Chapter One:Introduction

1. Introduction To Control Systems

1.1. Introduction

Automatic control has played a very important role in the advance of engineering and science. In addition to its extreme importance in space – vehicle systems, missile – guidance systems, robotic systems, and the like, automatic control has become an important and integral part of modern manufacturing and industrial processes. It is essential in the design of autopilot systems in the aerospace industries, and in the design of cars and trucks in the automobile industries. It is also essential in such industrial operations as controlling pressure, temperature, humidity, viscosity, and flow in the process industries.

1.2. Definitions

Before we can discuss control systems, some basic terminologies must be defined.

System: a combination of components that act together to perform a function not possible with any of the individual parts. The word *System* as used herein is interpreted to include physical, biological, organizational, and other entities, and combinations.

Plant: may be a piece of equipment, perhaps just a set of machine parts functioning together, the purpose of which is to perform a particular operation. We shall call any physical object to be controlled (such as a mechanical device, a heating furnace, a chemical reactor, or a spacecraft) a plant.

Process: is a natural, progressively continuing operation or development marked by a series of gradual changes that succeed one another in a relatively fixed way and lead toward a particular result or end; or an artificial or voluntary, progressively continuing operation that consists of a series of controlled actions or movements systematically directed toward a particular result or end. We shall call any operation to be controlled a process. Examples are chemical economic and biological process.

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 is an input.

Command Input: the motivating input signal to the system, which is independent of the output of the system.

Reference Selector (Reference Input Element): The unit that establishes the value of the reference input. The reference selector is calibrated in terms of the desired value of the system output.

<u>Reference Input:</u> the reference signal produced by the reference selector, i.e., the command expressed in a form directly usable by the system. It is the actual signal input to the control system.

<u>Output (controlled variable):</u> The quantity that must be maintained at a prescribed value, i.e., following the command input without responding the disturbance inputs.

<u>Forward element (system dynamics):</u> The unit that reacts to an actuating signal to produce a desired output. This unit does the work of controlling the output and thus may be a power amplifier.

<u>Feedback element:</u>The unit that provides the means for feeding back the output quantity, or a function of the output, in order to compare it with the reference input.

<u>Actuating signal:</u> The signal that is the difference between the reference input and the feedback signal, it is the input to the control unit that causes the output to have the desired value.

<u>Open-Loop control system:</u> a system in which the output has no effect upon the input signal.

<u>Closed-Loop control system:</u> a system in which the output has an effect upon the input quantity in such a manner as to maintain the desired output value.

<u>Servomechanism (servo):</u> the term is often used to refer to a mechanical system in which the steady-error is zero for a constant input signal. Sometimes, by generalization, it is used to refer to any feedback control system.

<u>Regulator:</u> this term is used to refer to systems in which there is a constant steady-state output for a constant signal. the name is derived from the early speed and voltage controls, called speed and voltage regulators.

1.3. <u>Closed-Loop Control Versus Open-Loop Control:</u>

Feedback Control Systems: system that maintains a prescribed relationship between the output and the reference input by comparing them and using the difference as a means of control is called a *feedback control system*. An example would be a room temperature control system. By measuring the actual room temperature and comparing it with the reference temperature (desired temperature), the thermostat turns the heating or cooling equipment on or off in such a way as to ensure that the room temperature remains at a comfortable level regardless of outside conditions.

Open-Loop Control Systems: those systems in which the output has no effect on the control action are called *open-loop control systems*as shown in figure (1.1.a). In other words, in an open loop control system the output is neither measured nor fed back for comparison with input. One practical example is a washing machine. Soaking, washing, and rinsing in the washer operate on a time basis. The machine does not measure the output signal, that is, the cleanliness of the clothes. In any open-loop control system the output is not compared with the reference input. Thus, to each reference input there corresponds a fixed operating condition; as a result, the accuracy of the system depends on calibration. In the presence of disturbances, an open-loop control system will not perform the desired task. Open-loop control can be used in practice, if the relationship between the input and output is known and if there are neither internal nor external disturbances.

Closed-Loop Control Systems: feedback control systems are often referred to as *closed-loop control* systems as shown in figure (1.1.b). 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 (which may be the output signal itself or a function of the output signal and its derivatives and/or integrals), is fed to the controller so as to reduce the error and bring the output of the system to a desired value. The term closed-loop control always implies the use of feedback control action in order to reduce system error.

