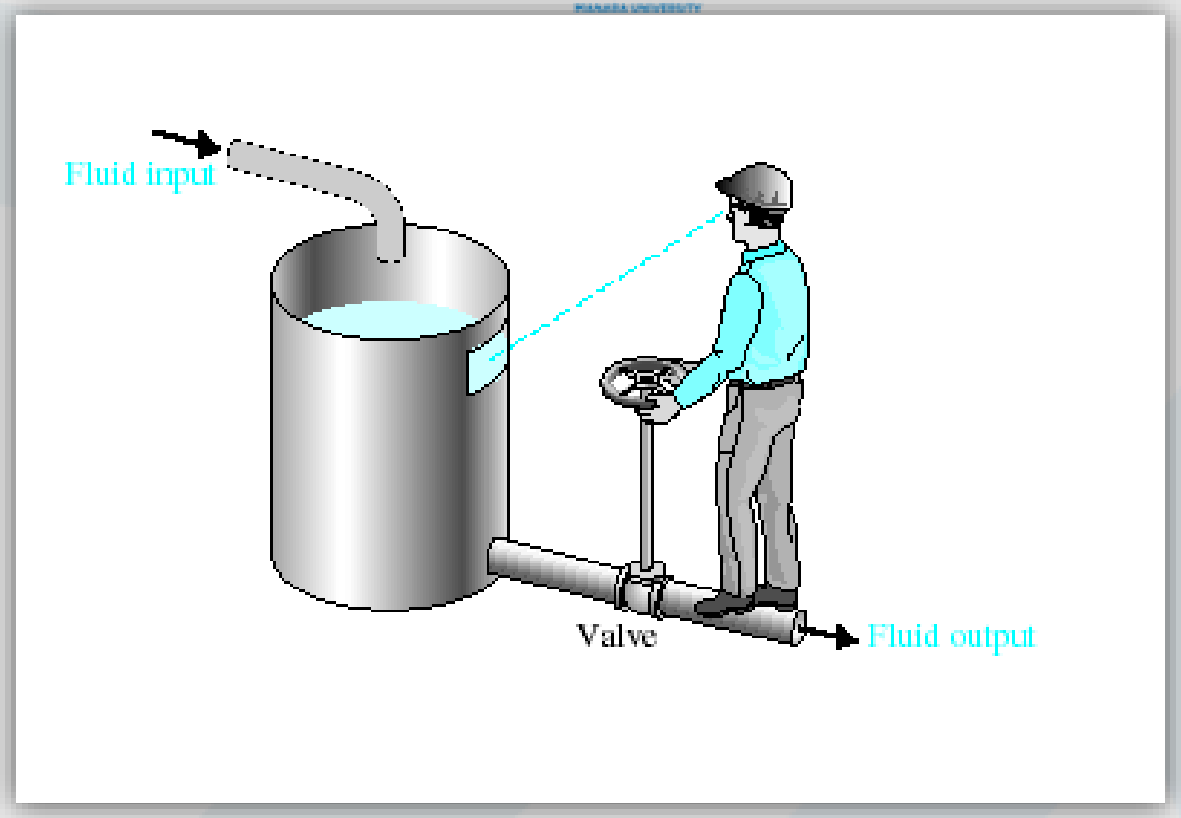
- Control - means measuring the value of the output variable of the system and applying the manipulated variable to the system to correct or limit deviation of the measured value from a desired value.
- Feedback Control - Feedback control refers to an operation that tends to reduce the difference between the output of a system and some reference input, and that does so on the basis of this difference.
- Transducer – a device used to measure the magnitude of the controlled variable y(t).
- Error signal e(t) – Difference between set point and measured controlled variable.

Classification of control systems:

Depending on the control strategy

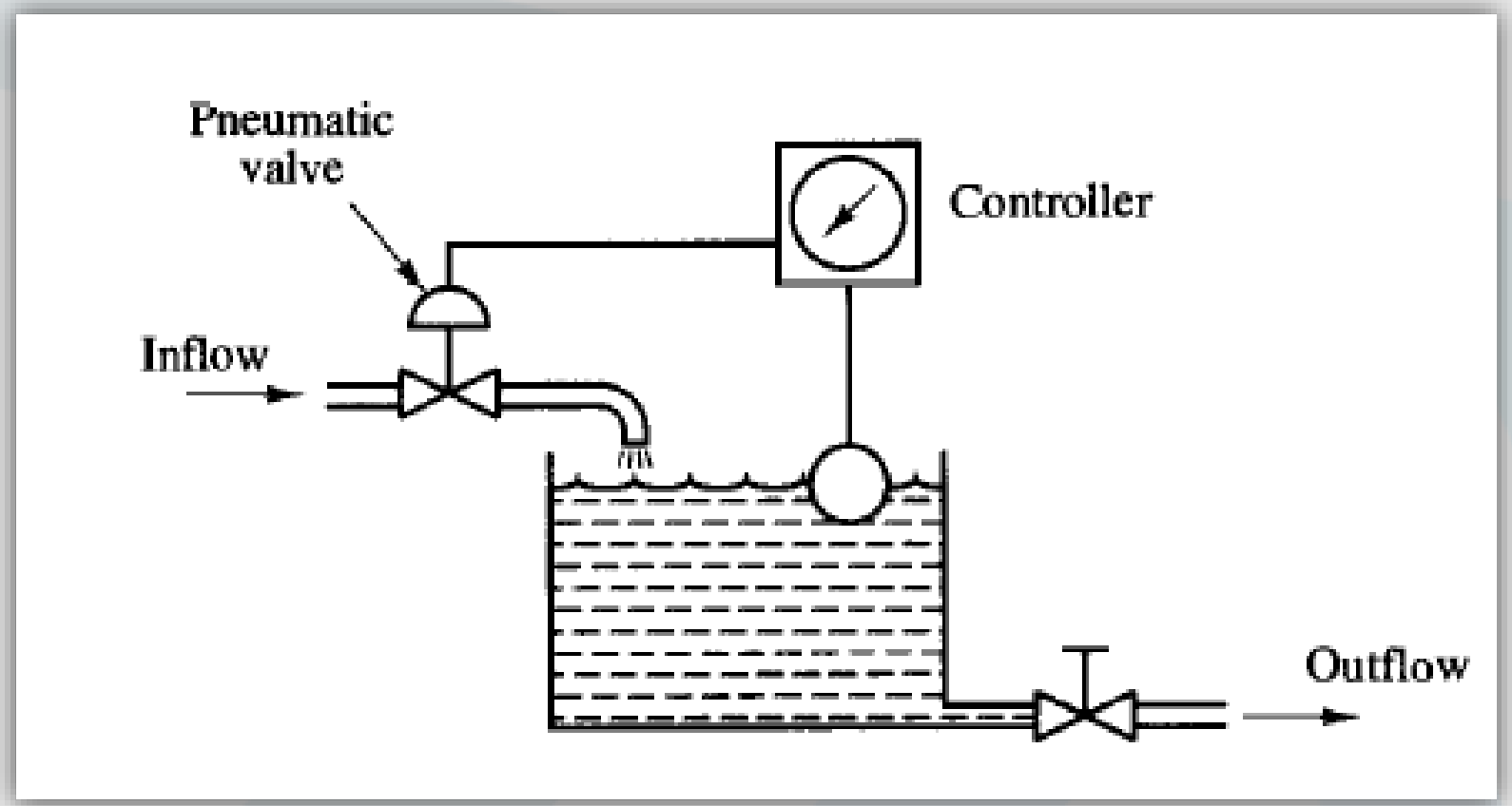
1. Manual v/s automatic
2. Open loop v/s closed loop

