MADE EASY

Electrical Engineering

Toppers Handwritten Notes

Control System

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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.

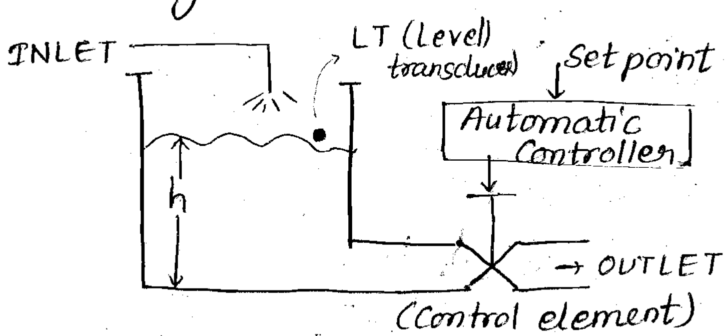
Controller o/p P(~~s~~) = f (e)

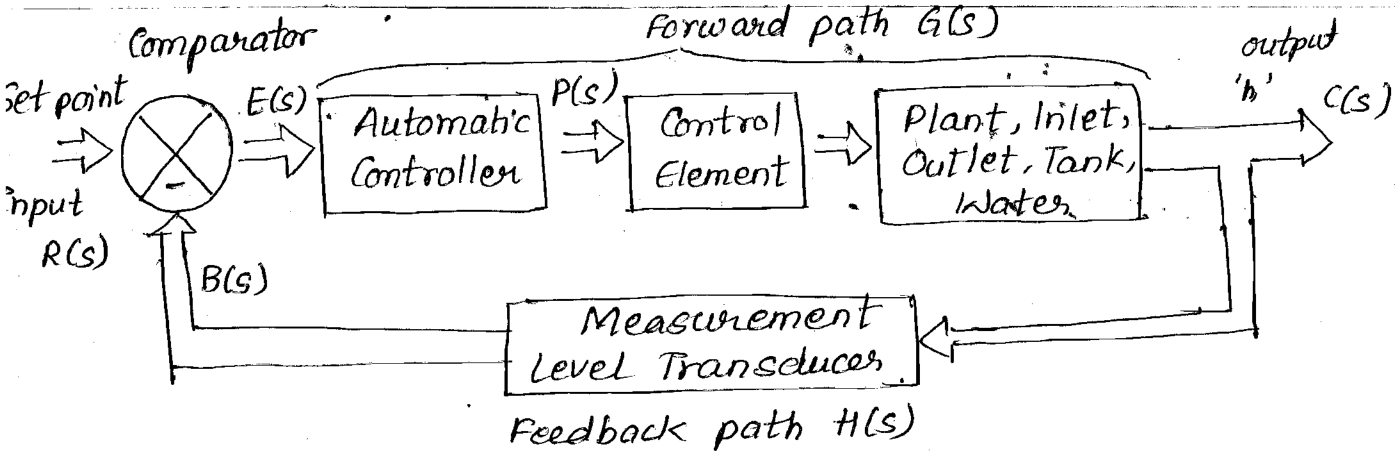
where, e - steady state error

- 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

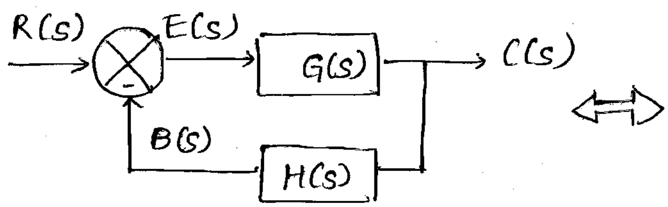
- In this configuration, the changes in the output are measured using feedback elements and compared with i/p or set point to achieve the control objective.
- Feedback implies measurement i.e feedback elements are measuring elements (sensors, transducers) in automatic control systems.

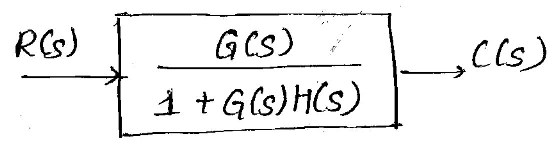




→ Control Canonical form

Equivalent Mathematical Form





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

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

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

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

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

(change in α due to β) $$S_\beta^\alpha = \frac{\%\text{ change in }\alpha}{\%\text{ change in }\beta} = \frac{\frac{\partial\alpha}{\alpha}}{\frac{\partial\beta}{\beta}}$$

