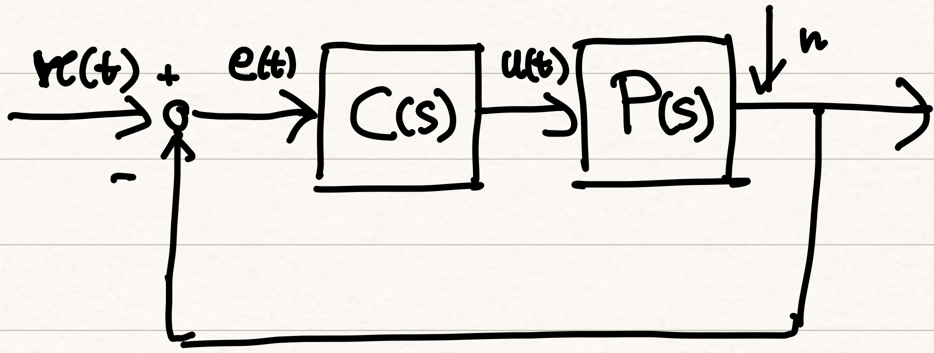
IMPROVING CONTROL DESIGN IN FREQ. DOMAIN

- How? through better architectures.
- SO FAR : TRACKING REFERENCE $r(t)$



- PERFORMANCE : → STABILITY

OF $W = \dfrac{CP}{1+CP}$ SPECIFIED IN THE TIME DOMAIN

→ TRANSIENT BEHAVIOR
↳ Dom. poles / crossover

→ ASYMPTOTIC REGIME
↳ TRACKING VIA IMP : exact asympt. track.

Alternative approach :
FILTERING PROPERTIES IN FREQ. DOM.

- Let $\mathcal{L}[r] = R(s)$;
- Assume it has "relevant" components to be tracked BELOW SOME FREQ. B_R

$\Rightarrow$ We want $W(j\omega) \simeq 1$ under B_r

$W(j\omega) \simeq 0$ over $B_n > B_r$

NOISE THRESHOLD

How? $W = \dfrac{CP}{1+CP} \rightarrow$ (A) $C(j\omega)P(j\omega) \gg 1$ below B_r

(B) $C(j\omega)P(j\omega) \ll 1$ above B_n

We need to take into account also:

ACTUATION : $\dfrac{U}{R} = \dfrac{C}{1+CP} \xrightarrow{A} \simeq \dfrac{1}{P}$ under B_r

SENSITIVITY : $\dfrac{1}{1+CP} \xrightarrow{B} \simeq 1$ above B_n

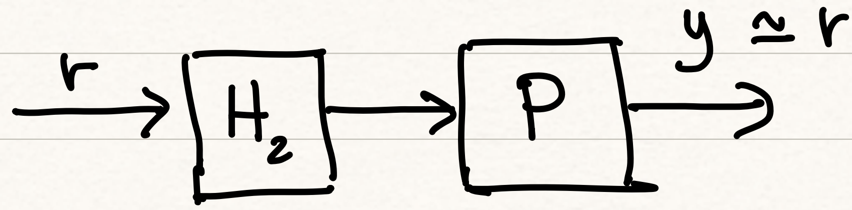
$\Rightarrow$ ALTERNATIVE APPROACH : Devide CONTROL EFFORT

1) DESIGN CONTROL TO WORK WELL AT NOMINAL CONDITIONS IN OPEN LOOP

2) USE FEEDBACK TO STABILIZE, DEAL WITH UNCERTAINTY

▶ Let us Try:

STEP 1: OPEN LOOP CONTROL



we want $HP = W \simeq 1$ under B_r

$\Rightarrow H \simeq P^{-1}$ under B_r

Pb - TYPICALLY P^{-1} NOT PROPER

(- cancellation unstable poles)

[e.g. $P(s) = \dfrac{K_m}{N s(1+T_m s)} \Rightarrow H_2(s) = \dfrac{N}{K_m} s + \dfrac{N T_m}{K_m} s^2$

