



Chapter I. Control Systems Terminology

I.1 Introduction:

Automatic control is concerned with making systems work by themselves, with as little human intervention as possible. Instead of having a person continuously control every step of a process, the system is designed to carry out the required task automatically and produce the expected result. This idea can be found in many areas of engineering. It is used in machines, industrial processes, electrical and mechanical systems, heating systems, and many other applications where a process changes or evolves with time. In automatic control, the system is the main element being studied. It receives one or more inputs, which act on it, and produces one or more outputs, which describe how the system responds. Understanding the relationship between the input and the output is therefore an important part of control engineering.

A simple example is the automatic filling of a water tank. The objective is to keep the water level at a desired value. To do this, the opening of the valve and the time during which it remains open must be controlled according to the required water level.

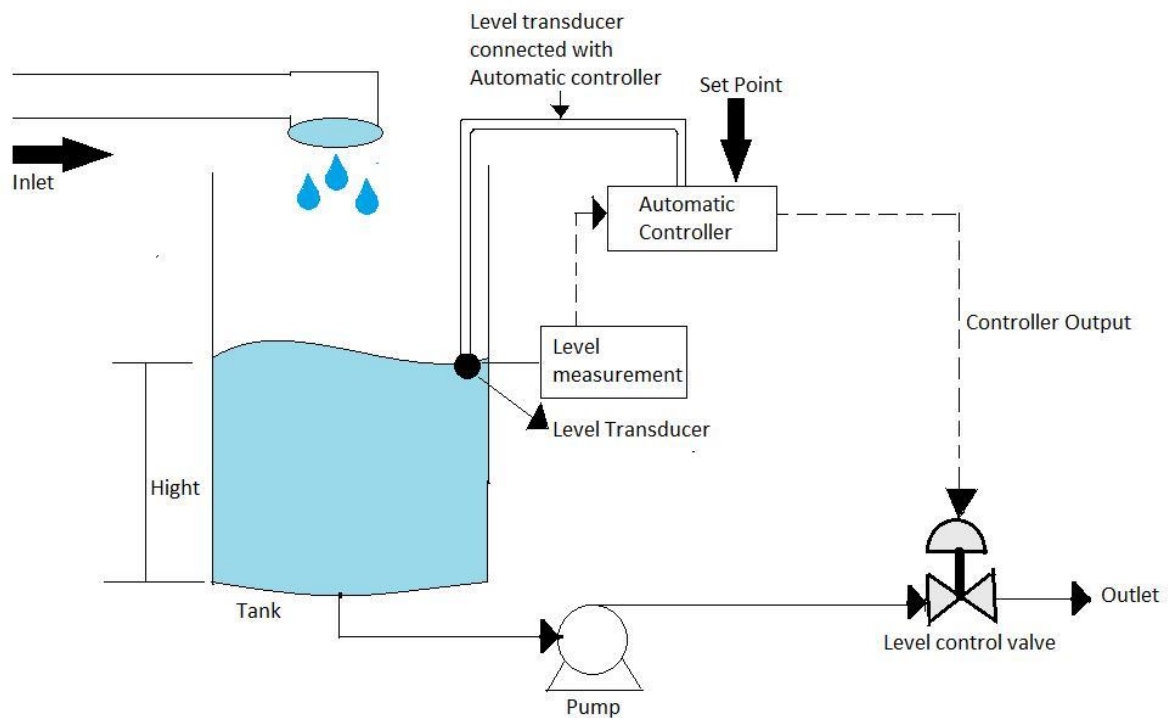


Figure.1 Example of an automated water-tank filling system.

The level-control loop can be represented by the functional diagram shown below. The desired level is compared with the measured level, and the resulting error is used by the controller to generate the command that controls the valve.

