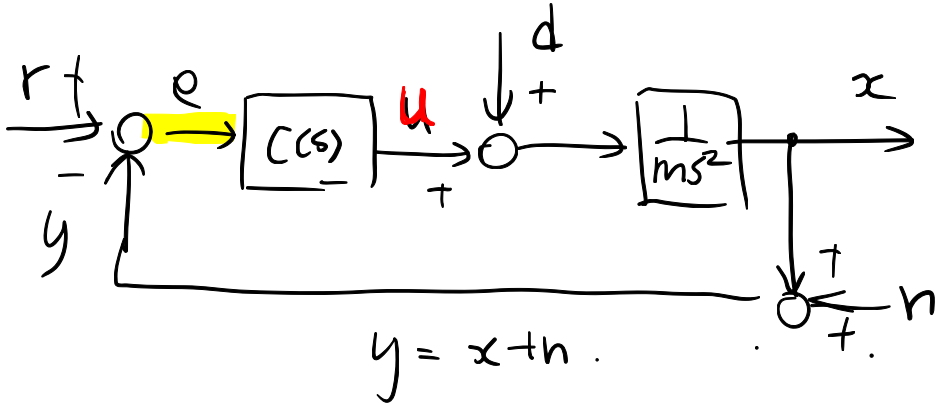
L16 – PID Control Design (cont'd)



- Gang of Four :

$$\frac{X}{R} = \frac{CP}{1+CP} \triangleq T \; ; \quad \text{Comp. sens.} \rightarrow \text{"Tracking"}.$$

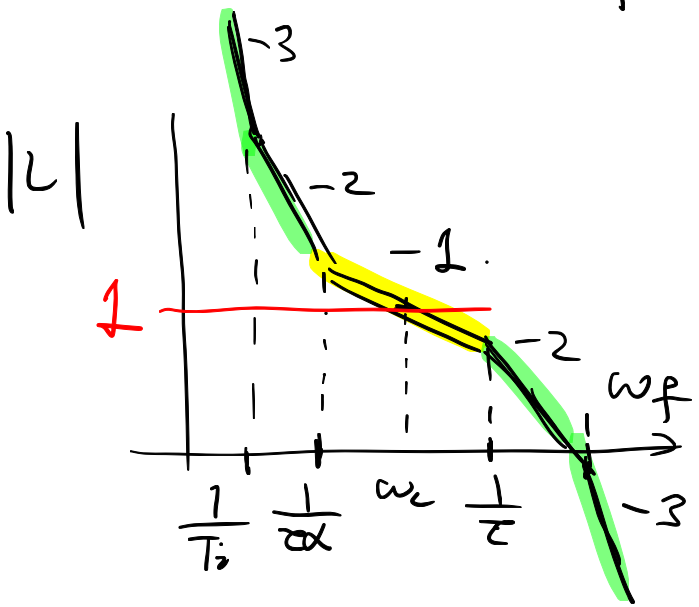
$$\frac{E}{R} = \frac{1}{1+CP} \triangleq S \; ; \quad \text{Sensitivity function.} \rightarrow$$

$$\frac{X}{D} = \frac{P}{1+CP} = P \cdot S \; : \; \text{"Load sensitivity"}$$

$$\frac{U}{N} = \frac{C}{1+CP} = C \cdot S \quad \text{"Noise sensitivity"}$$

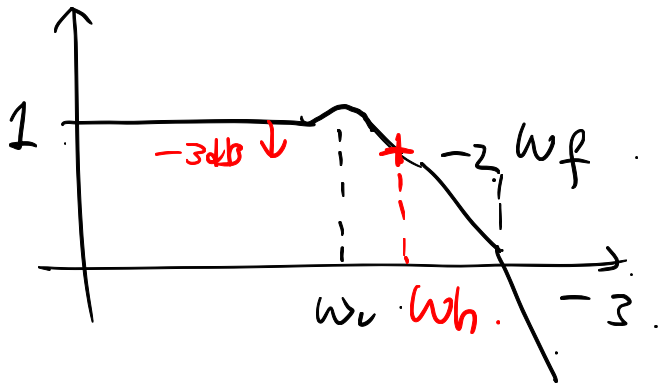
- Integrator : ↓ Load sensitivity at low freq.
- LPF : ↓ Noise sens. at high freq.