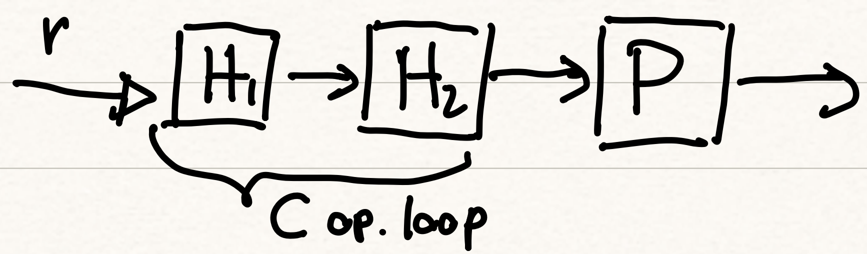
Derivatives

$\Rightarrow$ USE A PRE-FILTER, WITH POLES OUTSIDE B_N

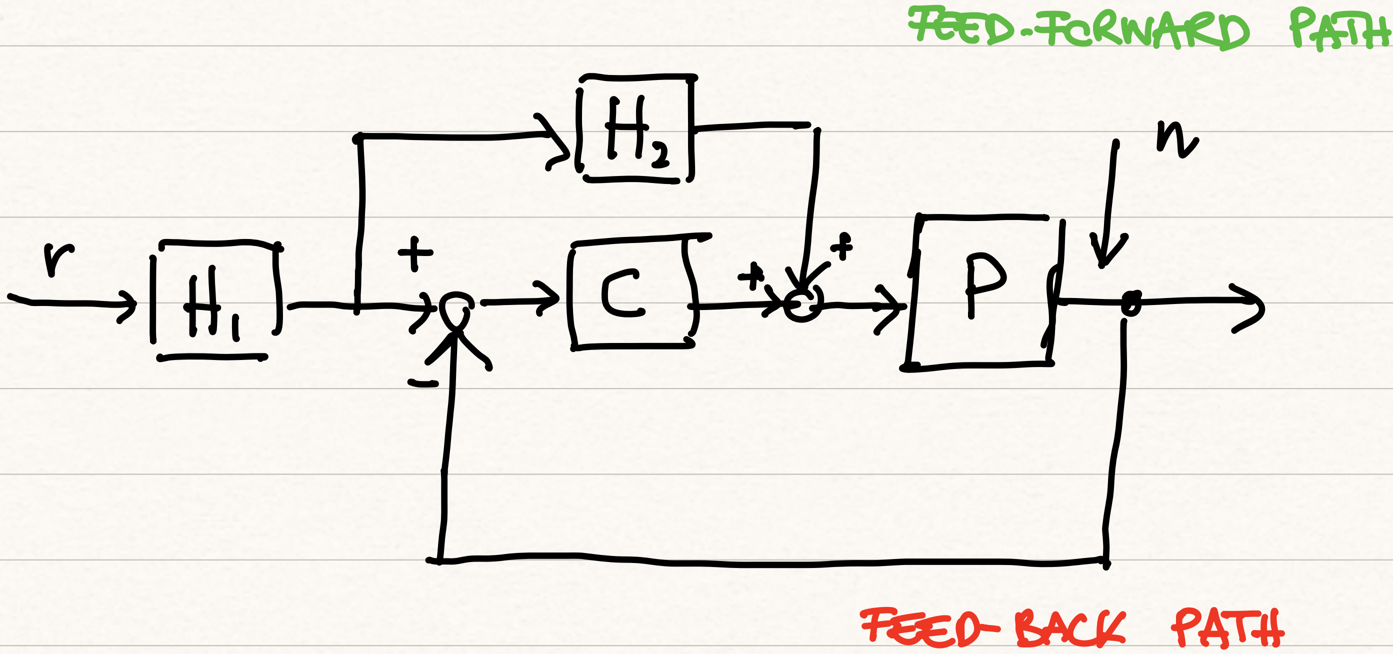
$H_1(s)$, so $H_1(s) H_2(s)$ is PROPER.

$\nearrow$ $H_1(s) H_2(s) \simeq 0$ past B_N

$\searrow$ $H_1(s) H_2(s) P(s) \simeq 1$ below B_r



STEP 2 : ADD FEEDBACK



▷ We have

$$W = H_1 H_2 \frac{P}{1+CP} + H_1 \frac{CP}{1+CP}$$

$$= H_1 \frac{[H_2 + C]\, P}{1+CP}$$

- Now to have $W \simeq 1$ under B_r we need

$$H_1 H_2 P \simeq 1 , \qquad CP << 1$$

$\Rightarrow$ ACTUATION : $H_1 H_2 + \frac{C}{1+CP} H_1$

$\Rightarrow$ SENSITIVITY : $\dfrac{1}{1+CP}$

ADVANTAGES :

▷ WITH H_1 I ENSURE $W \simeq 0$ above B_n

▷ WITH H_2 I DO NOT NEED $CP \gg 1$ below B_r (BUT THE OPPOSITE!)