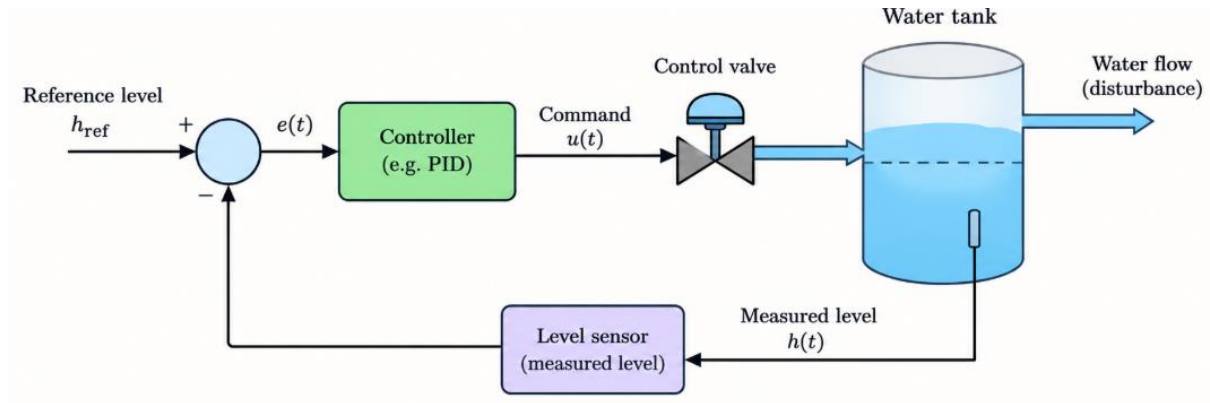


Figure.2 Functional diagram of the level-control loop.

I.2 Basic Concept of a System:

A system can be viewed as a set of physical or chemical processes that evolve with time. For a simple representation, the system is usually drawn as a block. The variables entering the block are the inputs, and the variable leaving the block is the output. The output is the effect produced by the system that we want to observe or control. The input variables are the causes that act on the system.

I.2.1 Input signals and variables:

Inputs come from outside the system. They are therefore considered as causes. Two main types of input can be distinguished:

- Command or reference input: this is a variable that can be selected or changed by the user or the control system. It represents the desired behavior of the system.
- Disturbance input: this is an external influence that affects the system. A disturbance may be known, unknown, measurable, or difficult to predict.

I.2.2 Output signals and variables:

The outputs represent the response of the system. They depend on the system itself and on the applied inputs. When the output has to be controlled, it must be measurable or observable. Sensors are used for this purpose. The following diagram shows a system with one command input, one disturbance input, and one output. A system can also be represented by a block diagram containing its transfer function. The transfer function describes the relationship between the input and the output in the Laplace domain.

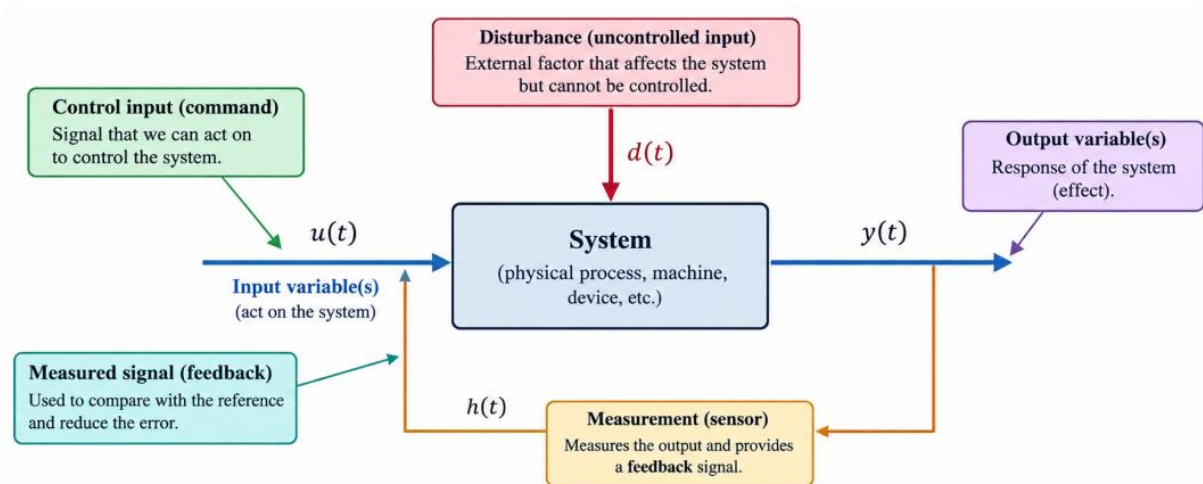


Figure.3 Block diagram showing the main signals associated with the system.