Closed-loop versus Open-loop: An advantage of the closed-loop control system is the fact that the use of feedback makes the system response relatively insensitive to external disturbances and internal variations in system parameters. It is thus possible to use relatively inaccurate and inexpensive components to obtain the accurate control of a given plant, whereas doing so is impossible in the open-loop case.
From the point of view of stability, the open-loop control system is easier to build because system stability is not major problem. On the other hand, stability is a major problem in the closed-loop control system, which may tend to overcorrect errors and thereby can cause oscillations of constant or changing amplitude.

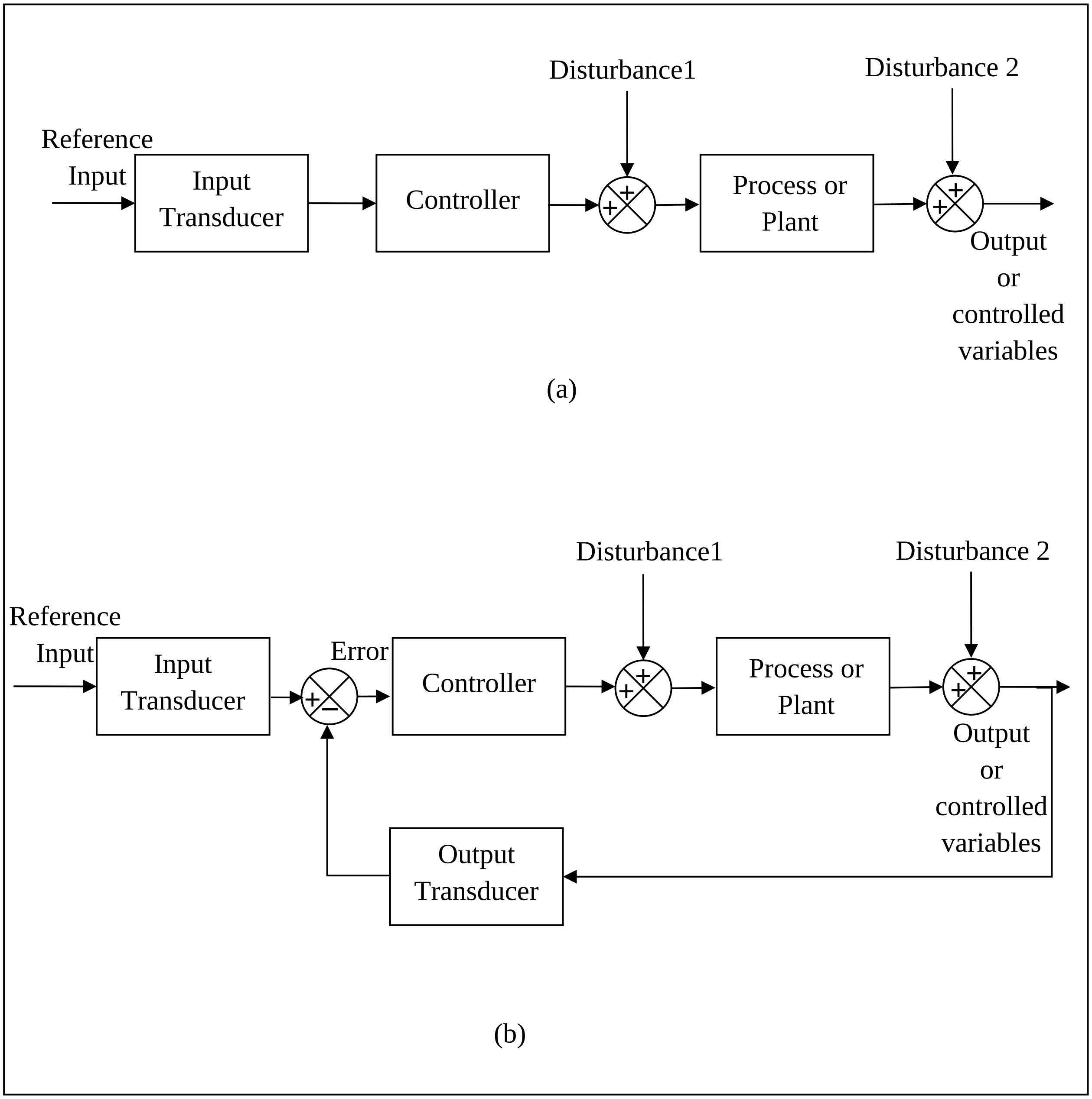

Figure (1.1) *a*) *open-loop b*)*closed-loop*

Open-Loop Control System	Closed-Loop Control System
1. An open-loop system has the ability to perform accurately, if its calibration is good. If the calibration is not perfect its performance will go down	1. A closed-loop system has got the ability to perform accurately because of the feedback
2. It is easier to build.	2. is difficult to build.
3. Weak against disturbance	3. Can reduce the effect of disturbance

