# Chapter 1

# Introduction to control systems

## 1.1 Introduction

The Automatic has found its way into almost every area of daily life:

- ➢ The temperature of the rooms is "regulated" by a thermostat, so that it is constant whatever the outside temperature;
- ➢ The transport sector also offers many examples:
  - Automatic control of a boat's helm;
  - Automatic piloting of an aircraft;
  - Cruise control of an automobile; …
- ➢ The introduction of robots into assembly lines in the industrial sector replacing some human interventions;
- ➢ In the military field: target tracking by a missile; …

So, an automatic system always seeks to perform a certain number of operations without human intervention. In some cases, the goal is to replace humans for economic reasons or to avoid them having to do tedious tasks, in others it will be to obtain a better quality product.

There are actually two major areas in Automatics:

- On the one hand, we can look for the automation of a sequence of instructions known in advance, we are then dealing with a so-called sequential system. This work is carried out using an industrial programmable logic controller (PLC).
- On the other hand, we can seek to ensure the regulation (i.e. the maintenance at a constant value) of a physical quantity or impose a certain evolution on the latter (we speak of pursuit).

We then enter the world of servitude.

## 1.2 General information on systems

A system is understood to be an isolated device subject to the laws of physics and characterized by certain quantities. In the one-variable system, we are interested in the relationship between a particular quantity or the main input $e(t)$, corresponding to an external action exerted on the system and one of the output quantities characterizing its state which we designate by $s(t)$.

The application of the laws of physics to the system leads to the establishment of a certain relationship between $e(t)$ And $s(t)$. Other quantities which have an action on the system and which are therefore likely to modify the existing relationship between $e(t)$ And $s(t)$, are called parasitic inputs or disturbances.

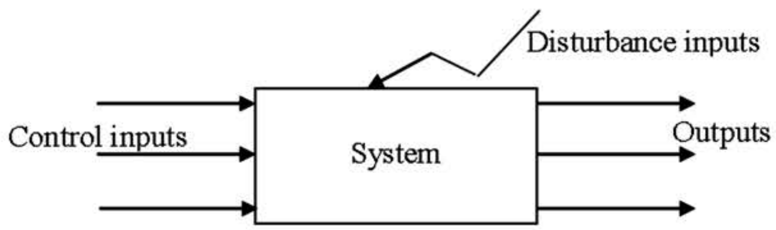



**Fig. 1.1: General representation of a system.**

Various variables can be highlighted on a process:

- Control inputs, which allow you to act on the evolution of the process.
- Disturbance inputs, generally not controllable by the user and which also act on the process.
- Outputs, measurable or at least detectable variables, which characterize the action of the process on its environment.
- State variables, internal variables of the system, whose action on the environment is not necessarily directly perceptible but whose evolution governs that of the process.

**Example systems**: Car, TV, Oven, Robot, Airplane, Solar panels, etc.

## 1.3 Control system

A control system is an assembly of physical components connected or linked together in such a way that they can control, direct or regulate themselves; or control, direct or regulate another system. For example, the driver at the wheel of a vehicle (car) → It must follow the road.

To do this, he observes the road and its environment and assesses the distance between his vehicle and the edge of the road. He determines, depending on the context, the angle he must give to the steering wheel to follow the road. He acts on the steering wheel (therefore on the system); then again, he begins his observation for the entire duration of the trip. If a gust of wind deviates the vehicle, after observing and measuring the deviation, he acts to oppose this disturbance. If we want a system to replace man in various tasks, it will have to have behavior and organs similar to those of a human being. That is to say, it will have to be able to appreciate, compare and act.

If a gust of wind deflects the vehicle, after observing and measuring the deviation, it acts to oppose this disturbance. If we want a system to replace man in various tasks, it will have to have behavior and organs similar to those of a human being. That is to say, it will have to be able to appreciate, compare and act.

## 1.4 Continuous systems

A physical system is said to be continuous if all the characteristic quantities are of a continuous nature, the information representing these quantities is available at each instant and can take all possible values between two limits. Their evolutions over time are a continuous signal in the mathematical sense of the term.

## 1.5 Classification of systems

- Depending on the nature of the operating regimes (static and dynamic).
- According to the mathematical description (linear, non-linear).
- According to dynamic properties (localized parameters, distributed parameters).
- Depending on the evolution of the parameters (stochastic, deterministic).
- Depending on the number of variables (single variable (SISO), multi variable (MIMO))

## 1.6 Linear systems

A physical system is linear if the relationship between the input quantities and the output quantity(ies) is a system of linear differential equations.