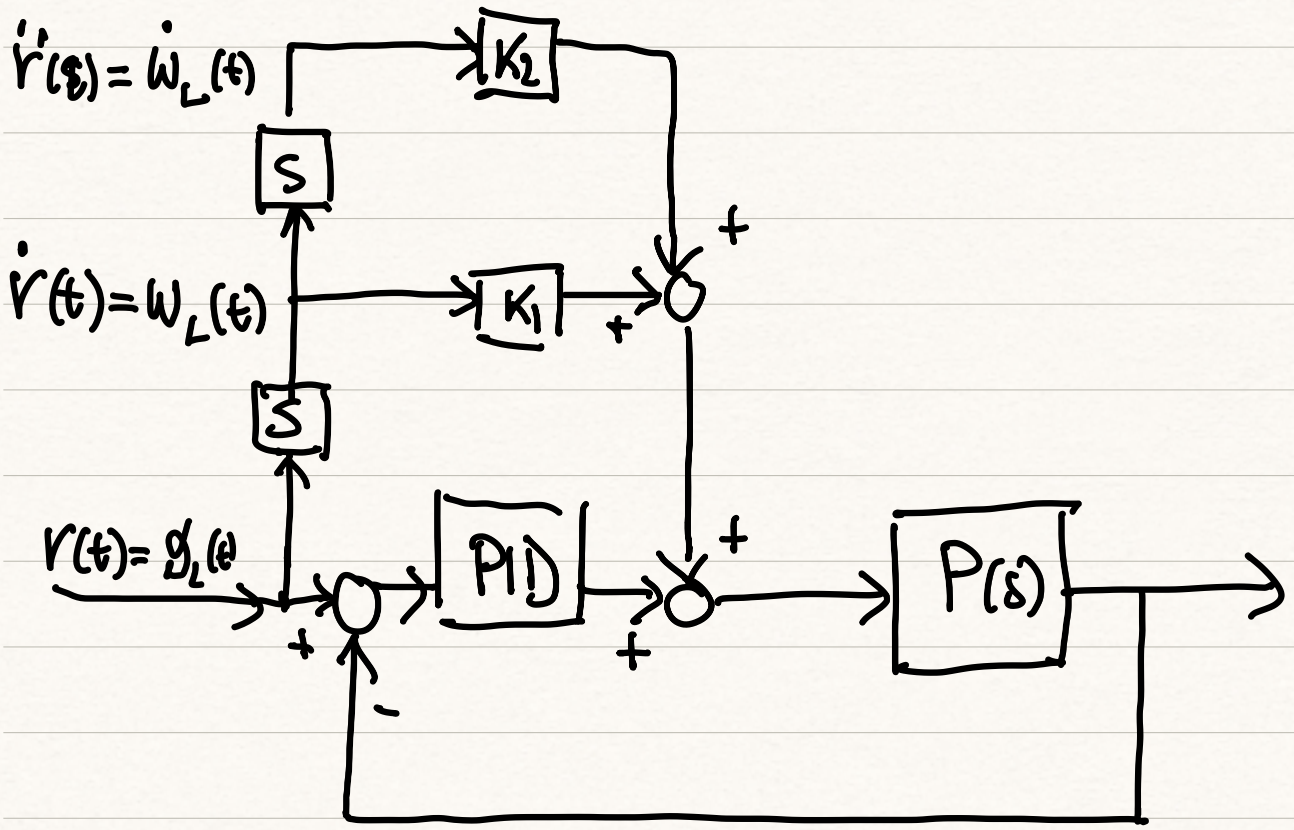
↳ SENSITIVITY : STILL PROBLEMATIC $\nsim 1$ under B_r, BUT WE CAN SHAPE IT ABOVE B_n!

↳ ACTUATION : H_1 takes care over B_r, we have more freedom shaping C.