4. If non – linearity's are present; the system operation is not good	4. Even under the presence of non – linearity's the system operates better than open loop system
5. Feed back is absent	5. Feed back is present

1.4. Examples of Control Systems

Temperature Control System. Figure (1.2) shows a schematic diagram of temperature control of an electric furnace. The temperature in the electric furnace is measured by a thermometer, which is an analog device. The analog temperature is converted to a digital temperature by an A/D converter. The digital temperature is fed to a controller through an interface. This digital temperature is compared with the programmed input temperature, and if there is any discrepancy (error), the controller sends out a signal to the heater, through an interface, amplifier, and relay, to bring the furnace temperature to a desired value.

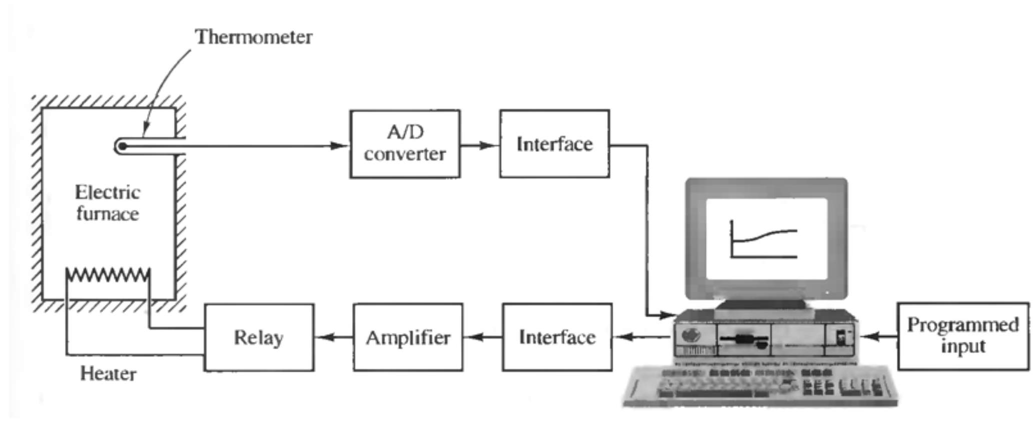

Figure (1.2) Temperature Control System

Missile launching and guidance system. A schematic diagram of a missile launching and guidance system is shown in figure (1.3). The radar detects the presence of the target aircraft through its rotating antenna and passes the detection signal to the launch computer indicating the velocity and position of the target. The computer calculates the firing angle which is the launch command signal. this command signal is passed to the launcher, i.e. the driver motor, through the power amplifier. The launcher angular position is fed back to the launch computer and the missile is fired at the moment when the difference between the launch command signal and the missile firing angle becomes zero. After the missile is launched, the guiding signal is from the radar beam itself as the radar antenna is locked on to the target and it continuously tracks the target. The missile after being launched comes under the guidance of the radar beam.
The control system available within the missile now obtains the guidance signal from the beam which automatically adjusts the control surfaces of the missile in such a manner that the missile moves along the beam. Finally, the target will be hit.

