Program : **B.Tech**

Subject Name: **Instrumentation and Control**

Subject Code: **ME-402**

Semester: **4th**

UNIT-5

Introduction: Automated control systems are becoming more common in new road vehicles. In general, automation is designed to assist with mechanical or electrical accomplishment of tasks (Wickens & Hollands, 2000). It involves actively selecting and transforming information, making decisions, and/or controlling processes (Lee & See, 2004). Automated vehicle control systems are intended to improve safety (crash avoidance and mitigation), comfort (decrease of driver's workload; improved driving comfort), traffic efficiency (road capacity usage; reduced congestion), and the environment (decreased traffic noise; reduced fuel consumption).

The automation of basic control functions (e.g., automatic transmission, anti-lock brakes and electronic stability control) has proven very effective, but the safety implications of more advanced systems may be unclear in some cases**.** It is controversial that system safety will always be enhanced by allocating functions to automatic devices rather than to the drivers. A potential concern may be the out-of-loop performance problems that have been widely documented as a potential negative consequence of automation (e.g., Weiner & Curry, 1980).

System – An interconnection of elements and devices for a desired purpose.
Control System – An interconnection of components forming a system configuration that will provide a desired response.
Process – The device, plant, or system under control. The input and output relationship represents the cause-and-effect relationship of the process.

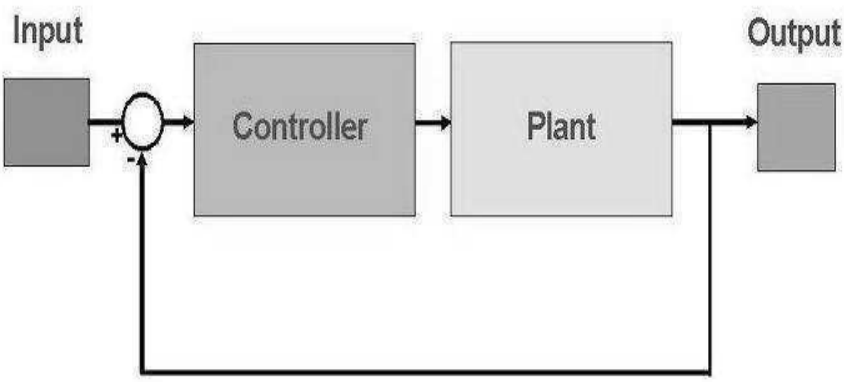


Fig.1

Control engineering is based on the foundations of feedback theory and linear system analysis, and it generates the concepts of network theory and communication theory. Accordingly, control engineering is not limited to any engineering discipline but is applicable to aeronautical, chemical, mechanical, environmental, civil, and electrical engineering.
A control system is an interconnection of components forming a system configuration that will provide a desired system response. The basis for analysis of a system is the foundation

provided by linear system, which assumes a cause effect relationship for the components of a system.

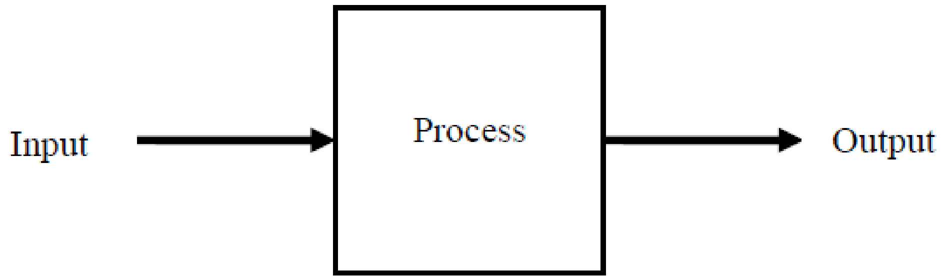


Fig.2: Basic Control system

An open-loop control system utilizes a controller or control actuator to obtain the desired response as shown in Figure. The open-loop control system utilizes an actuating device to control the process directly without using device. An example of an open-loop control system is an electric toaster.

