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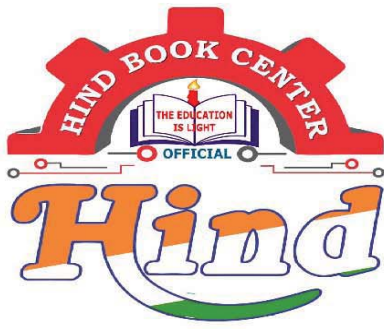
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BY Sai Krishna Sir**

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Control System

PART-I Introduction to Control System

- Consider a liquid level control system whose control objective is to keep the water level in the tank at a prescribed height 'h'.
- Controller is an automatic device whose output is expressed as a function of error.

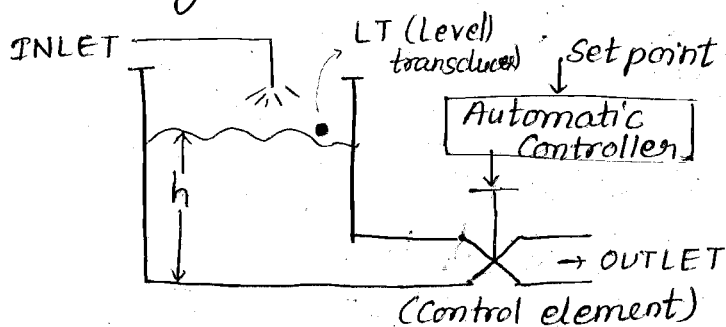
$$\text{Controller o/p } P(s) = f(e)$$

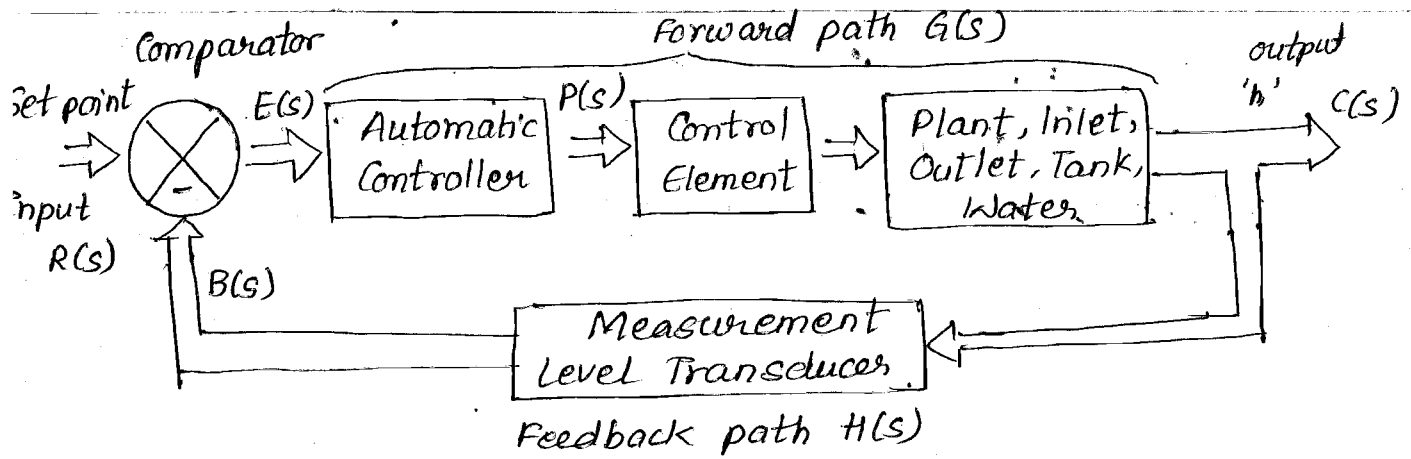
where, e - steady state error

- There are two basic control loop configurations :-
 - (i) Closed loop or Feedback control system.
 - (ii) Open loop control system.