▷ IN OUR CASE : I FEEDFORWARD FROM REFERENCE

$$P(s) = \frac{K_m}{sN(1+T_m s)} \Rightarrow P(s)^{-1} = \frac{N}{K_m}(T_m s^2 + s)$$

$$U_{FF}(s) = \frac{N T_m}{K_m} s^2 R(s) + \frac{N}{K_m} s R(s)$$

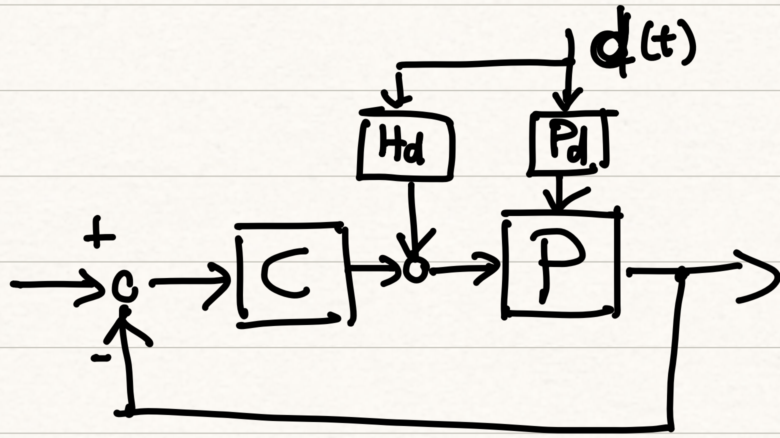


(II) COMPENSATION OF KNOWN DISTURBANCE

typical scenario:

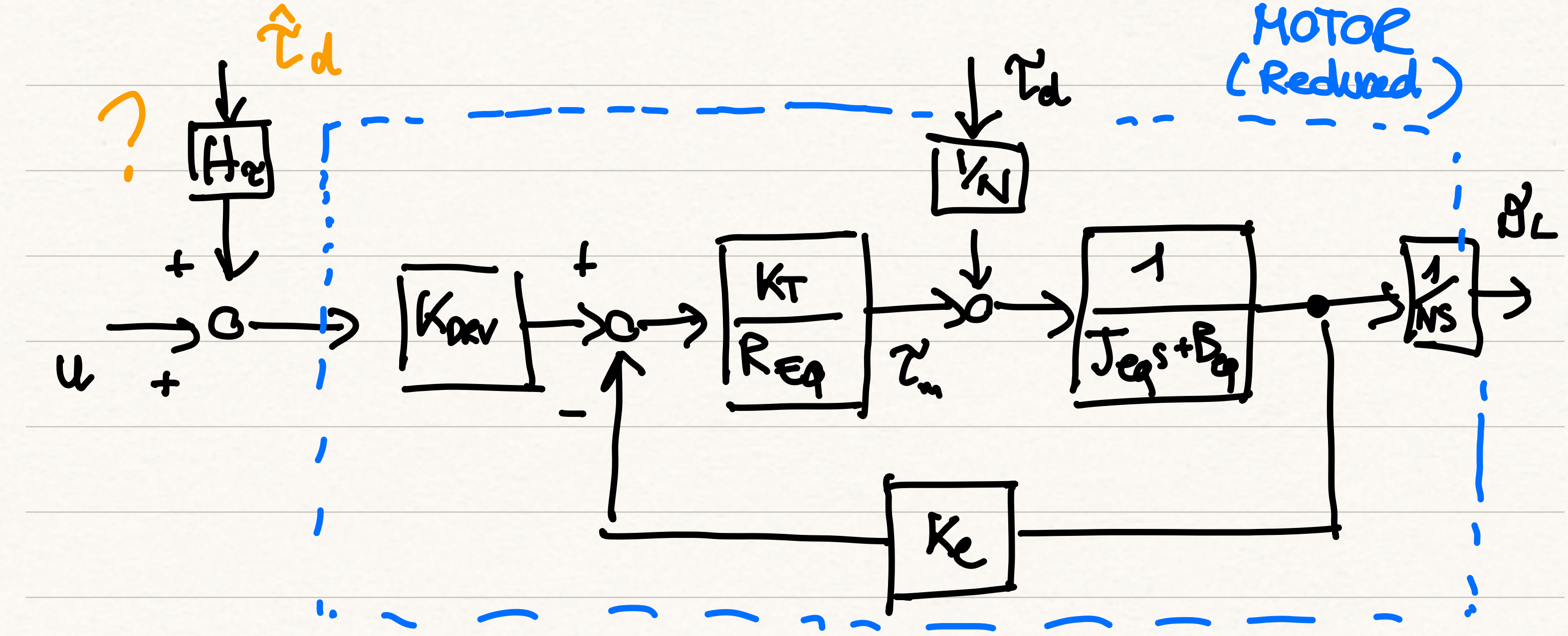
$H_d = ?$

$= -P_d P^{-1}$



IN OUR CASE: $\tau_d = -\tau_{SF}\,\text{sign}(\omega_m)$

(Pb) ENTERS "IN" $P(s)$



What do I have to match?