Manual Liquid-level control system

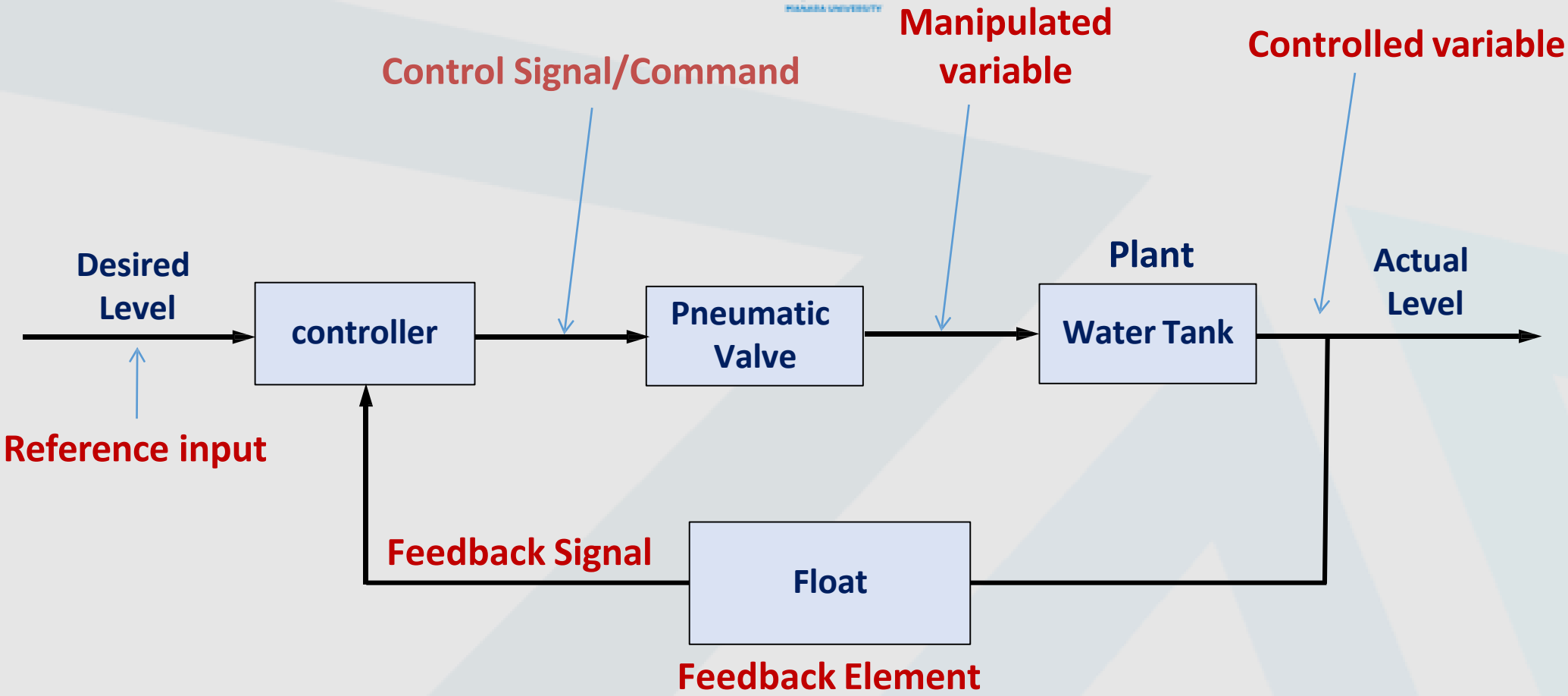


A manual Control System for regulating the level of fluid in a tank by adjusting the output valve. The operator views the level of fluid through a port in the side of the tank.

Automatic Liquid-level control system



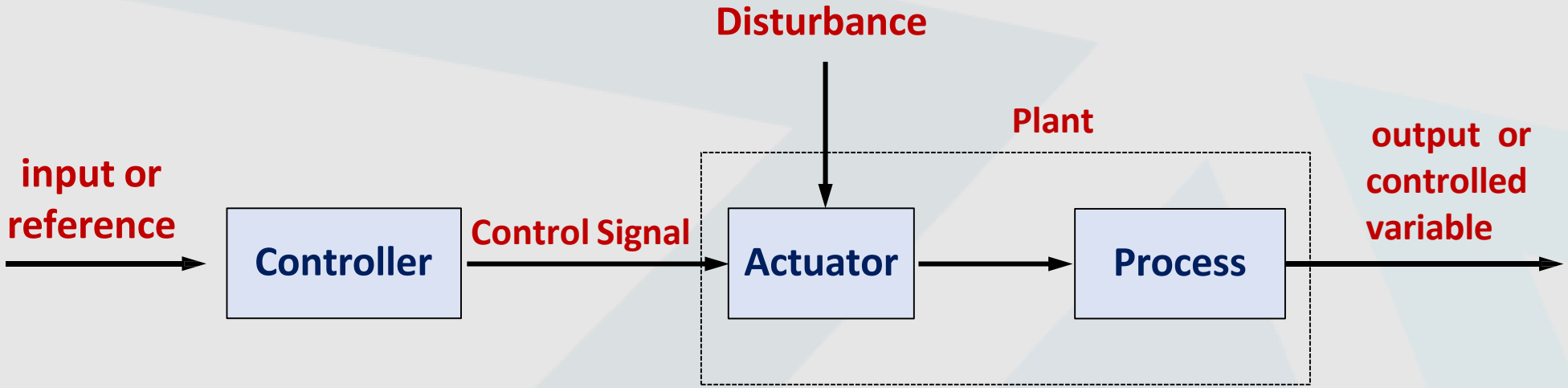
Automatic Liquid-level control system



Open-loop control systems

- Those systems in which the output has **no effect on the control action** are called open-loop control systems.
- In other words, in an open-loop control system the output is neither measured nor fed back for comparison with the input.
- In the presence of disturbances, an open-loop control system will not perform the desired task.
- Open-loop control can be used, in practice, only if the relationship between the input and output is known and if there are neither internal nor external disturbances.

Open-loop control systems



An open-loop system

Examples:

TV Remote Control.
Electric Hand Drier.

Timer Based Systems:

- Traffic lights
- Automatic Water Faucet.
- Washing machine.
- Electric Bulb.

Example: 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.***

Open-loop control systems

Advantages:

- Simple construction, ease of maintenance, and less expensive.
- There is no stability concern.
- Convenient when output is hard to measure or measuring the output precisely is economically not feasible. (For example, in the washer system, it would be quite expensive to provide a device to measure the quality of the washer's output, cleanliness of the clothes).

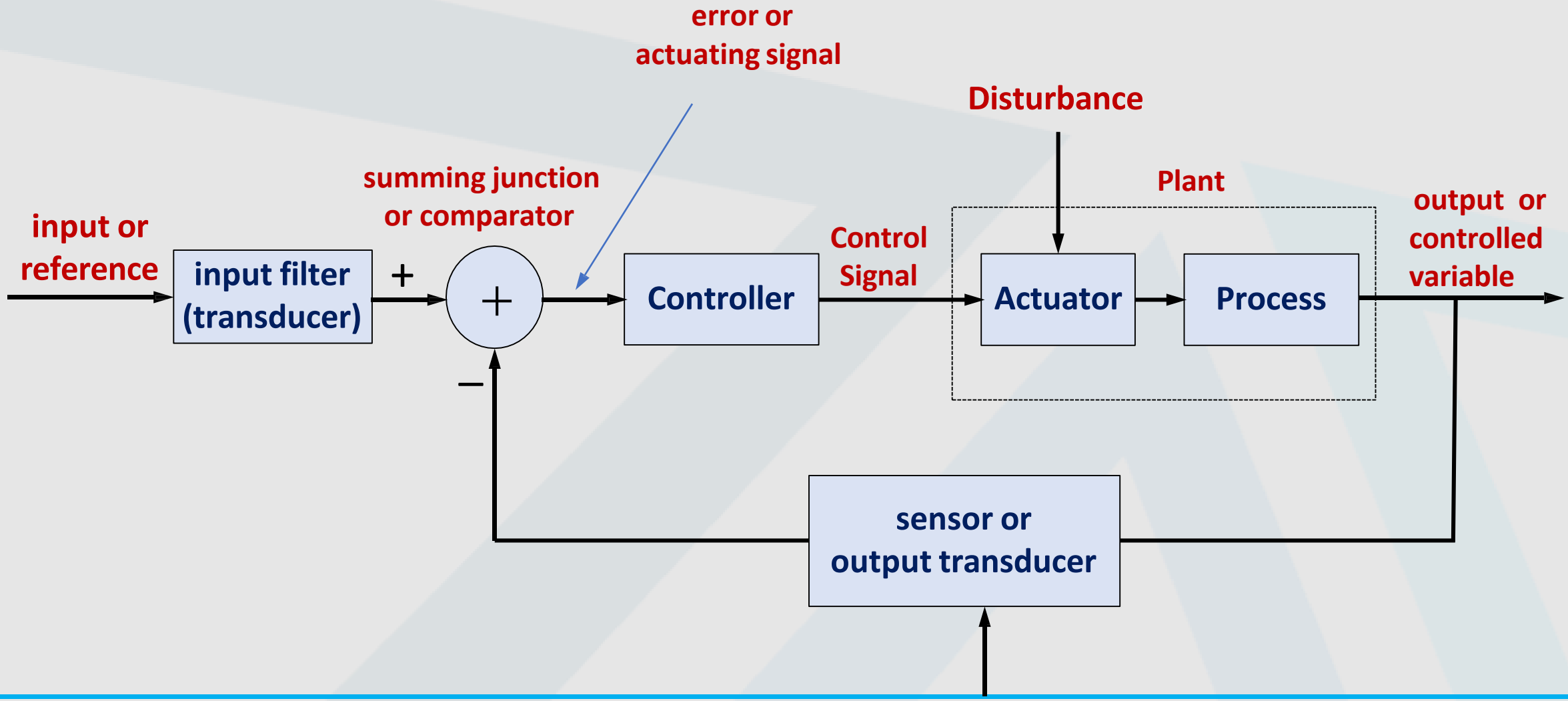
Disadvantages:

- Disturbances cause errors, and the output may be different from what is desired.
- Recalibration is necessary from time to time.