## 1.7 Nature of input and output signals

The input and output signals of a system are functions of time: if at each instant their amplitudes are perfectly known, the signal is said to be deterministic (example: unit step, sinusoid, etc.).

If, on the other hand, at each instant, we only know the probability for the signal to have such and such an amplitude, we say that it is random (example: noise).

- **Input signal**: An input signal is the stimulus excitation applied to the control system from an external energy source, generally in order to provoke a specific response.
- **Output signal**: An output signal is the actual response obtained from the control system; it may or may not coincide with the response that the input signal should normally cause.

## 1.8 Definition of a servo system

A servo system is a control system, the word servo is taken in the sense of adjustment, to command, or to regulate, to command another system. Generally speaking, the system includes (fig. 1.3):

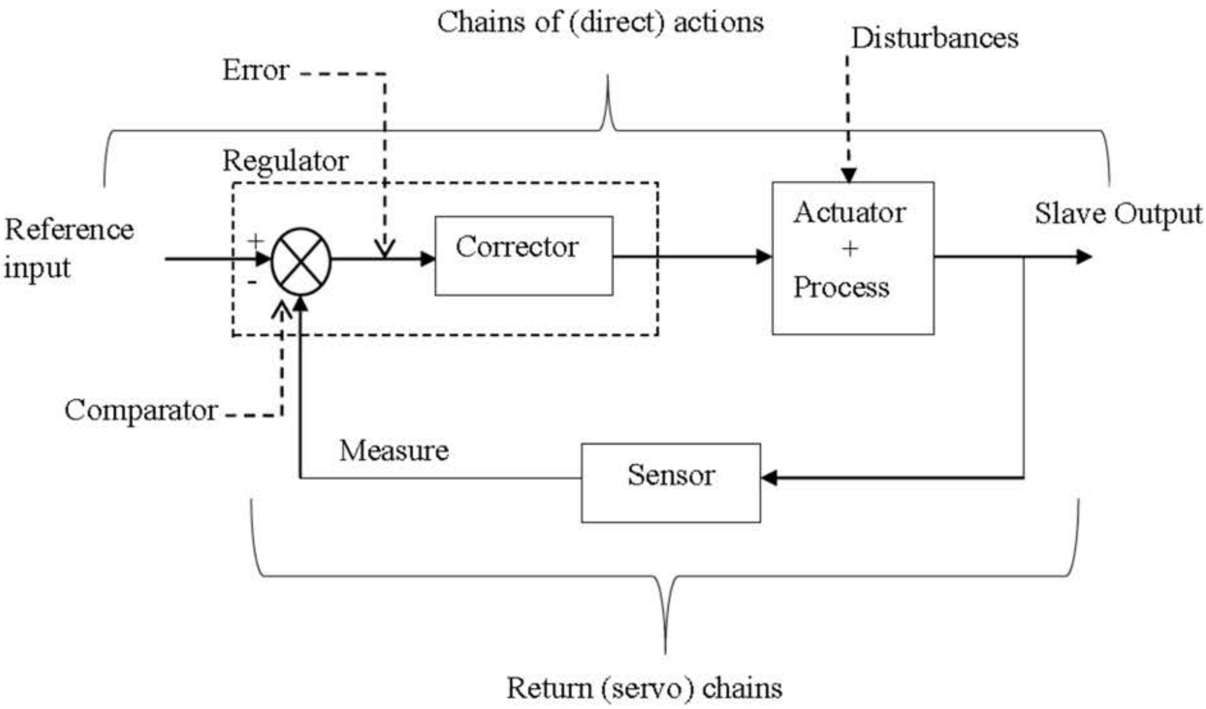



**Fig. 1.2: Functional diagram of a servo system.**

A controlled system is defined by its purpose and is characterized by two chains:

**Chains of (direct) actions**:

- They include amplifier elements and possibly power converters, linked to the energy source.
- Includes all power organs (requiring an external energy supply) which perform work.

- The nature of these elements is not specified on the diagram; they could be electrical, mechanical, pneumatic, etc.

**Return (servo) chains**:

- They are made up of generally passive precision elements, they are not power chains, they transmit information on the output quantities to the input. This information is compared to the input signals by means of compensators.

In more detail, we distinguish:

**The regulator**: It includes:

- **The comparator** (deviation detector): It is a two-input, one-output system proportional to the error between the two inputs.
- **The corrector:** installed between the gap detector and the amplifier, it improves the performance of a linear servo system (LSS) such as: Precision, Response time, Stability, Speed, etc. Example: P, PI, PID.
- **The amplifier:** It delivers the necessary input power to the actuator.