$$0 = \frac{1}{Ns} \cdot \frac{P_{mech}}{1+P_{mech}P_{el}K_e} \frac{1}{N}\tau_d + \frac{1}{Ns}\frac{P_{mech}P_{el}}{1+P_{mech}P_{el}K_e} K_{DRV} H_\tau \hat{\tau}_d$$

$$\Rightarrow \quad H_\tau \simeq \frac{1}{K_{DRV}P_{el}}\frac{1}{N} \simeq \frac{R_{eq}}{K_{DRV}P_{el}N}$$

$$\Rightarrow \quad u_d(t) = \frac{R_{eq}}{K_{DRV}P_{el}N}\tau_{SF}\,\mathrm{sign}(\omega_m)$$

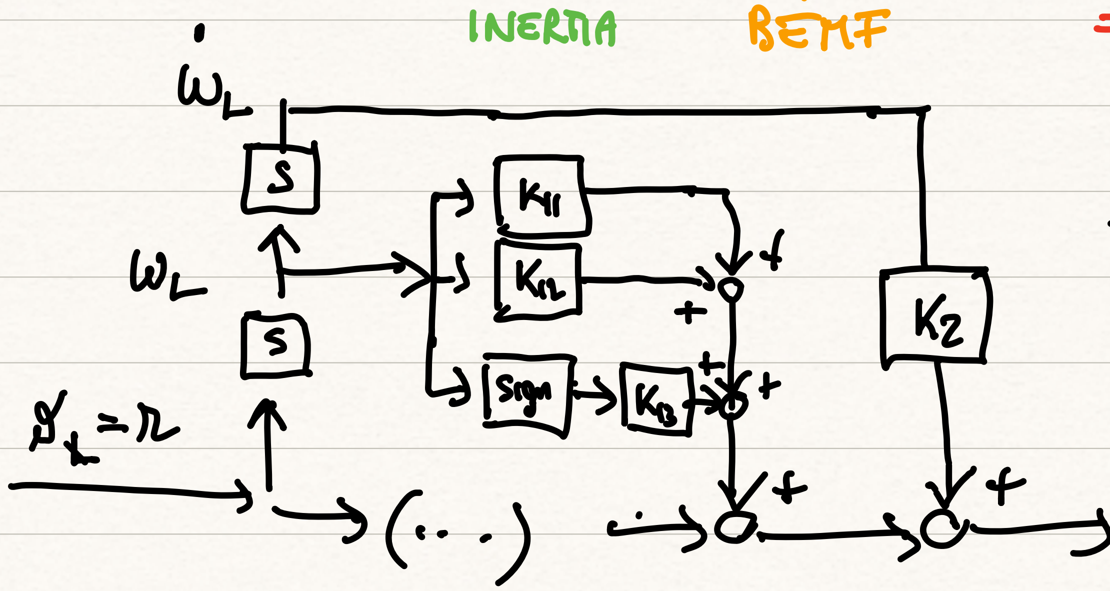
COMBINING THE ~~FEEDFORWARDS~~ :

$$u_{FF}(t) + u_d(t) = \underbrace{\left(\frac{N R_{eq} J_{eq}}{K_{DRV}K_T}\right)}_{K_2}\dot{\omega}_L + \left(\overbrace{\frac{NK_e}{K_{DRV}}}^{K_{11}} + \overbrace{\frac{R_{eq}NB_{eq}}{K_{DRV}K_T}}^{K_{12}}\right)\omega_L$$

$$+ \left(\frac{R_{eq}\tau_{SF}}{K_{DRV}K_T N}\right) \underbrace{\mathrm{sign}(\omega_L)}_{\text{NL. funct.}}$$

K_{13}

$$= \underbrace{K_1 \dot{\omega}_L}_{\text{INERTIA}} + \underbrace{K_{11}\,\omega_L}_{\text{BEMF}} + \underbrace{K_{12}\,\omega_L + K_{13}\,\mathrm{sign}(\omega_L)}_{\text{FRICTION}}$$



FULL F.F. SCHEME

∀ DERIVATIVES : NOT PROPER, NEED FILTERING.