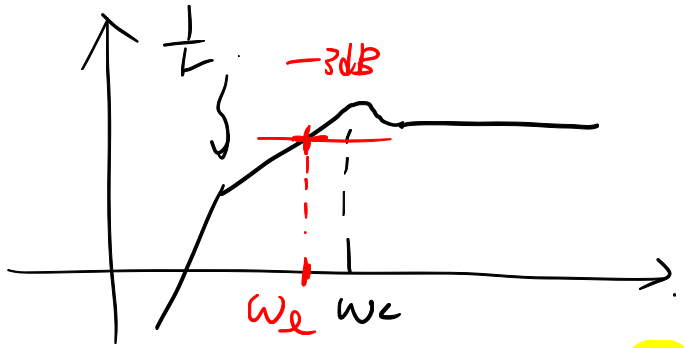
- $L(s) = C(s)\,P(s)$, $C(s) = K_p\left(1+\frac{1}{T_i s}\right)\left(\frac{\alpha\tau s+1}{\tau s+1}\right)\left(\frac{\omega_p}{s+\omega_p}\right)$



$T = \frac{L}{1+L}$

S

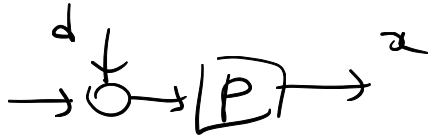




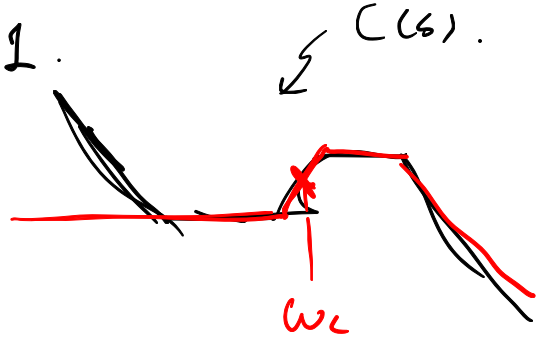
① $T+S=1$ $\omega_e \simeq \omega_c \simeq \omega_h$

② $\frac{1}{1+L}$

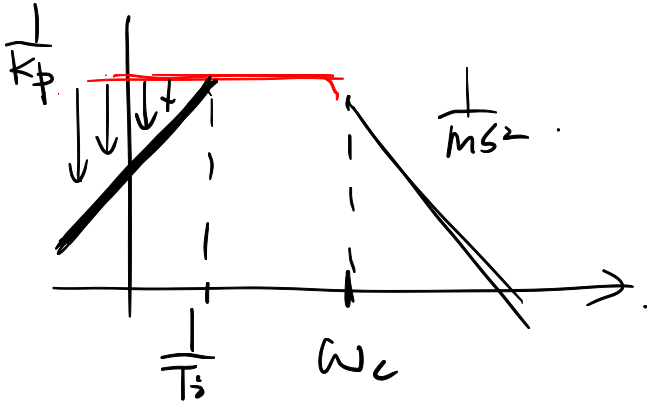
- Load Sensitivity



$$\frac{x}{p} = \frac{P}{1 + CP} = \begin{cases} \frac{1}{C} & |L| \gg 1 \\ P & |L| \ll 1 \end{cases}$$

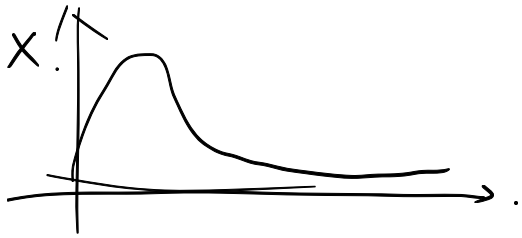


① . Without integrator .