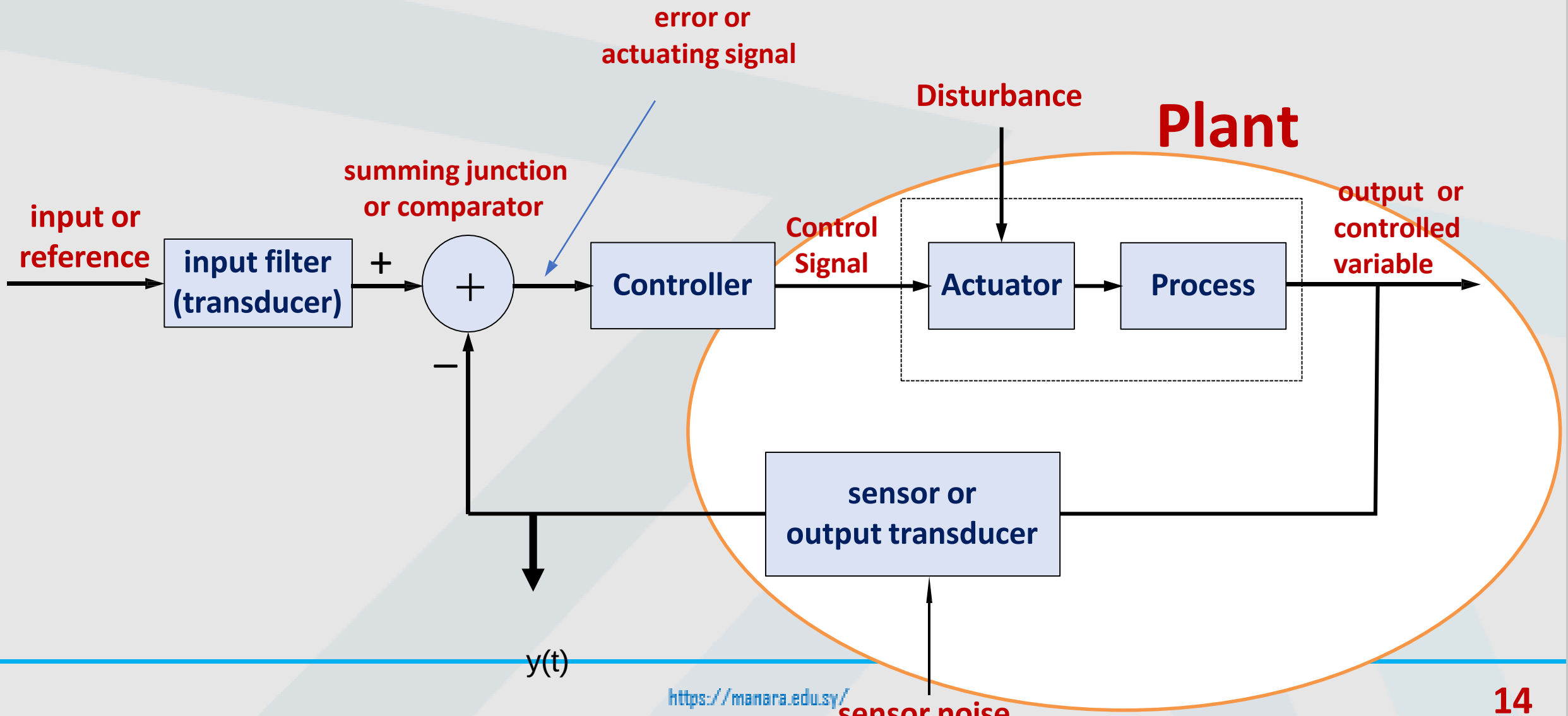
Closed-loop control systems

- 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.
- In a closed-loop control system the actuating error signal, which is the difference between the input signal and the feedback signal , is fed to the controller so as to reduce the error and bring the output of the system to a desired value.

Closed-loop (feedback) control



Closed-loop (feedback) control [Real life]



Examples:

Thermostat Heater
Sun seeker solar system
Auto Engine
Robots/Quadcopter balance system
Automatic Clothes Iron
A human traveling on the road
Automatic voltage regulator (within generators)
Dental chair compressor

Closed-loop control systems

Advantages:

- High accuracy
- Not sensitive to disturbance (less than open loop)
- Controllable transient response
- Controllable steady state error

Disadvantages:

- More Complex, and More Expensive.
- Possibility of instability.
- Need for output measurement.
- Recalibration is necessary from time to time.