**The actuator:** is an element that controls the slave system, its fundamental function is therefore execution.

**The process:** is the element that we want to impose a regulation of certain of its parameters.

**The sensor**: It controls the servo quantity (output value) and reports to the regulator.

## 1.9 Definition of a regulation system

A control system is a system capable of maintaining a determined variable constant and equal to a value, called a set point, without human intervention (example: regulation of the temperature of an oven).

## 1.10 Classification of a controlled system

Depending on the type of reference entry:

a. **<u>Regulation</u>***:* maintain a determined variable, constant and equal to a value, called a set point, without human intervention. Example: Regulation of the temperature of a room.

b. **<u>Enslavement</u>***:* to vary a given quantity according to a law imposed by an element of comparison. Example: Regulation of the speed of an engine, Trajectory tracking of missile.

## 1.11 Regulated servo systems

Regulation allows a physical quantity to be maintained at a constant value regardless of external disturbances. The overall objective of regulation can be summarized by these three key words: Measure, Compare and Correct.

We are therefore led to carry out measurements to obtain certain knowledge before undertaking an action. These measurements will be obtained by means of specific equipment. And it is therefore varying a determined quantity according to a law imposed for an element of comparison, example: regulation of the speed of a motor.

Any servo-system will include these three categories of elements which fulfill the three major functions necessary for its proper functioning (fig.1.3):

- **Measurement (or observation)**
- **Comparison** between the goal to be reached and the current position (Reflection)
- **Power action**

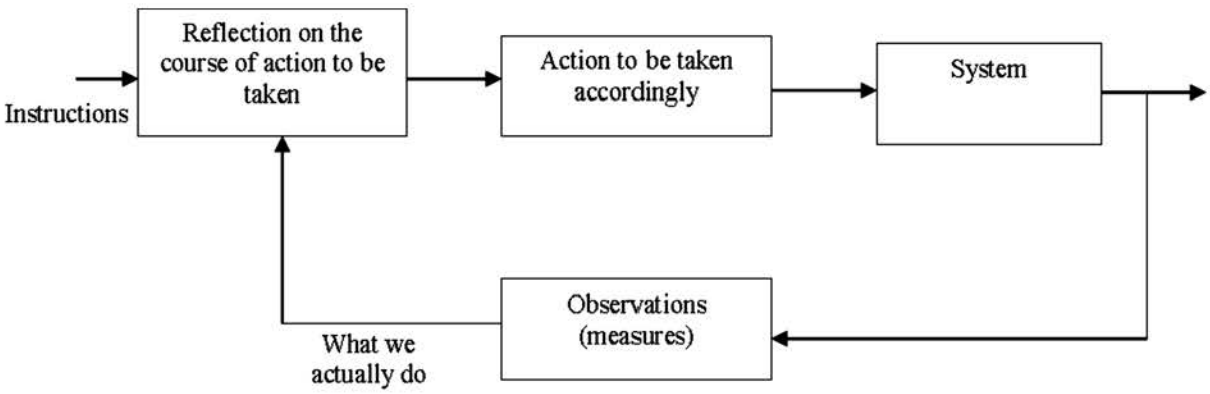
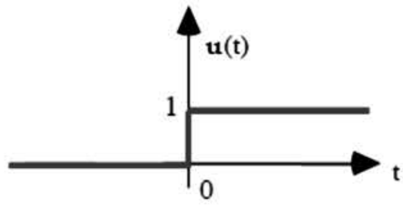



**Fig. 1.3: General concept of a servo.**

# 1.12 Nature of input signals of a controlled system

## 1.12.1 The step function

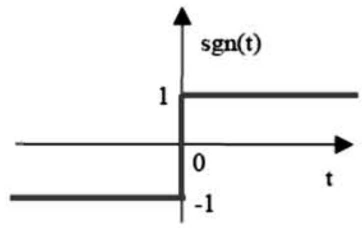
$$u(t) = \begin{cases} 0 & if\ t < 0 \\ 1 & if\ t \geq 0 \end{cases}$$




The response of the system is called the step response.

