Introduction

A *system* is a collection, set, or arrangement of elements (subsystems).

A *control system* is an interconnection of components forming a system configuration that will provide a desired system response.
Hence, a control system is an arrangement of physical components connected or related in such a manner as to command, regulate, or direct itself or another system.

In order to identify, or define a control system, we introduce two terms: *input* and *output* here.
The *input* is the excitation, or command applied to a control system,
and the *output* is the actual response resulting from a control system.
The *output* may or may not be equal to the specified response implied by the input.
Inputs could be physical variables or abstract ones such as *reference, set point* or *desired* values for the output of the control system.
Control systems can have more than one input or output. The input and the output represent the desired response and the actual response respectively.
A control system provides an output or response for a given input as shown in Fig. 1.1.

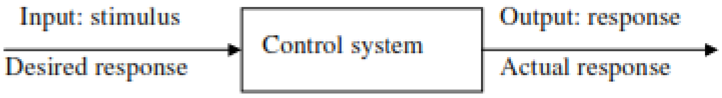

Fig. 1.1 Description of a control system

The output may not be equal to the specified response implied by the input.
If the output and input are given, it is possible to identify or define the nature of the system's components.

Broadly speaking, there are three basic types of control systems:
(*a*) Man-made control systems
(*b*) Natural, including biological-control systems
(*c*) Control systems whose components are both man-made and natural.

CONTROL SYSTEM CONFIGARATION

There are two control system configurations: open-loop control system and closed loop control system.

(*a*) ***Block.*** A block is a set of elements that can be grouped together, with overall characteristics described by an input/output relationship as shown in Fig. 1.3. A block diagram is a simplified pictorial representation of the cause-and-effect relationship between the input(s) and output(s) of a physical system.

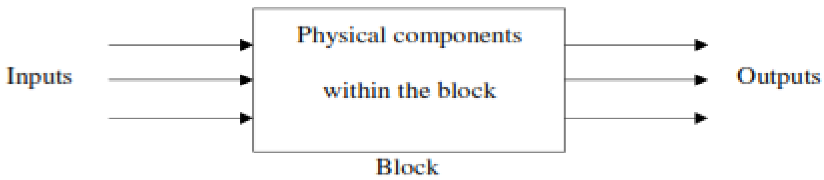

Fig. 1.3 Block diagram

The simplest form of the block diagram is the single block as shown in Fig. 1.3. The input and output characteristics of entire groups of elements within the block can be described by an appropriate mathematical expressions as shown in Fig. 1.4.

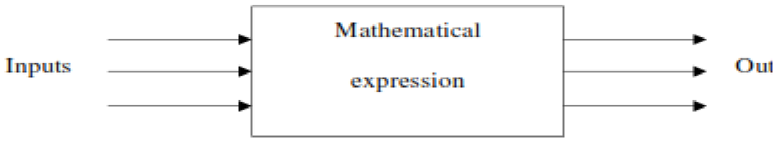

Fig. 1.4 Block representation

(*b*) ***Transfer Function.*** The transfer function is a property of the system elements only, and is not dependent on the excitation and initial conditions. The transfer function of a system (or a block) is defined as the ratio of output to input as shown in Fig.1.5.

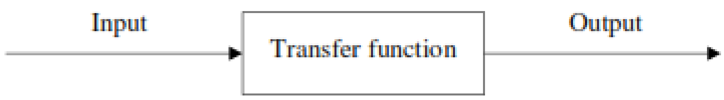

Fig. 1.5 Transfer function

Transfer function = Output/ Input

Transfer functions are generally used to represent a mathematical model of each block in the block diagram representation.

All the signals are transfer functions on the block diagrams. For instance, the time function reference input is $r(t)$, and its transfer function is $R(s)$ where t is time and s is the Laplace transform variable or complex frequency.

(*c*) ***Open-loop Control System.*** Open-loop control systems represent the simplest form of controlling devices. A general block diagram of open-loop system is shown in Fig. 1.6.