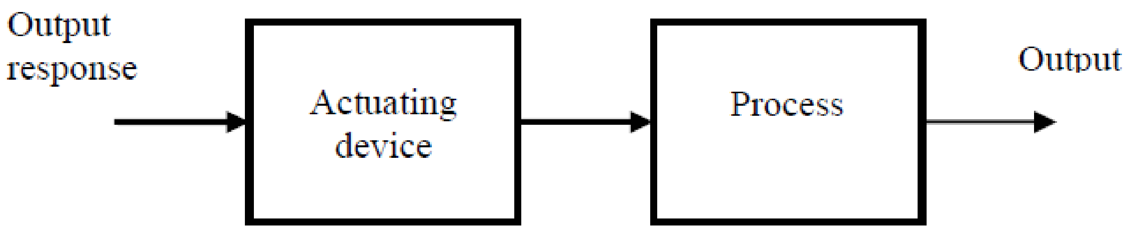


Fig.3: Open loop control system

A **closed-loop control system** utilizes an additional measure of the actual output to compare the actual output with the desired output response. The measure of the output is called the **feedback signal**. A feedback control system is a control system that tends to maintain a relationship of one system variable to another by comparing functions of these variables and using the difference as a means of control. As the system is becoming more complex, the interrelationship of many controlled variables may be considered in the control scheme. An example of closed-loop control system is a person steering an automobile by looking at the auto's location on the road and making the appropriate adjustments.

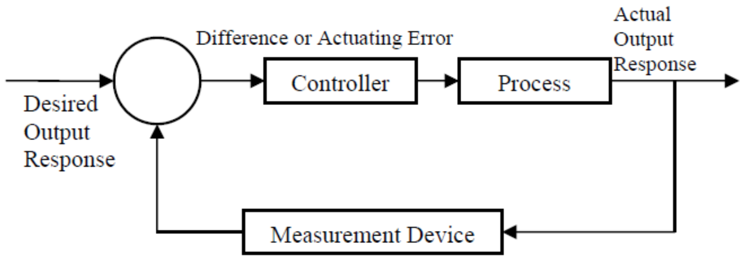
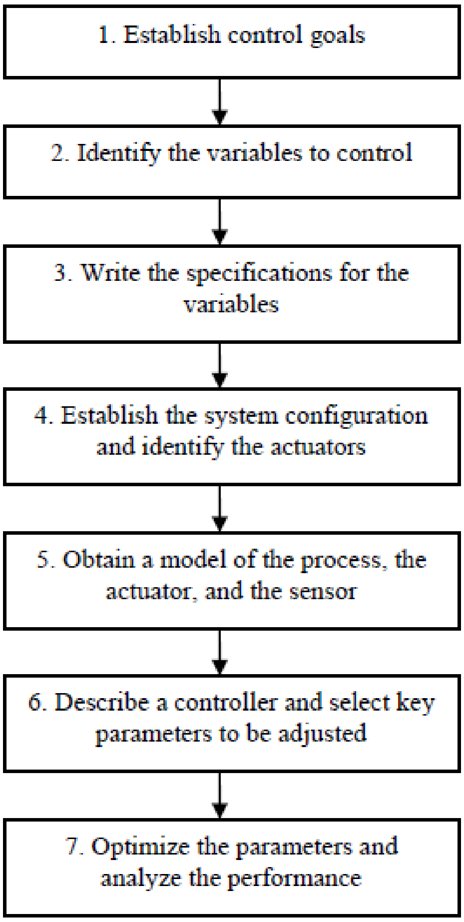


Fig.4: Close loop control system

CONTROL SYSTEM DESIGN

- Variables to control are the quantities or conditions that are measured and controlled.
- Process is a natural, progressively continuing operation marked by a series of gradual changes that succeed one another in a relatively fixed way and lead toward certain result or end.
- A system is a combination of components that act together and perform a certain objective.



Mathematical modelling of Dynamic Systems:

Linear Systems: For linear systems the principle of superposition is valid, and the response to a complex input can be calculated by summing up the responses to its components.