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

Sensitivity analysis of closed loop control system

Case 1 :- α = C.L.C.S = M(s)

β = 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 $M(s) = \frac{G(s)}{1+G(s)H(s)} \Rightarrow \frac{G(s)}{M(s)} = 1 + G(s)H(s)$ —— (1)

$$\frac{\partial M(s)}{\partial G(s)} = \frac{\partial}{\partial G(s)}\left[\frac{G(s)}{1+G(s)H(s)}\right]$$

$$= \frac{1+G(s)H(s) - G(s)H(s)}{(1+G(s)H(s))^2}$$

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

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

where, $1+G(s)H(s)$ = noise reduction factor

Case 2 :- α = C.L.C.S = M(s)

β = disturbances in feedbackpath elements i.e. H(s)

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

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

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

$$\frac{\partial M(s)}{\partial H(s)} = \frac{\partial}{\partial H(s)}\left[\frac{G(s)}{1+G(s)H(s)}\right]$$

$$= \frac{(1+G(s)H(s)) \times 0 - G(s).G(s)}{(1+G(s)H(s))^2}$$

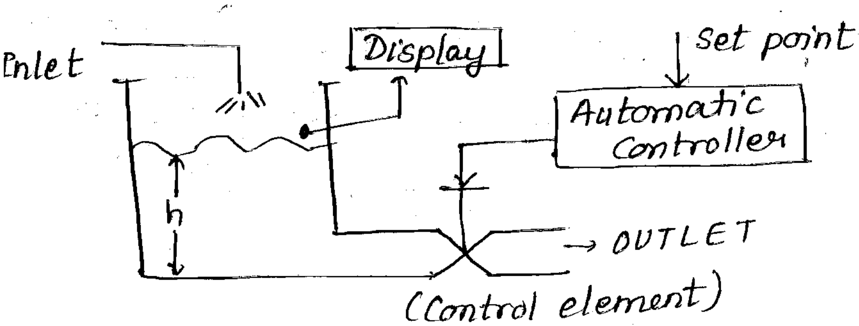
$$S_{H(s)}^{M(s)} = \frac{H(s)[1+G(s)H(s)]}{G(s)} \cdot \frac{-(G(s))^2}{(1+G(s)H(s))^2}$$

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

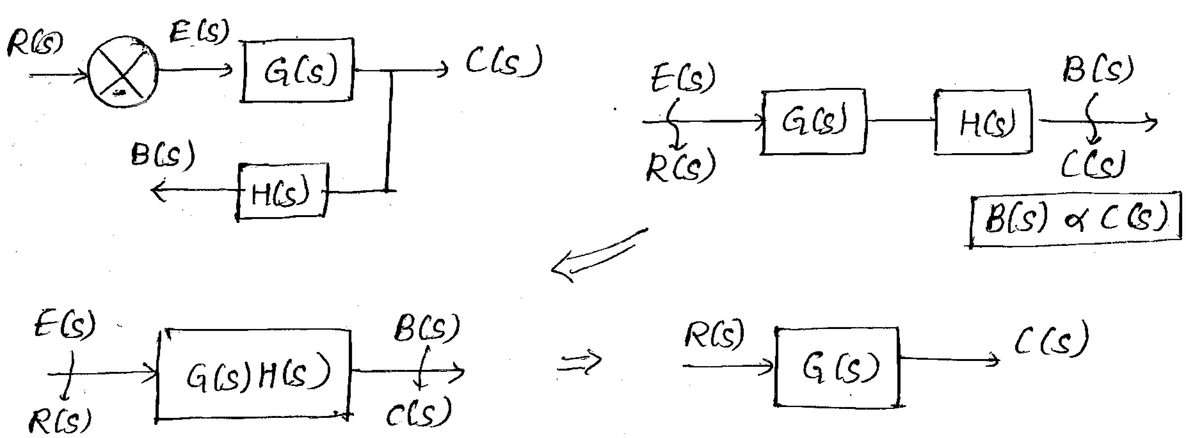
<u>Note</u>: A closed loop or f/b control system is more sensitive to disturbances in feedback elements i.e. H(s) than forward path elements i.e G(s).

<u>Open Loop Control system</u>

- 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.



<u>Representation of O.L.C.S</u>



<u>Sensitivity of O.L.C.S wrt disturbances in forward path elements i.e G(s)</u>

$\alpha = \text{O.L.C.S} = M(s)$

$\beta = G(s)$

$$S^{M(s)}_{G(s)} = \frac{G(s)}{M(s)} \frac{\partial M(s)}{\partial G(s)}$$