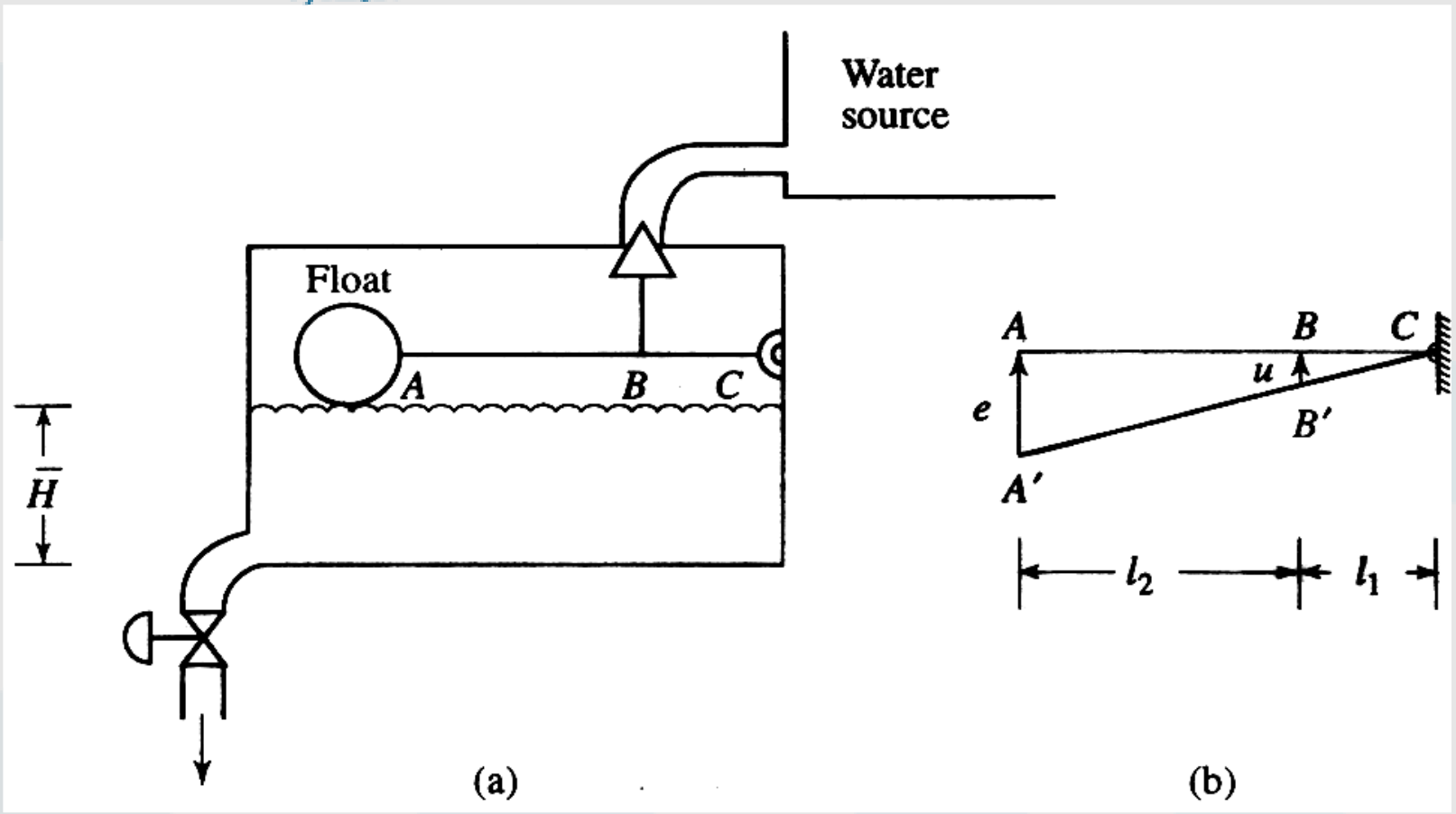
Example1:
Water tank level control

e: actuating error
u: control signal

$$\frac{AA'}{AC} = \frac{AA'}{AB + BC} = \frac{BB'}{BC}$$

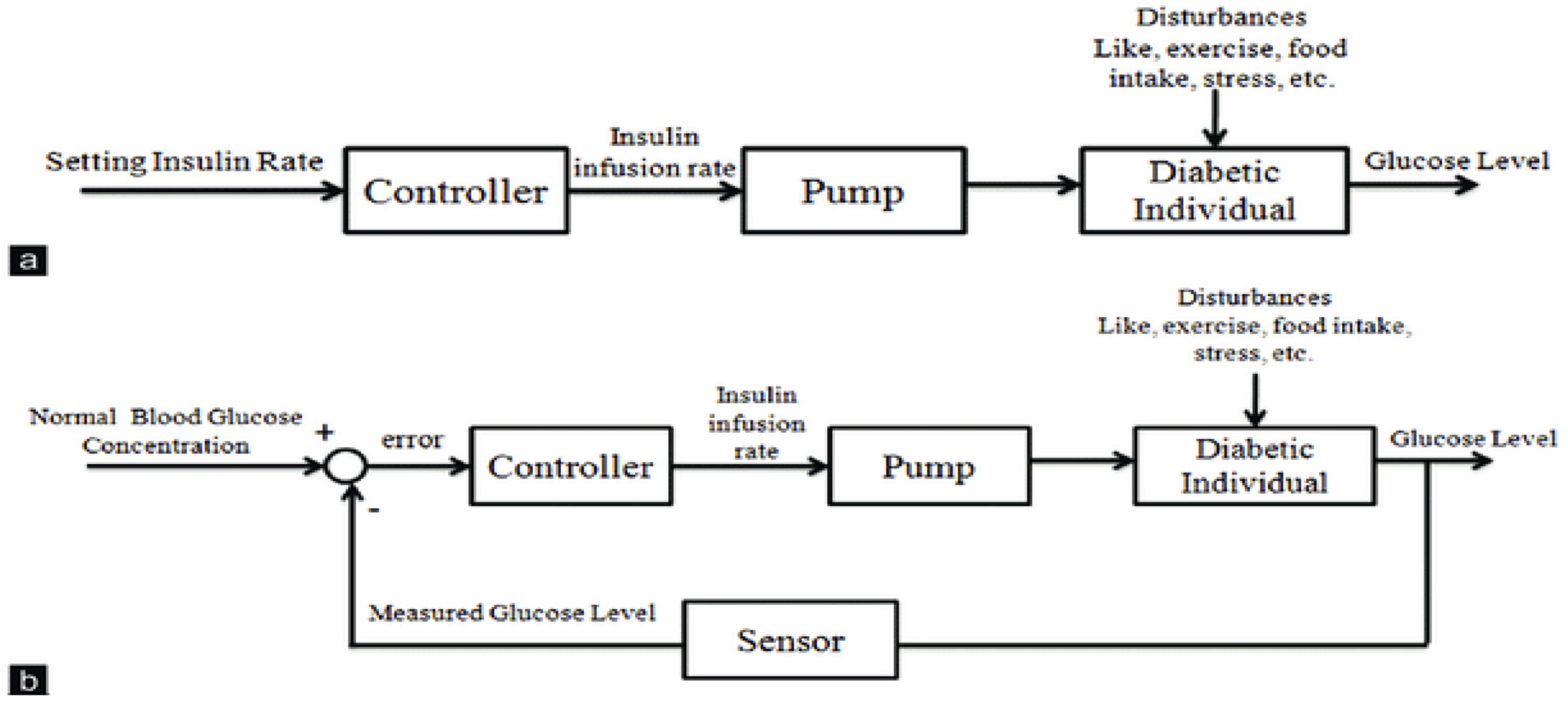
$$\frac{e}{\ell_1 + \ell_2} = \frac{u}{\ell_1}$$

$$u = \frac{\ell_1}{\ell_1 + \ell_2} e$$



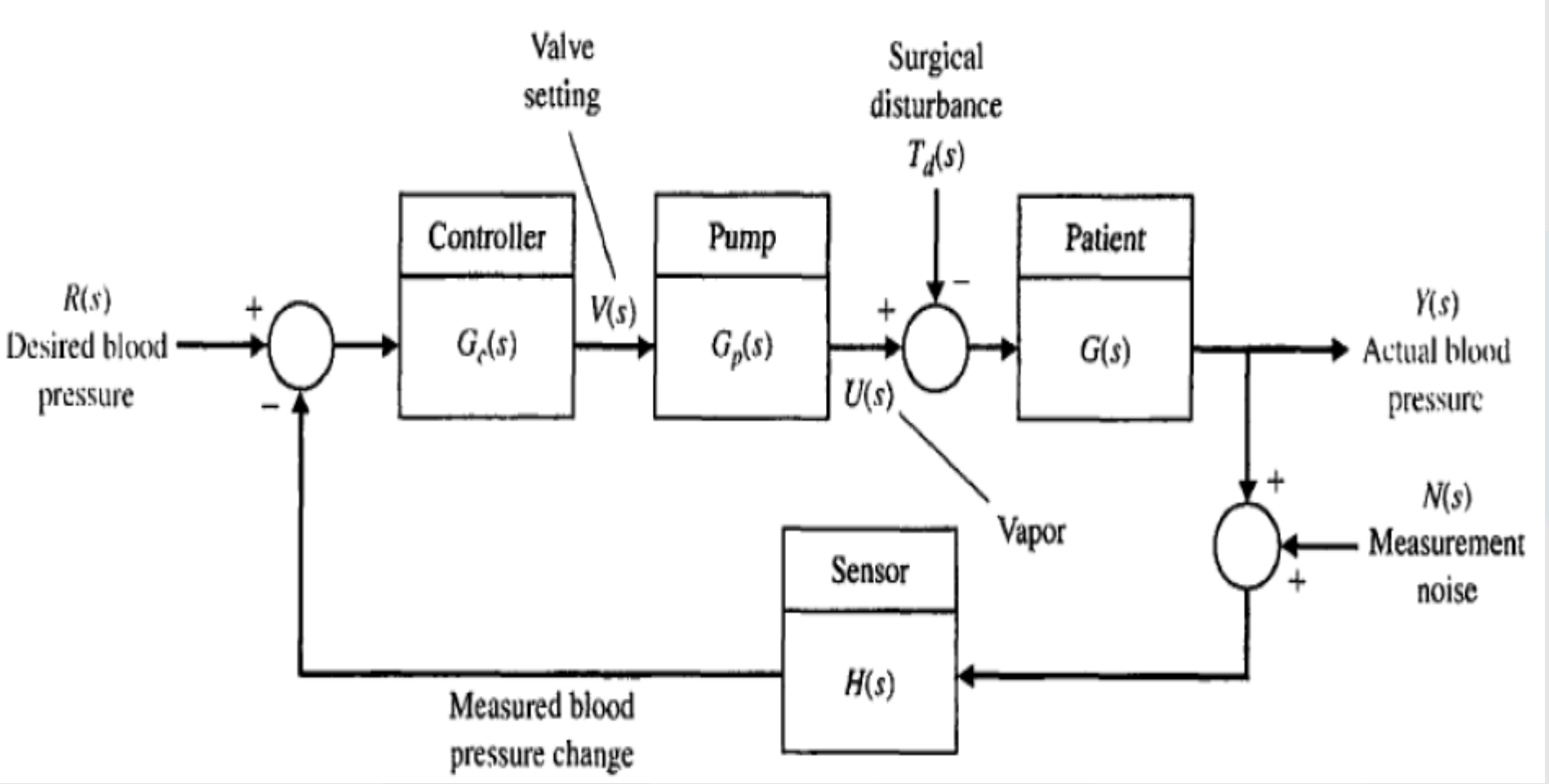
Water tank level control system

Example2:
Blood Glucose Control in Diabetes Patients



Insulin Pump Control System (Open Loop VS. Closed Loop)

Example3:
Mean arterial pressure (MAP)