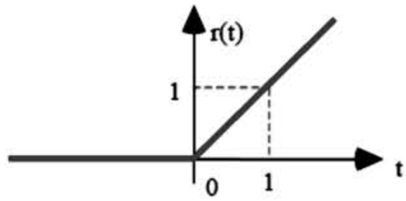
## 1.12.2 The sign function

$$\text{sgn}(t) = \begin{cases} 1 & \forall\ t > 0 \\ -1 & \forall\ t < 0 \\ 0 & t = 0 \end{cases}$$




## 1.12.3 The ramp function

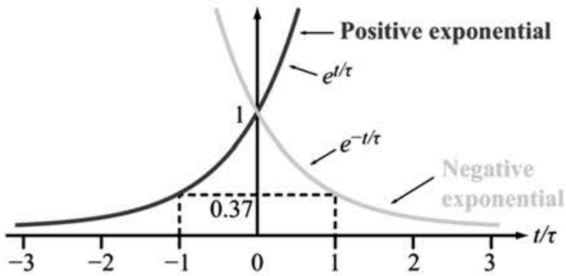
$$r(t) = \begin{cases} 0 & if\ t < 0 \\ t & if\ t \geq 0 \end{cases}$$




The system response is called a Ramp response.

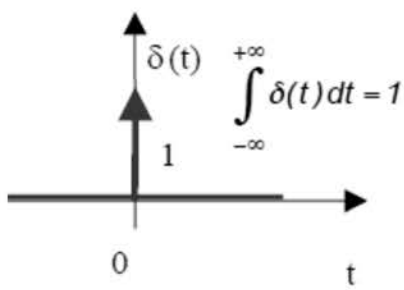
## 1.12.4 Real-valued exponential signal

$$s(t) = A.e^{\frac{t}{\tau}} \quad or \quad s(t) = A.e^{-\frac{t}{\tau}}$$




## 1.12.5 The Dirac impulse function

$$\delta(t) = \begin{cases} 1 & if\quad t = 0 \\ 0 & if\quad t \neq 0 \end{cases}$$




The response of the system is called the impulse response.

## 1.13 Definition of closed-loop and open-loop systems

Control systems fall into two general categories, open-loop (OL) systems and closed-loop (CL) systems.

### 1.13.1 A control system in OL

Is a system where the control signal is independent of the output signal. In open loop OL, the output has no feedback to the comparator. It includes the action chain and the measurement chain.

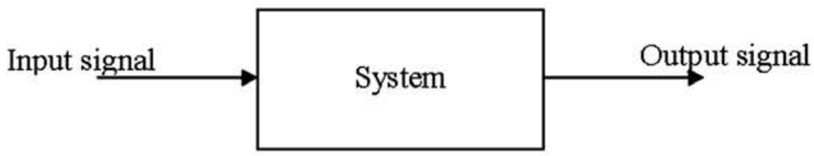



**Fig. 1.4: Open chain system.**

### 1.13.2 A control system in CL

Is a system where the control signal depends in some way on the output signal.

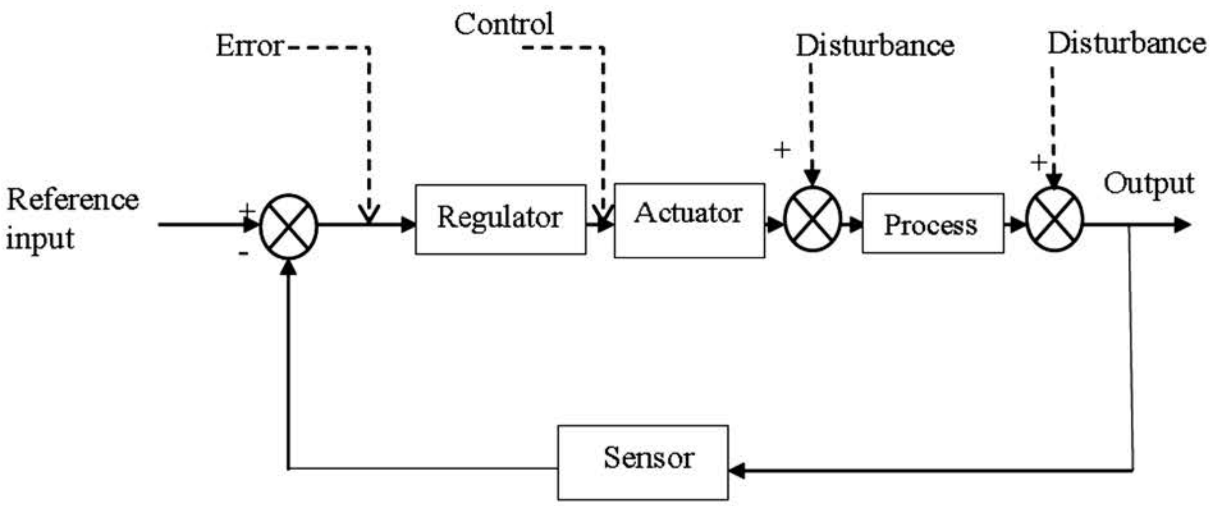



**Fig. 1.5: Closed loop system.**