Linear Time Invariant (LTI) Systems versus Linear Time Varying Systems

1. Linear Time Invariant (LTI) Systems = systems:

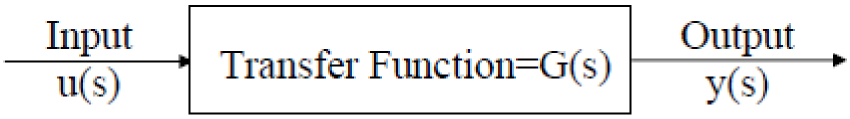
- represented by lumped components,
- described by linear differential equations
- Parameters of the equations are time invariant.

1. Systems with parameters that vary in time are called linear time varying systems.

Transfer Function

For zero initial condition

$$\text{Transfer Function} = G(s) = \frac{L\{\text{output}\}}{L\{\text{input}\}}$$



$$G(s) = \frac{y(s)}{u(s)}$$

The transfer function of a system represents the link between the input to the system to the output of the system. The transfer function of a system G(s) is a complex function that describes system dynamics in s-domains opposed t the differential equations that describe system dynamics in time domain. The transfer function is independent of the input to the system and does not provide any information concerning the internal structure of the system.

Same transfer function can represent different systems. The transfer function permits to calculate the output or response for various inputs.

The transfer function can be calculated analytically starting from the physics equations or can be determined experimentally by measuring the output to various known inputs to the system.

Impulse Response

The Laplace transform of an impulse function δ(t) is given by L {δ(t)} = 1

The output of a system due to an impulse input u(s) = δ(s) = 1 is = y(s) = G(s) .u(s) = G(s)

The impulse response of a system is identical to the transfer function of that system.

The inverse Laplace transforms of the impulse response G(s)

$$L^{-1} \{G(s)\} = g(t)$$

The transfer function, that contains complete information about the dynamic characteristics of a system, can be obtained by applying an impulse input u(t)= δ(t) and measuring system response y(t) which in this case is identical to g(t). The transfer function will then be

$$G(s) = L\{g(t)\}$$

Block Diagrams: Block diagrams are a graphical representation of the system model. The blocks represent physical or functional components of the system. Each block has inscribed the transfer function of that component relate the output of the component to its input.

Block diagrams consist of

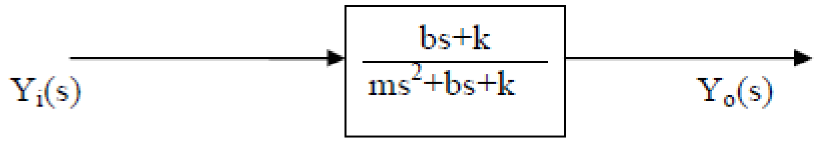
1. Blocks

2. Summation junctions

3. Paths

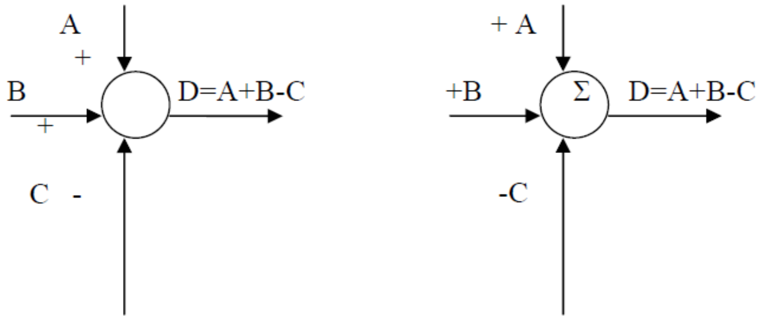
4. Branching points

Block



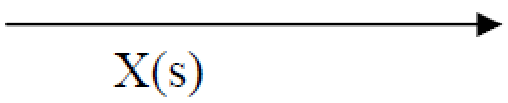
Blocks represent physical or functional components in the system. In the block is inscribed the transfer function of that component of the system.