Closed loop or Feedback control system

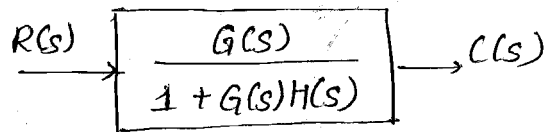
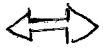
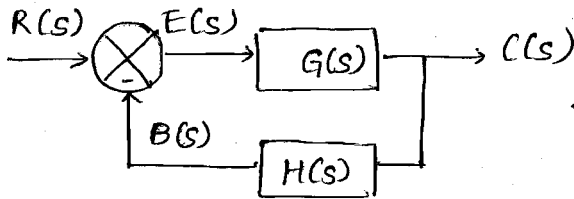
- In this configuration, the changes in the output are measured using feedback elements and compared with i/p or set point to achieve the control objective.
- Feedback implies measurement i.e. feedback elements are measuring elements (sensors, transducers) in automatic control systems.





→ Control Canonical form

Equivalent Mathematical Form



$$E(s) = R(s) - B(s)$$

$$\frac{C(s)}{G(s)} = R(s) - C(s)H(s)$$

$$C(s) = G(s)R(s) - G(s)H(s)C(s)$$

$$C(s) [1 + G(s)H(s)] = G(s)R(s) \Rightarrow C(s) = \left[\frac{G(s)}{1 + G(s)H(s)} \right] R(s)$$

Sensitivity analysis

A control system is said to be highly sensitive if its output or control objective is affected due to disturbances.

The desirable feature of a good control system is, it should be less sensitive to disturbances.

Sensitivity function

Let α = a variable that changes its value

β = a parameter that changes the value of α

$$\text{change in } \alpha \text{ due to } \beta \quad S_{\beta}^{\alpha} = \frac{\% \text{ change in } \alpha}{\% \text{ change in } \beta} = \frac{\frac{\partial \alpha}{\alpha}}{\frac{\partial \beta}{\beta}}$$

$$S_{\beta}^{\alpha} = \frac{\beta}{\alpha} \frac{\partial \alpha}{\partial \beta}$$

Sensitivity analysis of closed loop control system

Case 1 :- $\alpha = \text{C.L.C.S} = M(s)$

$\beta = \text{disturbances in forward path elements i.e. } G(s)$

$$S_{G(s)}^{M(s)} = \frac{G(s)}{M(s)} \cdot \frac{\partial M(s)}{\partial G(s)}$$

Since $M(s) = \frac{G(s)}{1 + G(s)H(s)} \Rightarrow \frac{G(s)}{M(s)} = 1 + G(s)H(s) \quad \text{--- (1)}$

$$\begin{aligned} \frac{\partial M(s)}{\partial G(s)} &= \frac{\partial}{\partial G(s)} \left[\frac{G(s)}{1 + G(s)H(s)} \right] \\ &= \frac{1 + G(s)H(s) - G(s)H(s)}{(1 + G(s)H(s))^2} \end{aligned}$$

$$S_{G(s)}^{M(s)} = (1 + G(s)H(s)) \cdot \frac{1}{(1 + G(s)H(s))^2}$$

$$S_{G(s)}^{M(s)} = \frac{1}{1 + G(s)H(s)}$$

where, $1 + G(s)H(s) = \text{noise reduction factor}$

Case 2 :- $\alpha = \text{C.L.C.S} = M(s)$

$\beta = \text{disturbances in feedback path elements i.e. } H(s)$

$$S_{H(s)}^{M(s)} = \frac{H(s)}{M(s)} \cdot \frac{\partial M(s)}{\partial H(s)}$$

Since, $M(s) = \frac{G(s)}{1 + G(s)H(s)} \quad \frac{M(s)}{H(s)} = \frac{G(s)}{H(s)[1 + G(s)H(s)]}$

$$\frac{M(s)}{H(s)} = \frac{H(s)}{M(s)} = \frac{H(s)[1 + G(s)H(s)]}{G(s)} \quad \text{--- (1)}$$

$$\begin{aligned} \frac{\partial M(s)}{\partial H(s)} &= \frac{\partial}{\partial H(s)} \left[\frac{G(s)}{1 + G(s)H(s)} \right] \\ &= \frac{(1 + G(s)H(s)) \times 0 - G(s) \cdot G(s)}{(1 + G(s)H(s))^2} \end{aligned}$$