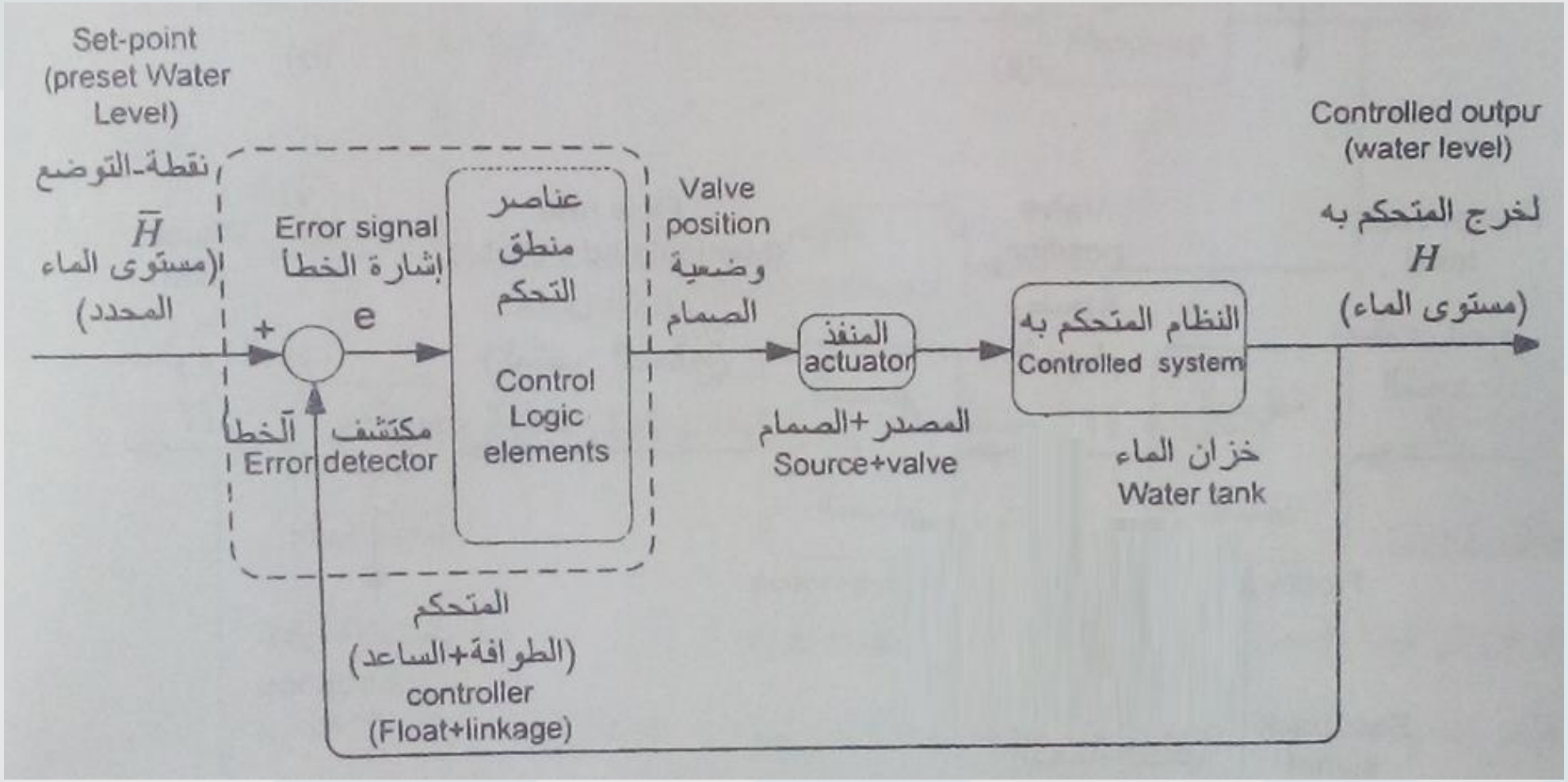


How do you manage mean arterial pressure? This is usually done with:

1- Intravenous fluids or blood transfusions to increase blood flow.

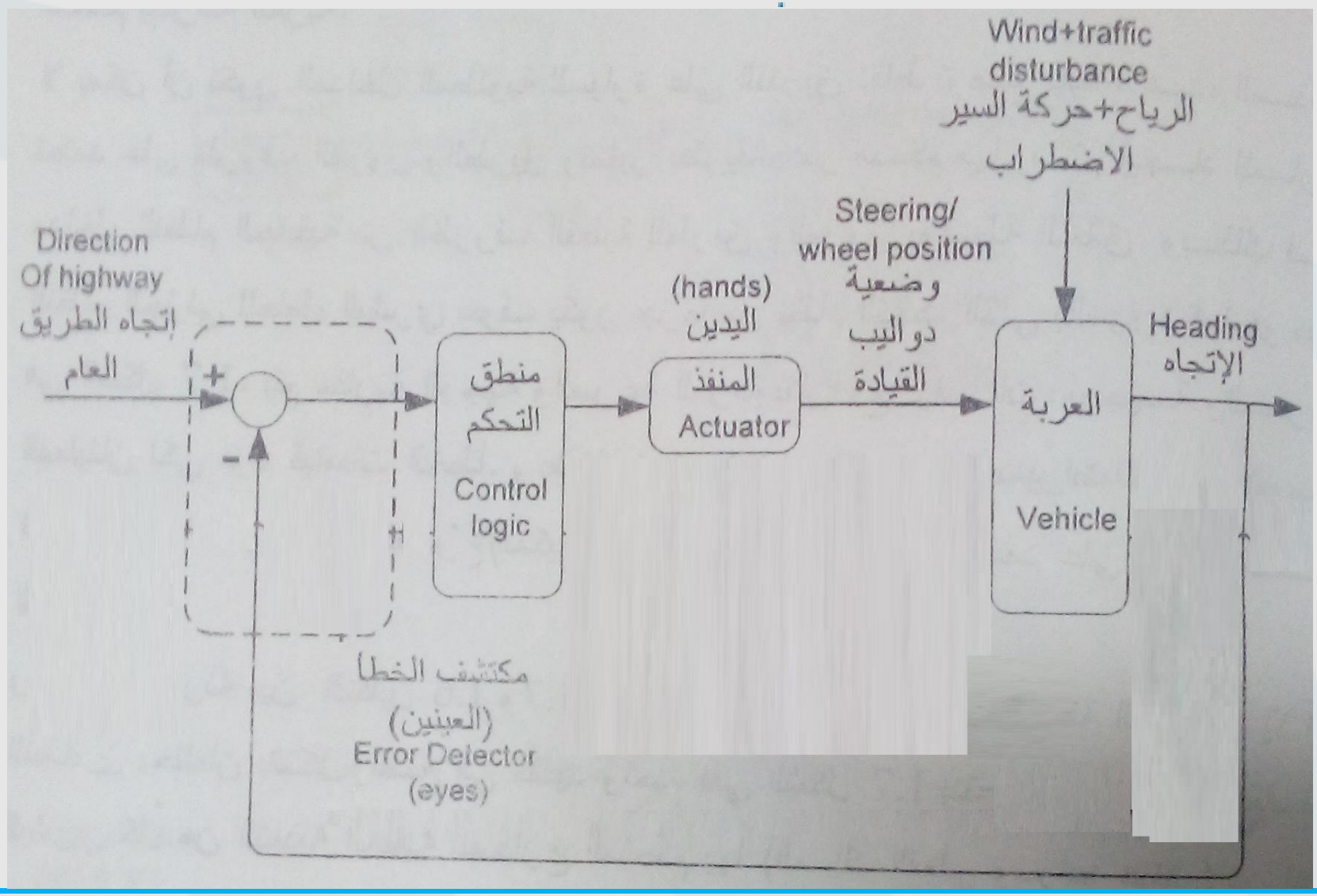
2- medications called “vasopressors” that tighten blood vessels, which can increase blood pressure and make the heart beat faster or pump harder.