Summation Junction

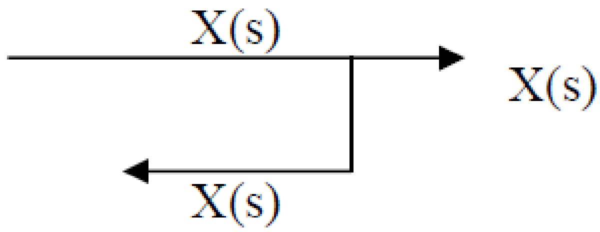


A summing junction results in the addition or subtraction of input signals for a single output.

Path
Signal X(s) flows along the directed path:



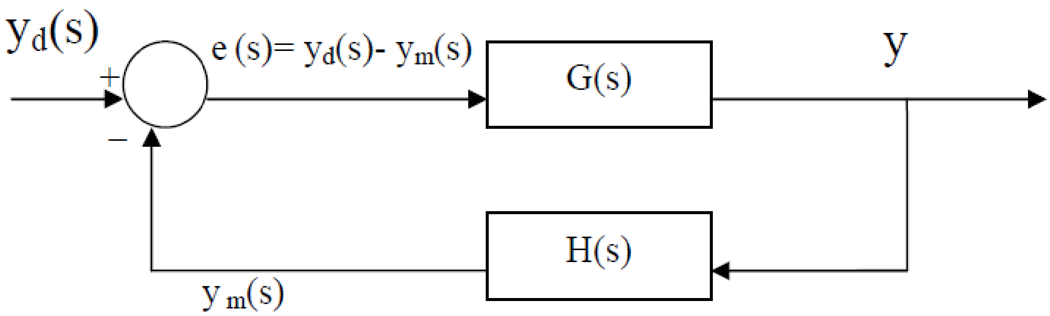
Branching Point



At the branching point a signal splits into two signals of the same value.

Block Diagram of a Closed Loop System

In a closed loop control system, also called feedback control system, the output variable y(s) is measured as ym(s), subtracted from its desired value yd(s) to calculate the error e(s) = yd(s) - ym(s).



G(s) is feed forward transfer function (of the controller, actuator and the system)

$$G(s) = y(s) / e(s)$$

H(s) is feedback transfer function (of the sensor)

$$H(s) = ym(s) / y(s)$$

G(s) H(s) = open loop transfer function

$$G(s)\ H(s) = [ym(s) / y(s)][\ y(s) / e(s)]= ym(s) / e(s)$$

yd(s) / y(s) is closed loop transfer function obtained from the above equations by eliminating

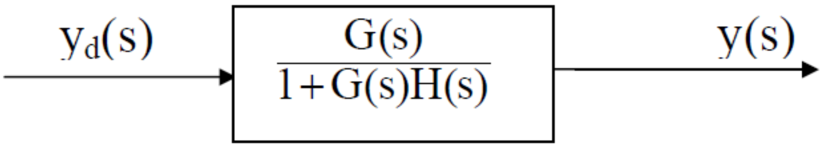
e(s) and ym(s)

$$y(s) = G(s)\ e(s) = G(s)\ [yd(s) - ym(s)]= G(s)\ [yd(s) – H(s)y\ (s)]$$

$$y(s) + G(s)\ H(s)\ y(s) =G(s)\ yd(s)$$

$$y(s) / yd(s) = G(s) / [1 + G(s) H(s)]$$

This equation gives the single block equivalent of the above closed loop system



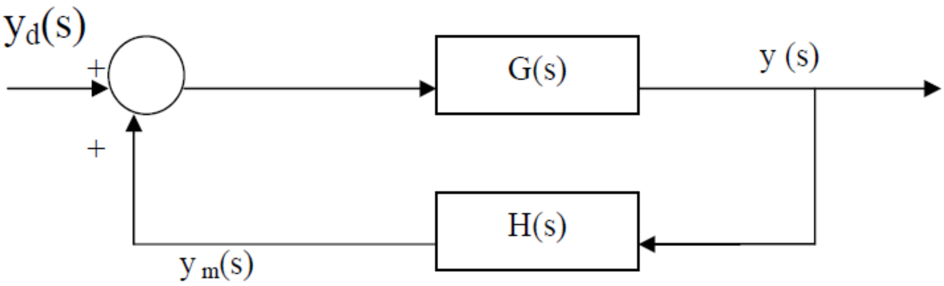
The transfer function represents the closed loop system dynamics with complex functions.