$\Rightarrow$ AC coupled system.

$$\frac{x}{p}\Big|_{\omega = 0} = 0 .$$

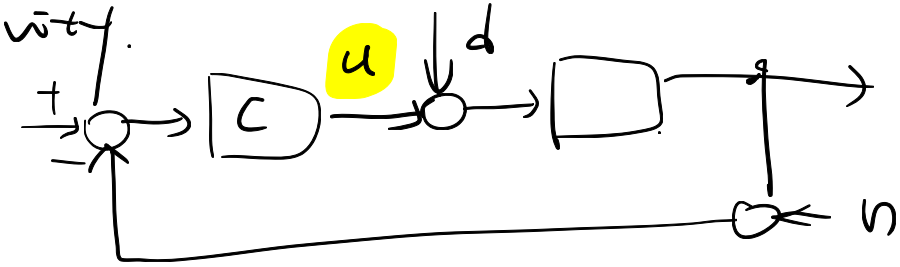


② With integrator .

Summary.

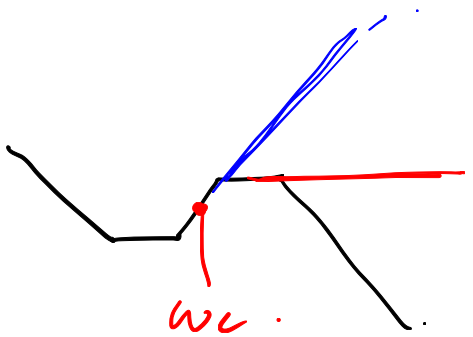
- Integrator ↓ load sens. at low freq.
  " disturb reject"

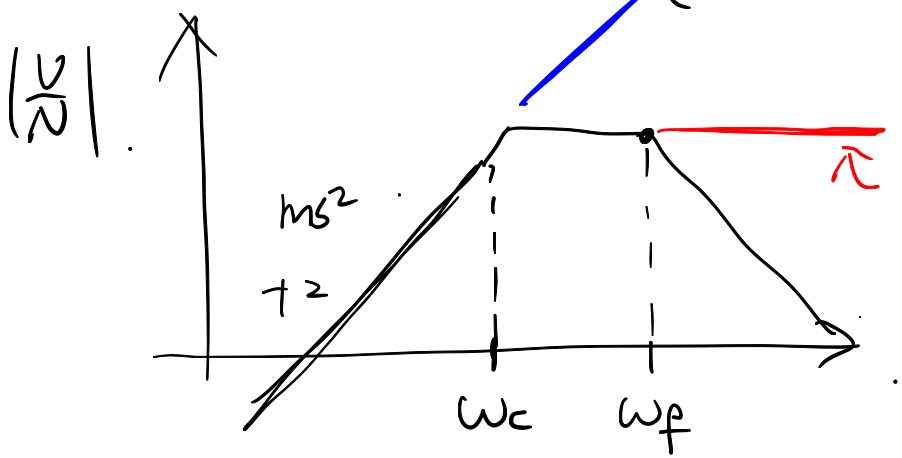
- Noise Sensitivity.



$$\frac{U}{N} = \frac{C}{1+CP} = \begin{cases} \frac{1}{P} & |L| \gg 1 \\ C & |L| \ll 1 \end{cases}$$

"Bad"



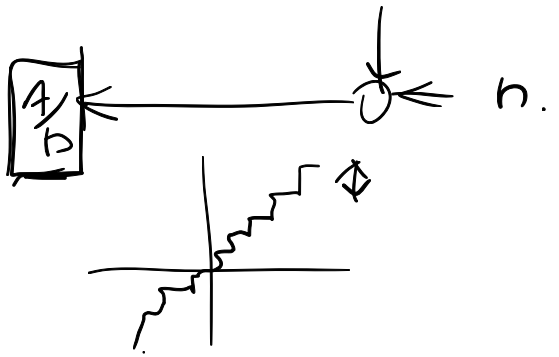


↑ No LPF.

① No LPF.