Example4:
Water tank level control



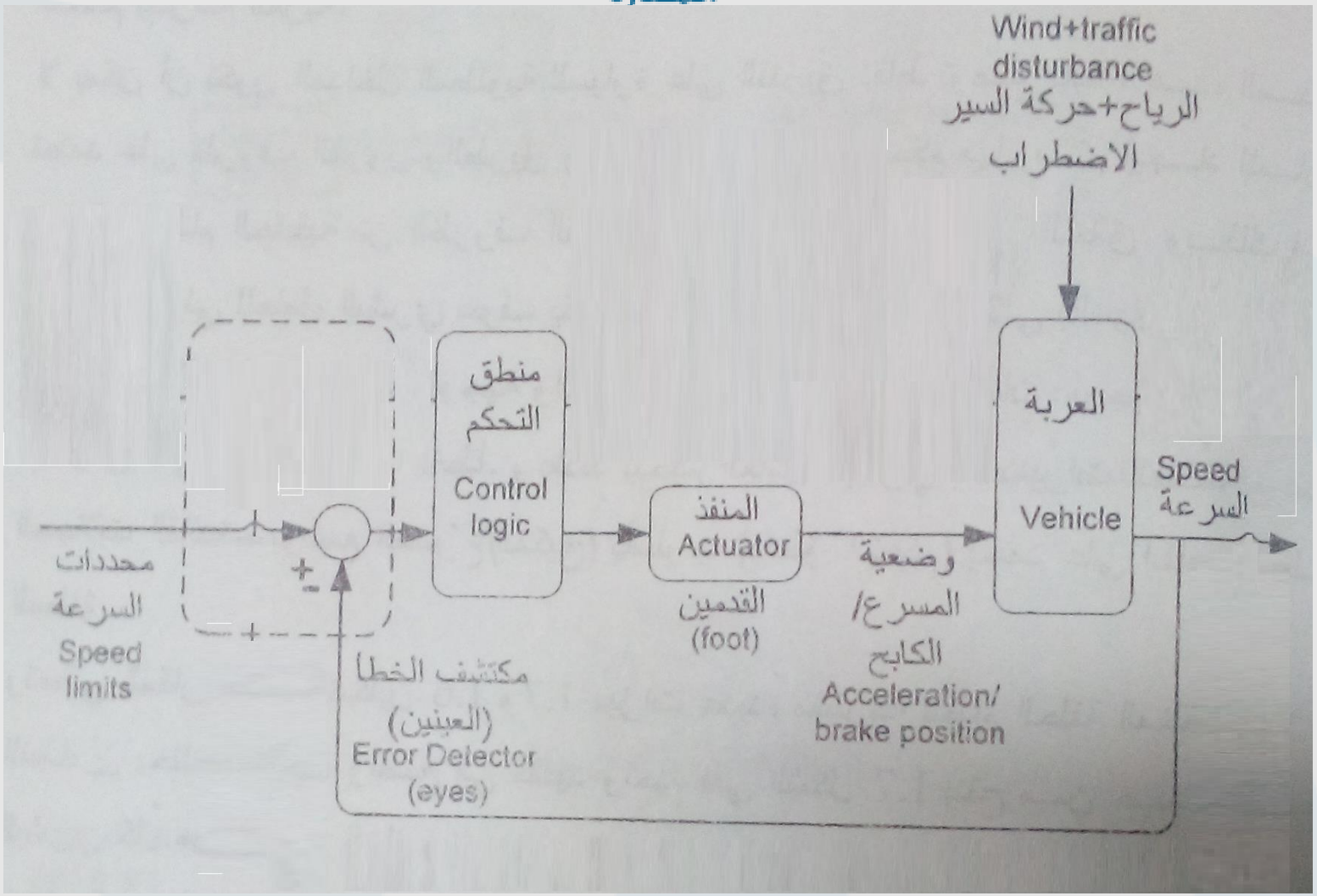
Water tank level control system

Example5: Car control system (Direction)



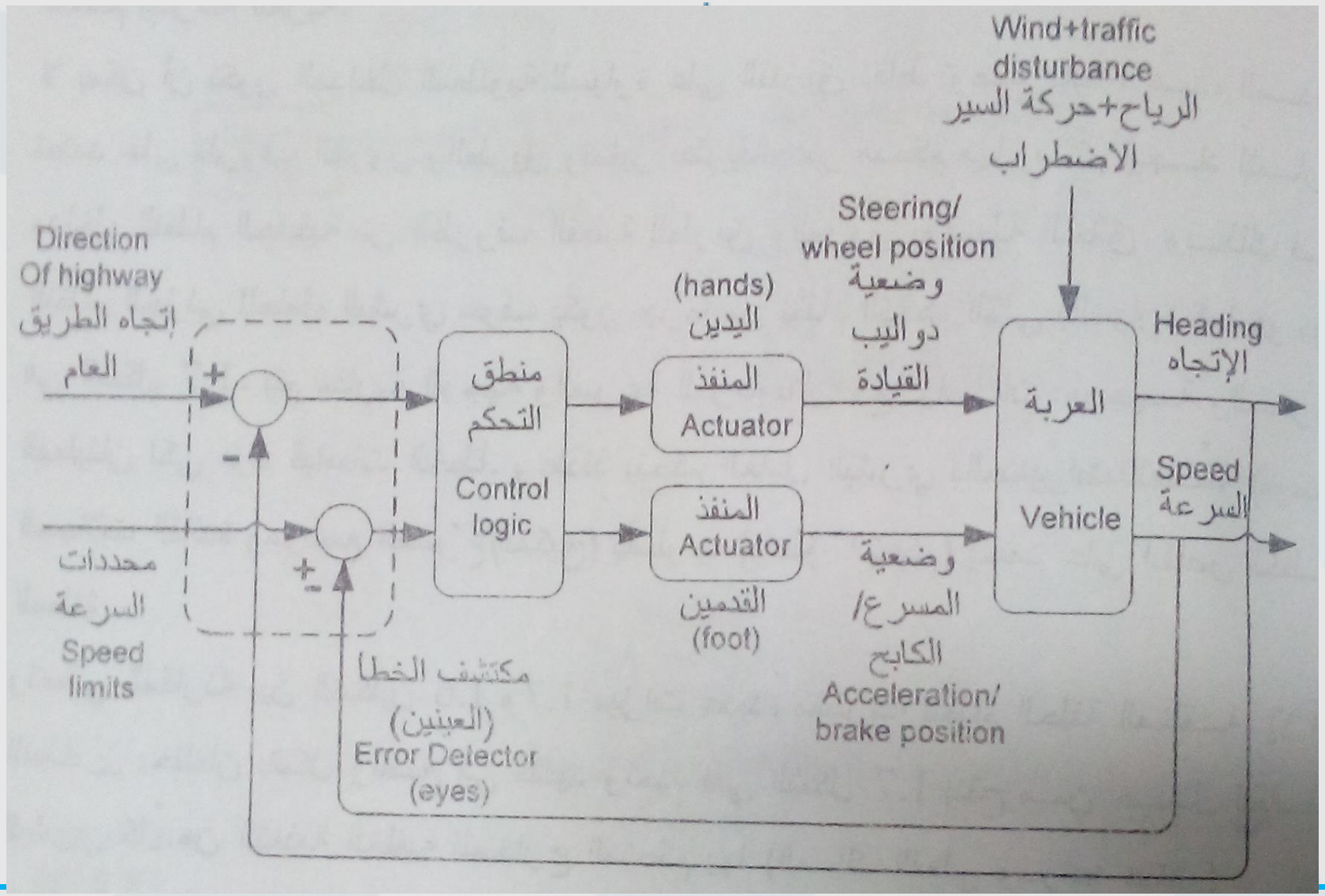
Car control system (Direction)

Example6: Car control system (Speed)



Car control system (Speed)

Example7: Car control system (Direction + Speed)



Example7: Car control system (Direction + Speed)

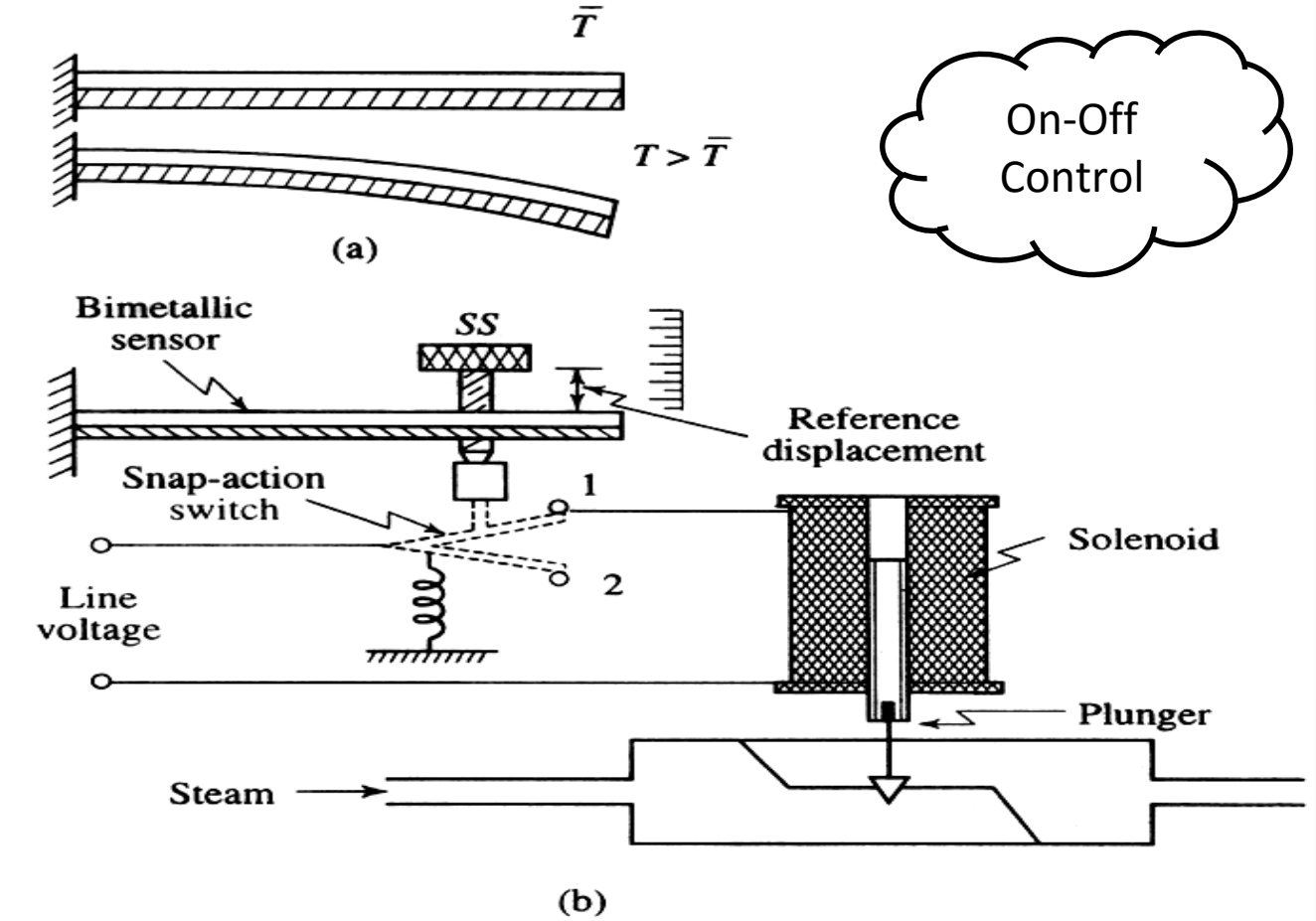
Car control system (Direction) or Car control system (Speed) :

- Single-input single-output (SISO) control system.
- A single output is controlled according to a single input.