Depending on the number of inputs and outputs, control systems can be classified as follows:

- **SISO**: Single Input Single Output: one input and one output.
- **MIMO**: Multiple Input Multiple Output: several inputs and several outputs.
- **SIMO**: Single Input Multiple Output: one input and several outputs.
- **MISO**: Multiple Input Single Output: several inputs and one output.

In the following parts of the course, the main focus is on continuous, linear, time-invariant SISO systems.

I.3 Servo Systems and Regulation Systems:

An automated system that uses analog or digital control and includes feedback can be considered a servo system or a regulation system. The two concepts are closely related, but their main objectives can be described differently.

I.3.1 Servo System:

A servo system is designed so that its output follows the changes in the reference or command as closely as possible, even when external disturbances affect the system.

A typical example is an antenna or radar positioning system. The output position is expected to follow the variations of the reference position.

I.3.2 Regulation System:

Regulation refers to the set of techniques used to keep a controlled variable close to its reference value. The controller takes disturbances into account and acts on another physical variable, called the control variable. The main objective is therefore to reduce or reject the effect of disturbances on the controlled variable.

I.4 Regulation or Servo-Control Chain:

A regulation or servo-control system can be described through three main functions:

- **Observation of the system state:** A sensor measures the output variable and provides information about the current state of the system.
- **Comparison and decision:** The measured value is compared with the desired value. The controller determines the required change in the command. It generally includes a comparator and a controller/corrector.
- **Action:** The actuator applies the command to the physical system and provides the power required to perform the task.

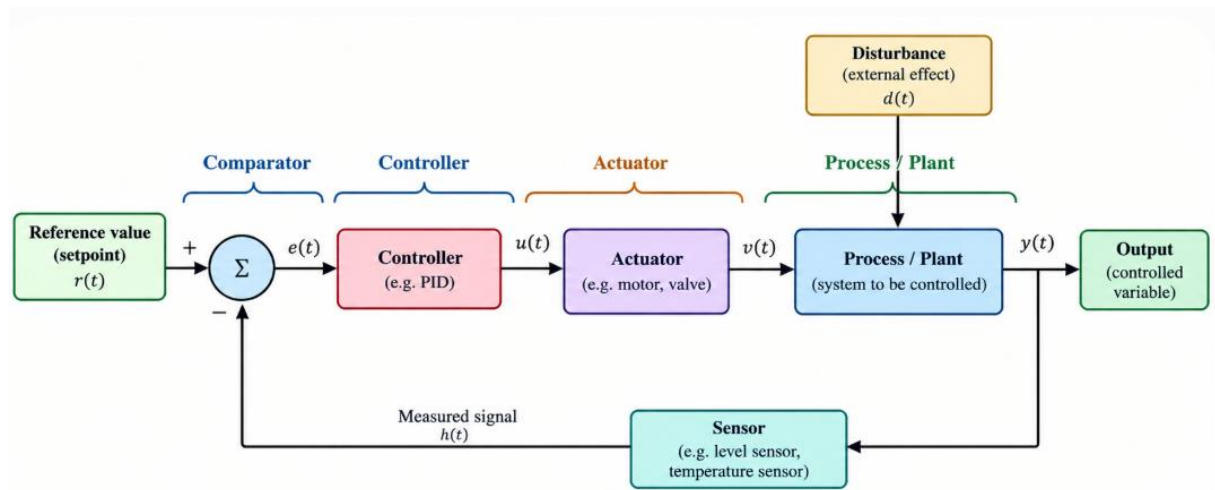


Figure.4 Main structure of regulation or servo control chain.