② pure "D"

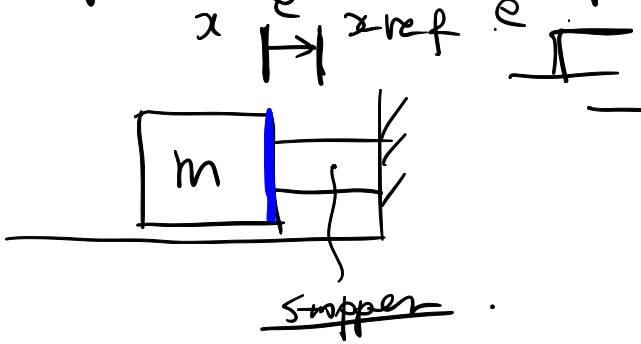
- Noise : Sensor noise.
  & ADC noise.

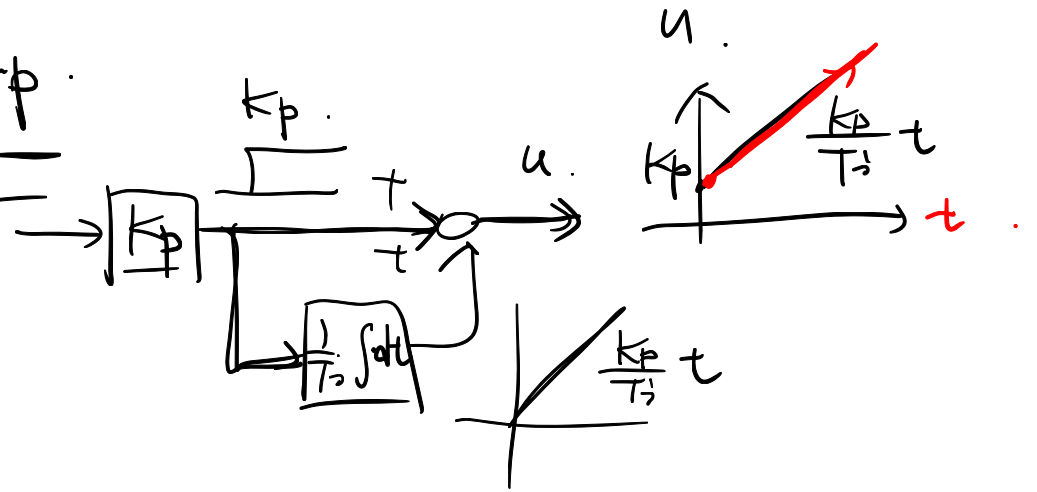


- Why Bad? High freq in "u"
  - Heat → Amplifier & Motor winding.
  - Vibration. → e.g. High-freq resonance.

  ⇒ Gradually damage the hardware.

- Integrator Anti-windup.



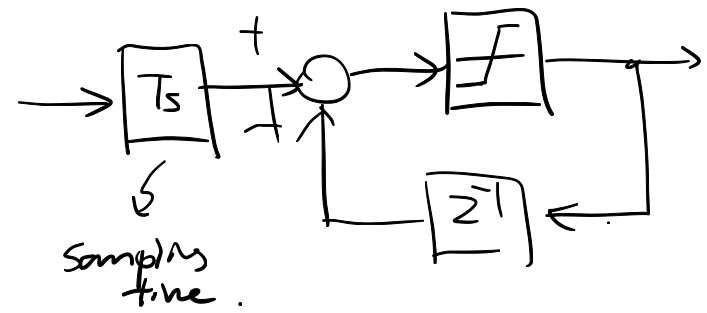


- Damage the hardware!
- 1. Limit "u" (e.g. saturation block).

→ Doesn't stop the integrator from accumulating the error.