Car control system (Direction + Speed):

- Multi-input Multi-output (MIMO) control system.
- Multivariable system
- One of the inputs is intended to control a specific output.
- In fact, each input can affect more than one output, and this is called coupling or interaction.
- The car's driving control system (Direction + Speed) can be divided into two SISO systems for design purposes, neglecting mutual interaction.

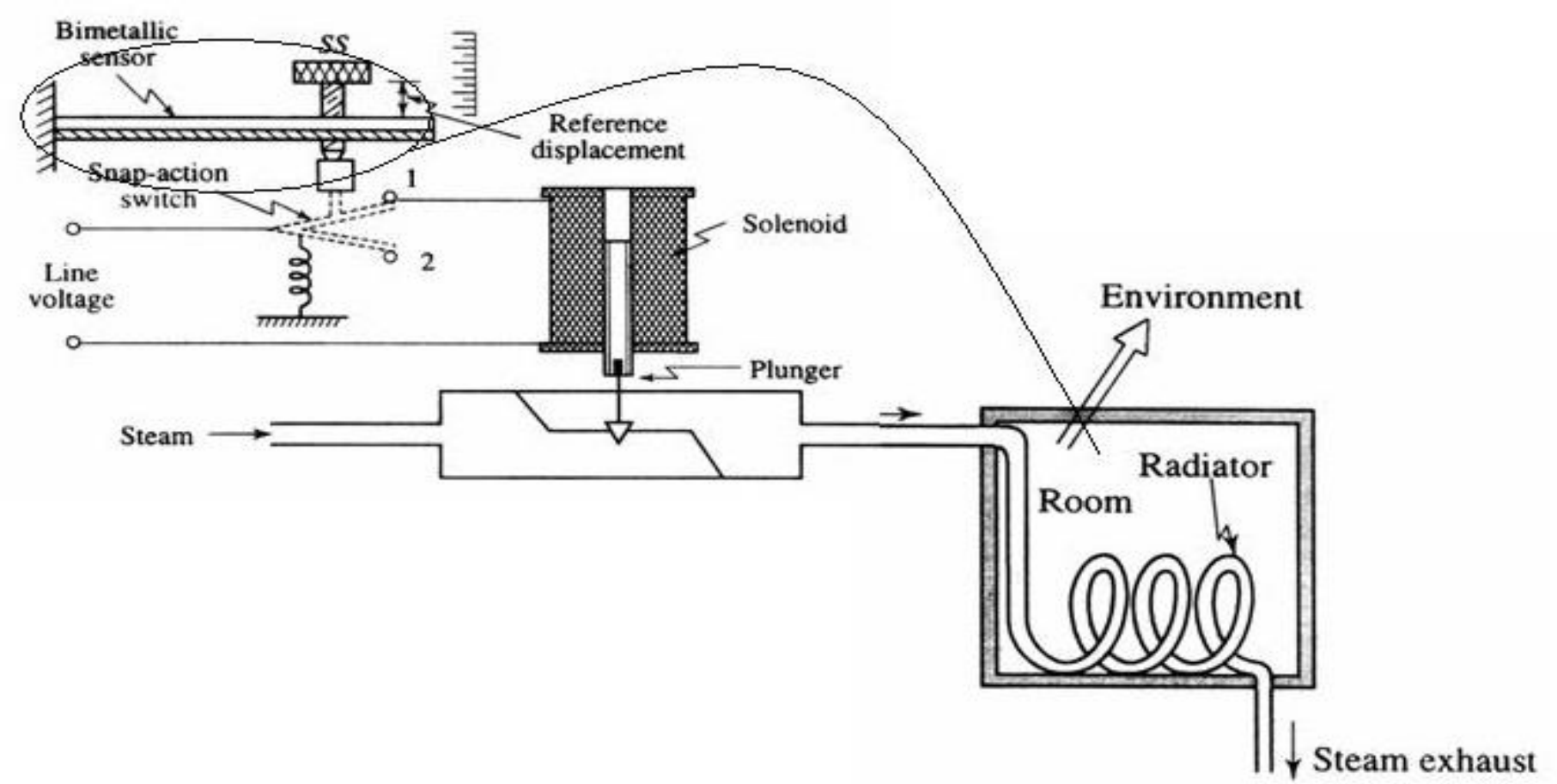
Example8: House automatic heating system:



Baby incubator
Egg incubator
Heat sterilizers
Heating/cooling devices

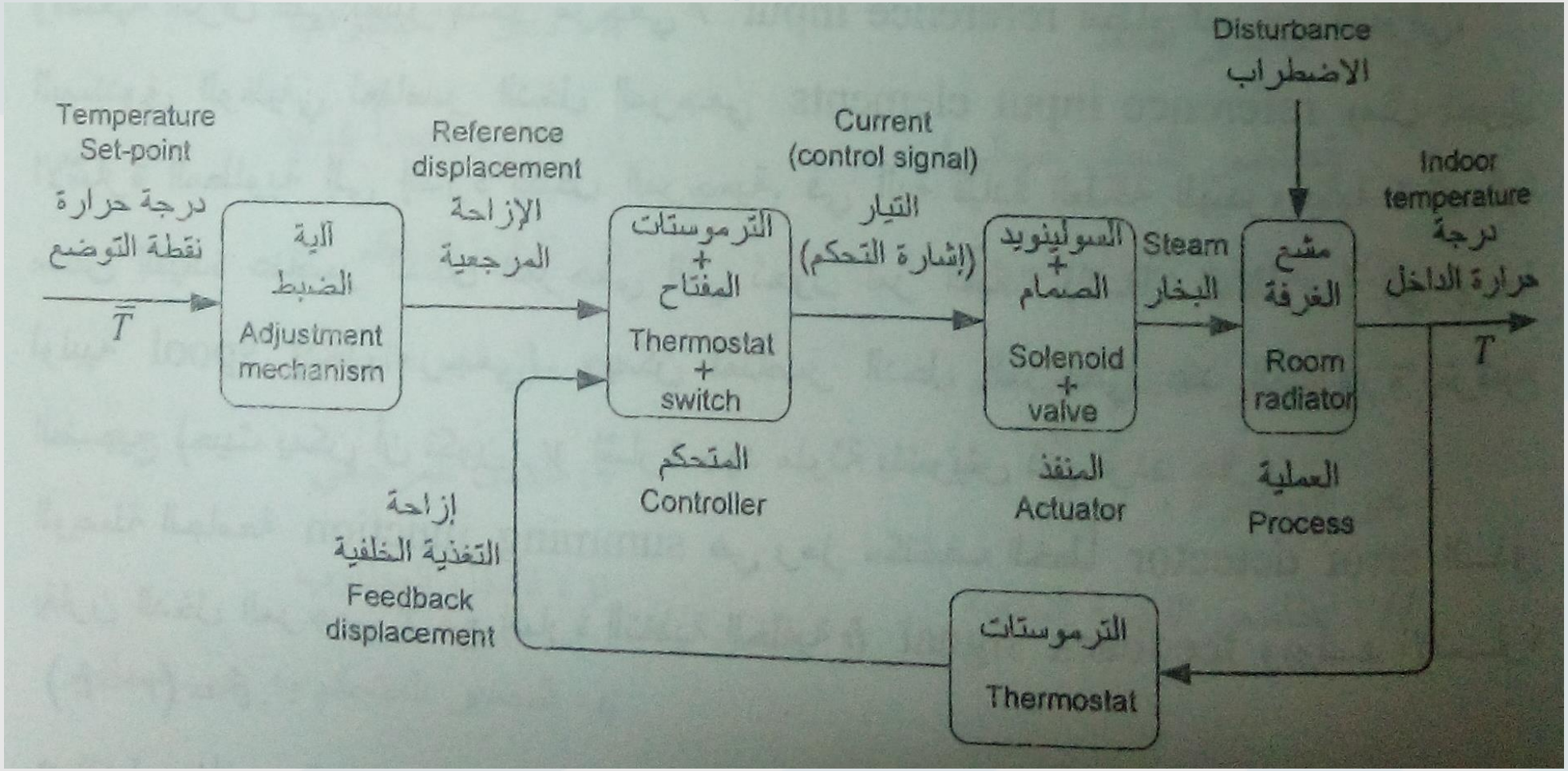
Parts of closed loop house automatic heating system