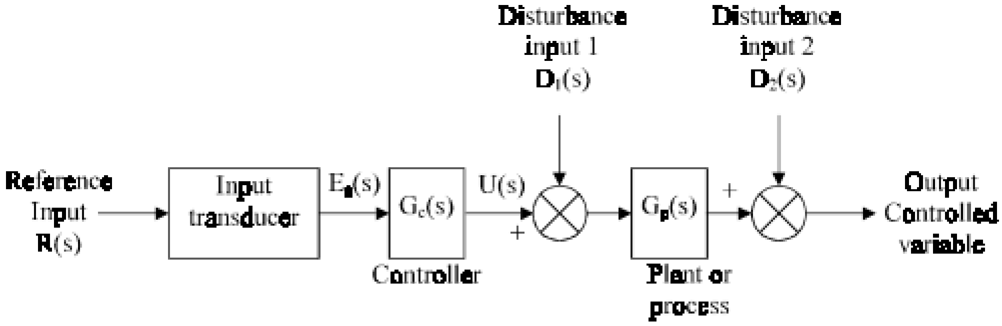

Fig. 1.6 General block diagram of open-loop control system

(*d*) ***Closed-loop (Feedback Control) System.*** Closed-loop control systems derive their valuable accurate reproduction of the input from feedback comparison. The general architecture of a closed-loop control system is shown in Fig. 1.7. A system with one or more feedback paths is called a **closed-loop system.**

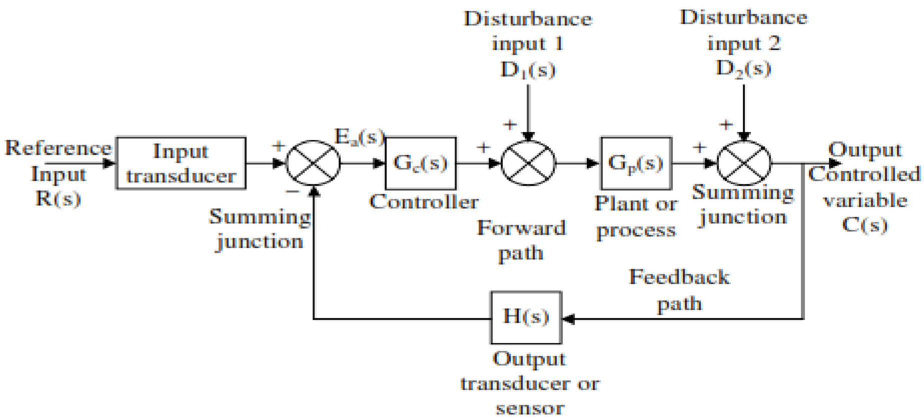

Fig. 1.7 General block diagram of closed-loop control system

Closed-Loop versus Open-Loop Control Systems.

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 a 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.

It should be emphasized that for systems in which the inputs are known ahead of

time and in which there are no disturbances it is advisable to use open-loop control. Closed-loop control systems have advantages only when unpredictable disturbances and/or unpredictable variations in system components are present.
Note that the output power rating partially determines the cost, weight, and size of a control system.
The number of components used in a closed-loop control system is more than that for a corresponding open-loop control system. Thus, the closed-loop control system is generally higher in cost and power. To decrease the required power of a system, open loop control may be used where applicable.
A proper combination of open-loop and closed-loop controls is usually less expensive and will give satisfactory overall system performance.
Most analyses and designs of control systems presented in this book are concerned with closed-loop control systems. Under certain circumstances (such as where no disturbances exist or the output is hard to measure) open-loop control systems may be desired. Therefore, it is worthwhile to summarize the advantages and disadvantages of using open-loop control systems.

The major advantages of open-loop control systems are as follows:
1. Simple construction and ease of maintenance.
2. Less expensive than a corresponding closed-loop system.
3. There is no stability problem.
4. 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.)
The major disadvantages of open-loop control systems are as follows:
1. Disturbances and changes in calibration cause errors, and the output may be different from what is desired.
2. To maintain the required quality in the output, recalibration is necessary from time to time