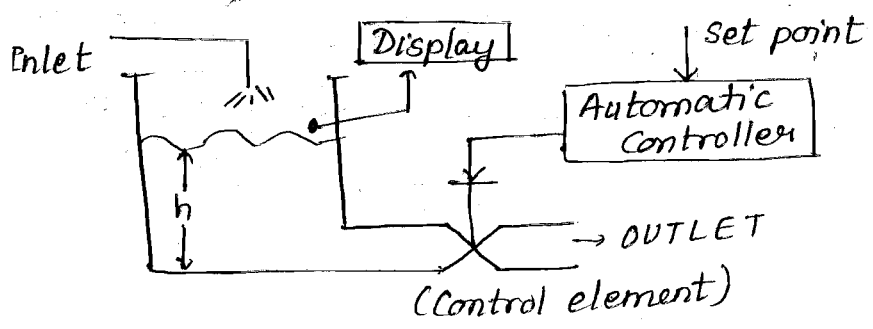
$$S_{H(s)}^{M(s)} = \frac{H(s)[1 + G(s)H(s)]}{G(s)} \cdot \frac{-G(s)}{(1 + G(s)H(s))^2}$$

$$S_{H(s)}^{M(s)} = \frac{-G(s)H(s)}{1 + G(s)H(s)}$$

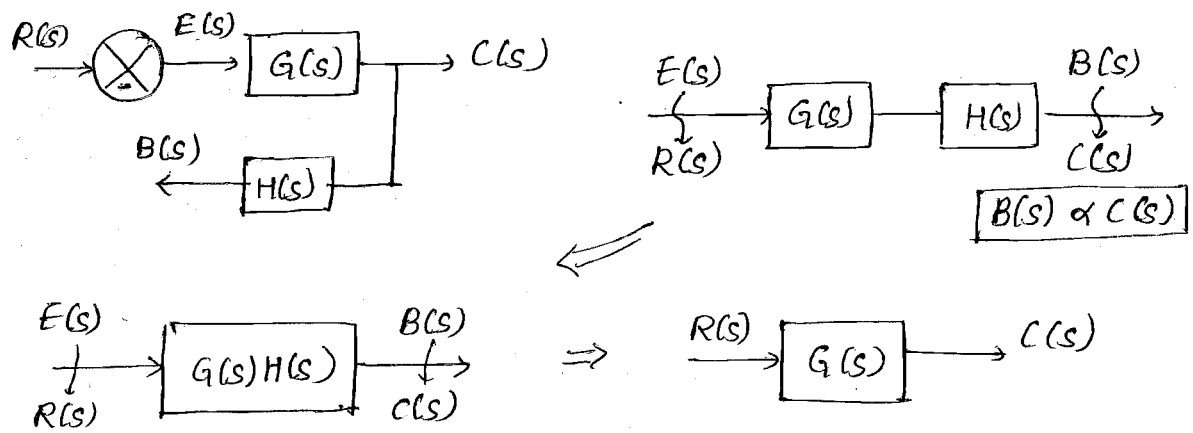
Note: A closed loop or f/b control system is more sensitive to disturbances in feedback elements i.e. $H(s)$ than forward path elements i.e. $G(s)$.

Open Loop Control system

- They are conditional control systems formulated under the condition that the system is not subjected to any type of disturbances including input.
- In this configuration, the f/b or measurement is not connected to forward path or controller (open loop) Feedback in open loop system acts as display element, its sensitivity in this configuration is nil.
- Performance analysis is not applicable to this system bcoz they are not subjected to any disturbances and for a given input, they give out desired output.



Representation of O.L.C.S



Sensitivity of O.L.C.S wrt disturbances in forward path elements i.e. $G(s)$

$\alpha = \text{O.L.C.S} = M(s)$
 $\beta = G(s)$
 $S_{M(s)}^{G(s)} = \frac{G(s)}{M(s)} \frac{\partial M(s)}{\partial G(s)}$