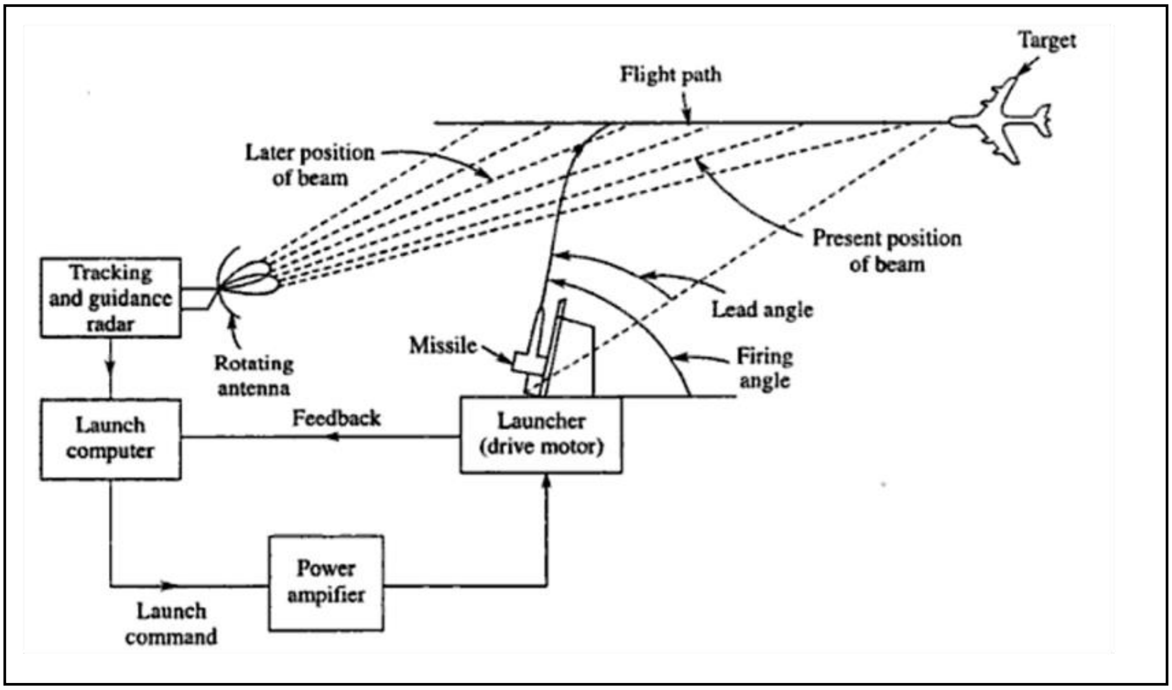

Figure (1.3)schematic diagram of a missile launching and guidance system

Automobile steering control system. Driving an automobile is pleasant task when the auto responds rapidly to the driver's commands. Many cars have power steering and brakes, which utilize hydraulic amplifiers for amplification of the force to the brakes or the steering wheel. A simple block diagram of an automobile steering control system is shown in figure (2.4). the desired course is compared with a measurement of the actual course in order to generate a measure of the error. This measurement is obtained by visual and tactile (body movement) feedback. There is an additional feedback from the feel of steering wheel by the hand (sensor).

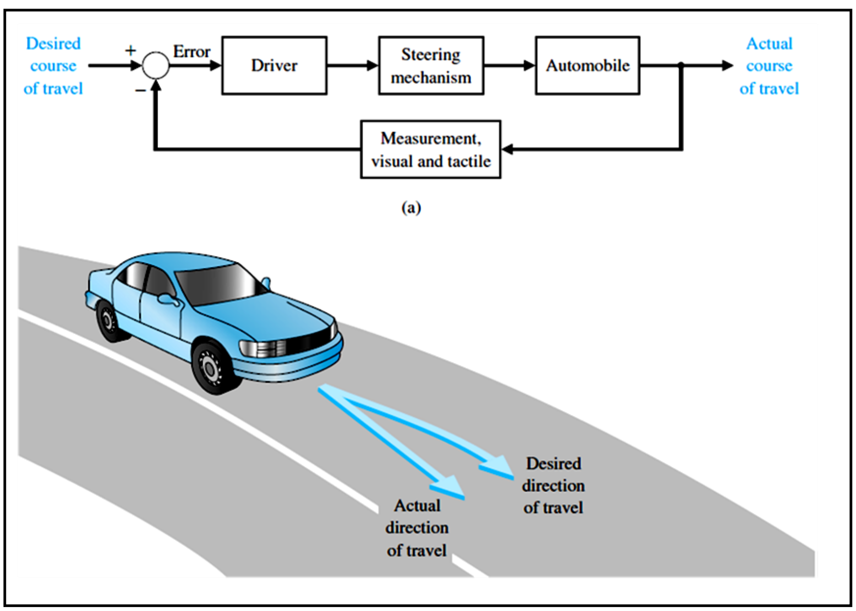

Figure (1.4) Automobile steering control system

1.5. <u>Types of Feedback Control Systems:</u>

Feedback control systems may be classified in a number of ways, depending upon the purpose of the classification. For instance, according to the method of analysis and design, control systems are classified as ***liner*** or ***nonlinear***, and ***time – varying*** or ***time – invariant***. According to the types of signal found in the system, reference is often made to ***continuous – data***or ***discrete – data*** systems, and ***modulated*** or ***unmodulated*** systems.

Control systems are often classified according to the main purpose of the system. For instance, a ***position – control system*** and a ***velocity – control system*** control the output variables just as the names imply. In general, there are many other ways of identifying control systems according to some special features of the system.