The output y(s) is given by

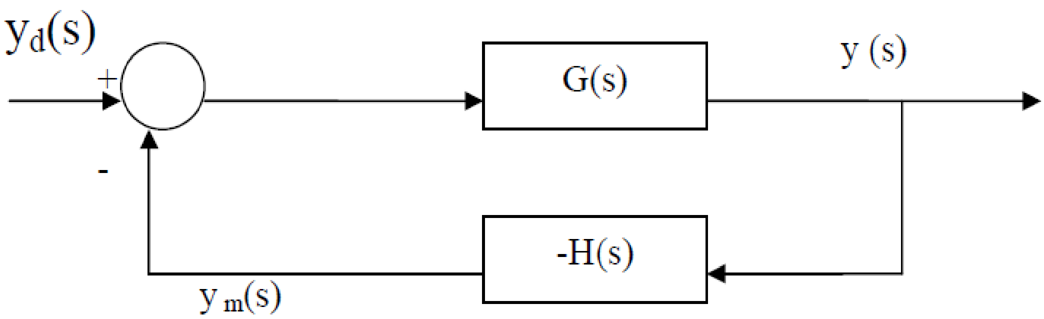
$$y(s) = G(s) / [1 + G(s) H(s)] \, yd(s)$$

and depends on the closed loop transfer function and the desired value of the output yd(s), called also the input (to the closed loop system).

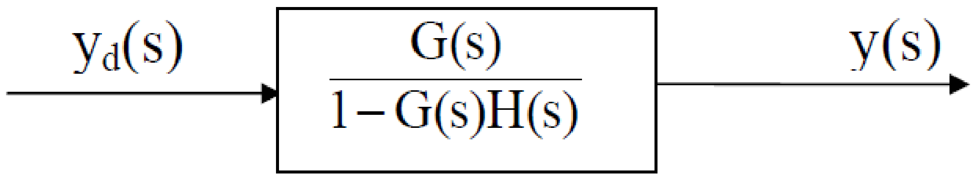
The following positive feedback block diagram



Is equivalent to negative feedback one if H(s) is replaced by –H(s).



This is equivalent to the block.