I.5 Open-Loop and Closed-Loop control systems:

A physical system is controlled when a relationship is established between an input variable and an output variable. Control structures are generally divided into two main groups: open-loop control and closed-loop control.

- In an open-loop system, the command is generated without using information about the output. There is no feedback path.
- In a closed-loop system, the command depends on the reference and on the measured output. Sensors provide the output information needed to calculate the control action.

I.5.1 Open-Loop control system:

In open-loop control, the command is generated from the known behavior or model of the system. The controller does not use the measured output to correct the command. This approach can be suitable when the system is well known and disturbances are negligible or can be ignored.

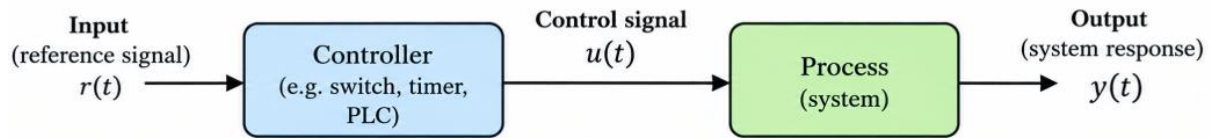


Figure.5 general diagram of an OL control system.

The main advantage of an open-loop system is its simple structure. It can also be fast and easy to implement. However, because there is no feedback, the system cannot automatically detect an error in the output and correct it.

I.5.2 Closed-Loop control system:

When the system is not perfectly known or when disturbances can significantly affect its behavior, feedback is introduced. The measured output is returned to the comparison point, where it is compared with the reference. The resulting error is used by the controller to calculate the control signal. In this way, the system can react to changes and reduce the difference between the desired and actual outputs.

Closed-loop control is particularly useful when disturbances or changes in system parameters are expected. It can improve several performance aspects, including accuracy, reference tracking, disturbance rejection, and robustness to parameter variations. Feedback can also help stabilize systems that are unstable in open loop.

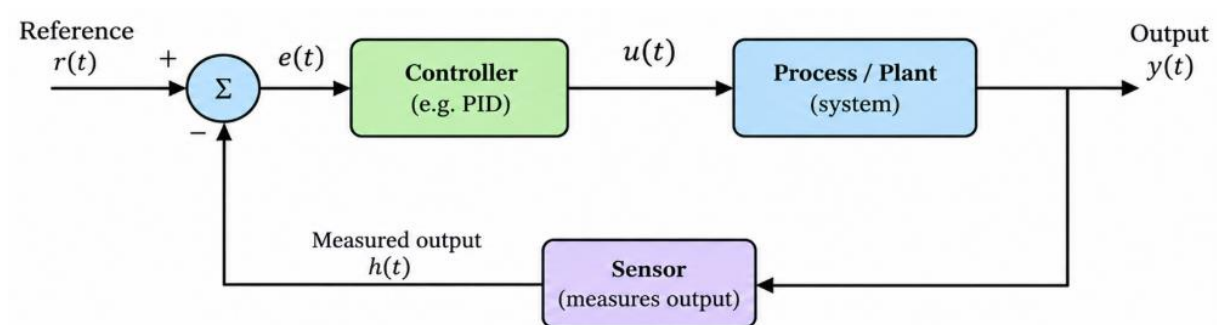


Figure.6 general diagram of an CL control system.

In the closed-loop diagram:

r : Reference or command value.

$e(t)$: Error signal, defined as $e(t) = r - h(t)$.

Controller: generates the control law and produces the command $u(t)$.

$y(t)$: System output or controlled variable.

$h(t)$: measured output obtained from the sensor.

Feedback means using information about what the system has actually produced to decide what should be done next. This principle is common in everyday activities.

For example, when driving a car, the driver continuously observes the road and corrects the steering when necessary.

A control action without feedback can give the expected result mainly when the behavior of the system is well known and remains nearly unchanged, and when external disturbances do not significantly modify the response.

In many practical situations, these conditions are not guaranteed. Feedback is therefore introduced so that the controller can use information about the current state of the process when generating the control signal.