Example8: House automatic heating system:



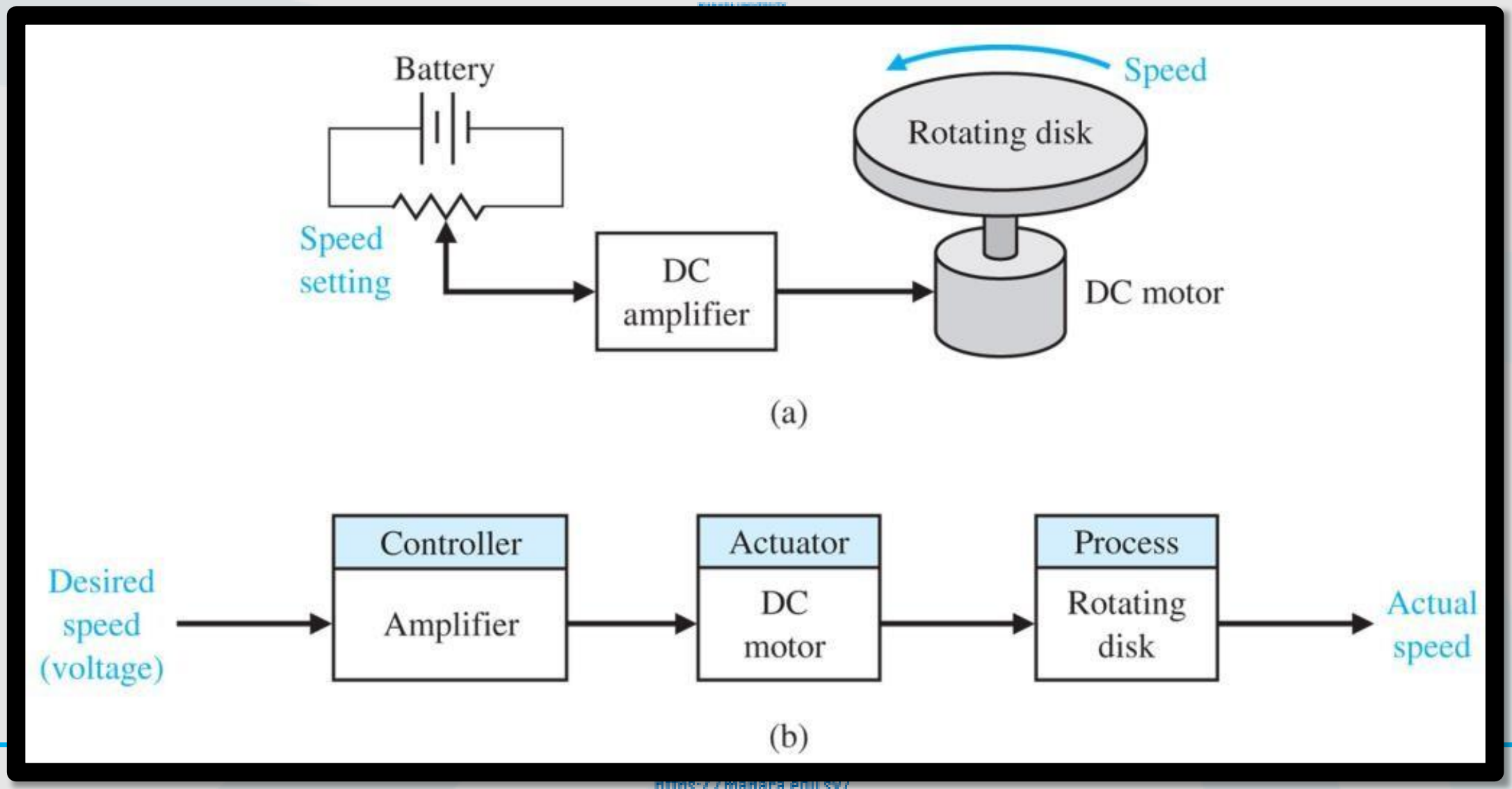
Parts of closed loop house automatic heating system

Example8: House automatic heating system:

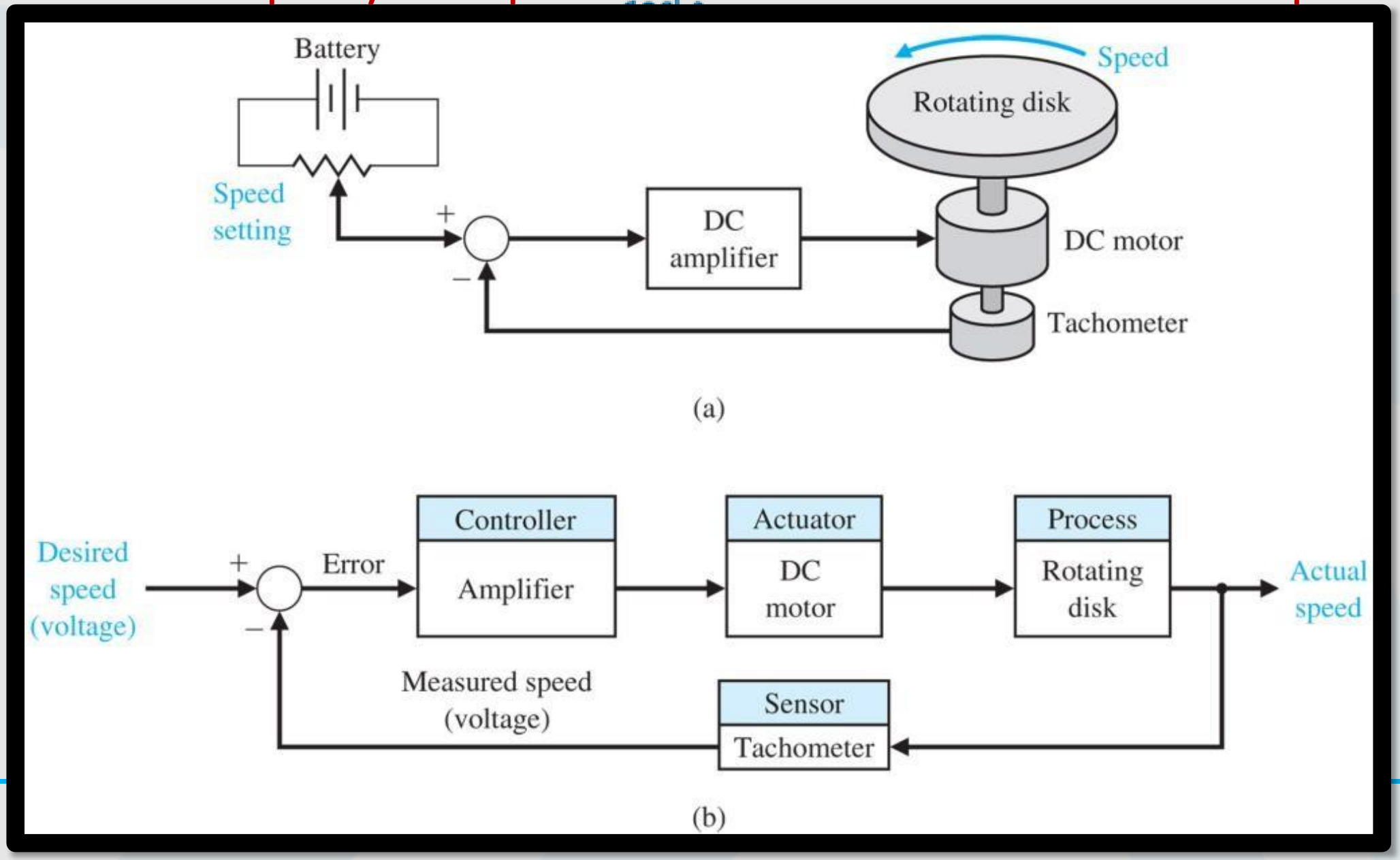


Closed loop house automatic heating system

Example 9: DC motor speed control: Open-Loop



Examle10: CD player speed control: Closed-Loop



Examle11: Disturbance Rejection

https://www.youtube.com/watch?v=aSwCMK96NOw

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