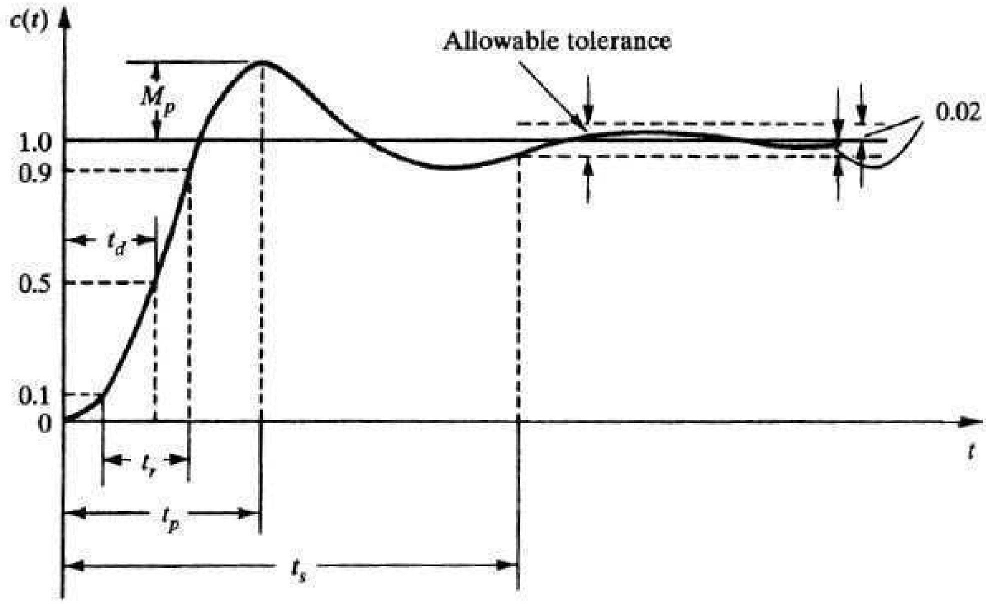


Transient Response Specifications

Because systems that stores energy cannot respond instantaneously, they exhibit a transient response when they are subjected to inputs or disturbances. Consequently, the transient response characteristics constitute one of the most important factors in system design.

In many practical cases, the desired performance characteristics of control systems can be given in terms of transient-response specifications. Frequently, such performance characteristics are specified in terms of the transient response to unit-step input, since such an input is easy to generate and is sufficiently drastic. (If the response of a linear system to a step input is known, it is mathematically possible to compute the system's response to any input). The transient response of a system to a unit step-input depends on initial conditions. For convenience in comparing the transient responses of various systems, it is common practice to use standard initial conditions: The system is at rest initially, with its output and all time derivatives thereof zero. Then the response characteristics can be easily compared.

The transient response of a practical control system often exhibits damped oscillations before reaching a steady state. In specifying the transient-response characteristics of a control system to a unit-step input, it is common to name the following:



Delay Time = T_d

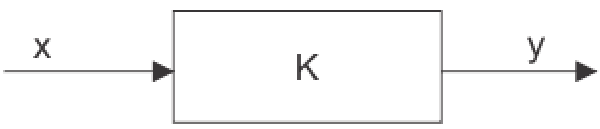
Risk Time = T_r

Peak Time = T_p

Maximum Overshoots = M_p

Settling Time = T_s

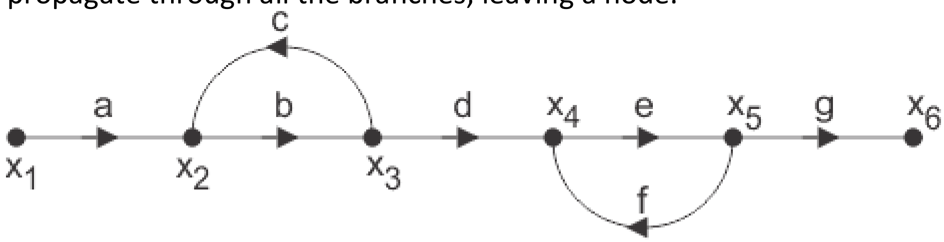
Signal flow graph of control system is further simplification of block diagram of control system. Here, the blocks of transfer function, summing symbols and take off points are eliminated by branches and nodes.
The transfer function is referred as transmittance in signal flow graph. Let us take an example of equation y = Kx. This equation can be represented with block diagram as below



The same equation can be represented by signal flow graph, where x is input variable node, y is output variable node and a is the transmittance of the branch connecting directly these two nodes.

Rules for Drawing Signal Flow Graph

1. The signal always travels along the branch towards the direction of indicated arrow in the branch.
2. The output signal of the branch is the product of transmittance and input signal of that branch.
3. Input signal at a node is summation of all the signals entering at that node.
4. Signals propagate through all the branches, leaving a node.



Simple Process of Calculating Expression of Transfer Function for Signal Flow Graph

- First, the input signal to be calculated at each node of the graph. The input signal to a node is summation of product of transmittance and the other end node variable of each of the branches arrowed towards the former node.
- Now by calculating input signal at all nodes will get numbers of equations which relating node variables and transmittance. More precisely, there will be one unique equation for each of the input variable node.

- By solving these equations we get, ultimate input and output of the entire signal flow graph of control system.
- Lastly by dividing inspiration of ultimate output to the expression of initial input we calculate the expiration of transfer function of that signal flow graph.