2. Integrator "anti-windup"

Saturation



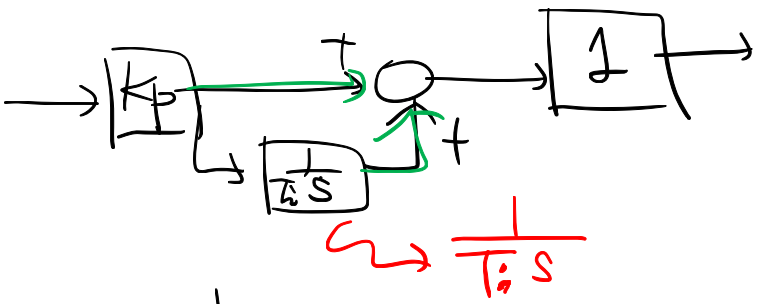
① → F → 1/s → (X)

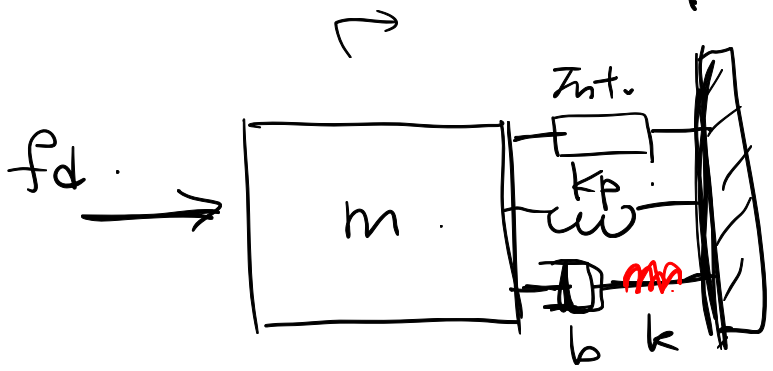
② → 1/s → F (X).

③ → 1/sF → (O). "Limit the State".

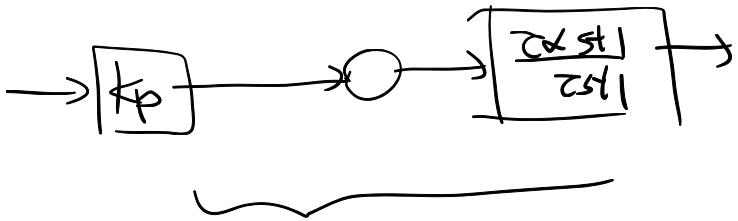
- Physical Meaning.

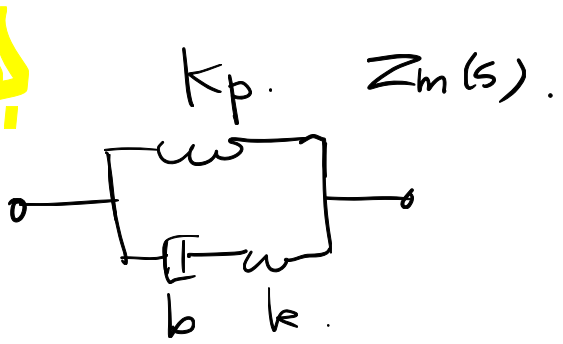
① $\omega < \frac{1}{T_i}$

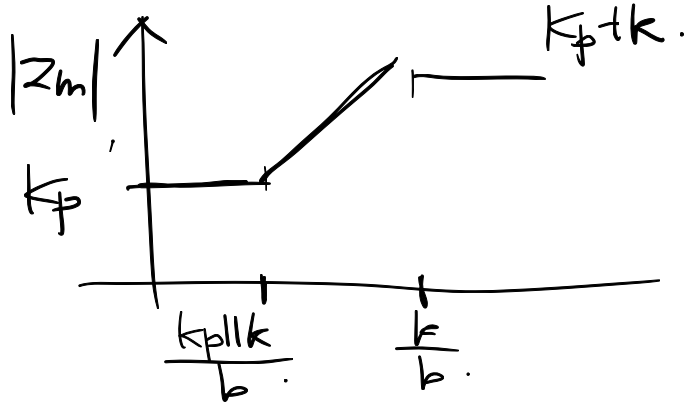




② $\omega > \frac{1}{T_i}$







- $x = 0$,

f_d is carried by Z_{mt} at dc.

- No Integrator.

f_d is carried by $K_p \Rightarrow$ $x = \frac{f_d}{K_p}$.