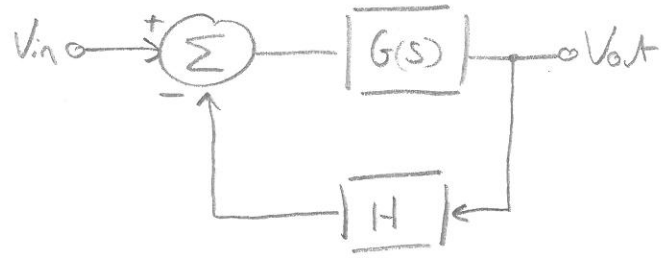
–VE FEEDBACK:






$$\Rightarrow H_{CL}(S) = \frac{G(S)}{1 + HG(S)}$$ ← closed loop characteristic equ.

• $G(S)$ = 2nd-order, low-pass system

$$\rightarrow G(S) = \frac{K}{(S-p_1)(S-p_2)}$$

• $p_1, p_2$ = open loop poles
• $K = p_1 p_2 A(0)$

$$\rightarrow 1 + HG(S) = 1 + \frac{H.K}{(S-p_1)(S-p_2)} = (S-p_1)(S-p_2) + H.K$$

$$= S(S-p_2) - p_1(S-p_2) + HK$$
$$= S^2 - Sp_2 - Sp_1 + p_1p_2 + HK$$
$$= S^2 - S(p_1+p_2) + p_1p_2 + H.K \quad \ldots (1)$$ = closed loop characteristic equ.

→ Roots of (1) give the closed loop poles.

$$\Rightarrow p_{CL1,2} = \frac{p_1+p_2 \pm \sqrt{(p_1+p_2)^2 - 4(p_1p_2 + HK)}}{2}$$

$$\rightarrow \mathcal{R}_e(S) = \underbrace{p_1+p_2/2}_{\sigma} = -ve$$ and constant for increasing K or A(0).

-ve → only exist in LHP in s-plane ⇒ never unstable in the BIBO sense.

→ decay envelope remains constant.
→ Settling time does not change.

$$\rightarrow I_m(S) = \underbrace{\pm\frac{\sqrt{(p_1+p_2)^2 - 4(p_1p_2 + HK)}}{2}}_{\omega}$$ = As K (or A(0)) grows, this term becomes increasingly imaginary or oscillatory.

→ More oscillations per unit time occur as K or A(0) grows.

• $\omega_n = \sqrt{p_1p_2 + H.K}$

→ $\omega_n$ increases with K. Since $\sigma$ remains constant, $\zeta = \sigma/\omega_n$ decreases.