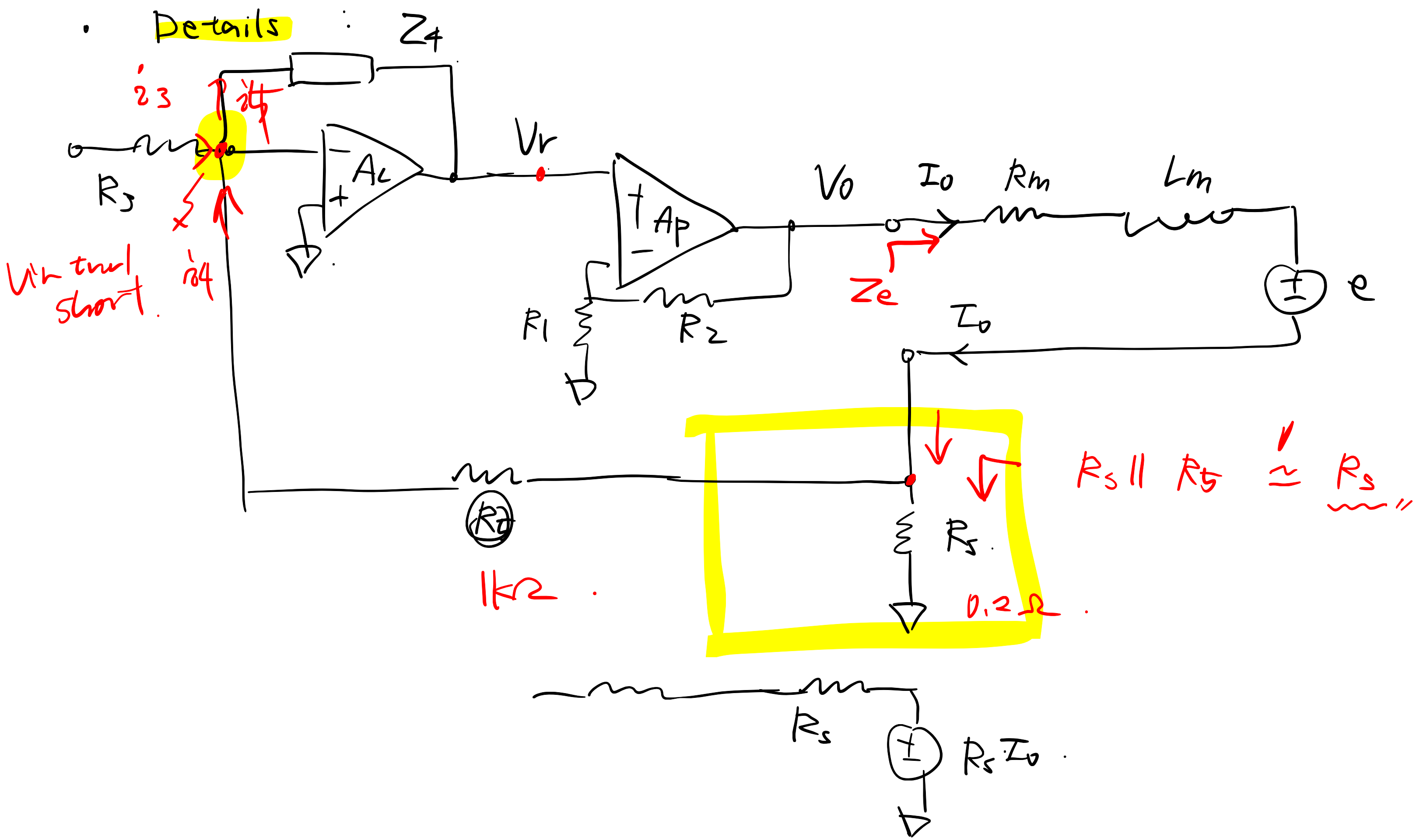
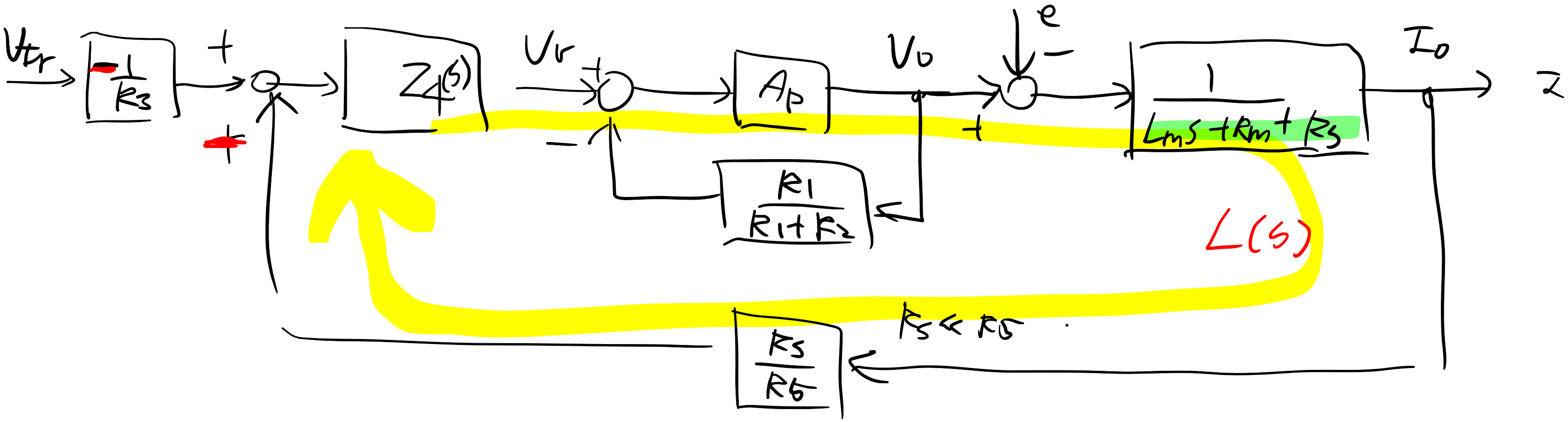
# L10 – Transconductance Amplifier Design

Design process : "Coarse to Fine"

- Strategy : current sensing + feedback.
- Concept : analog implementation.
- Details :

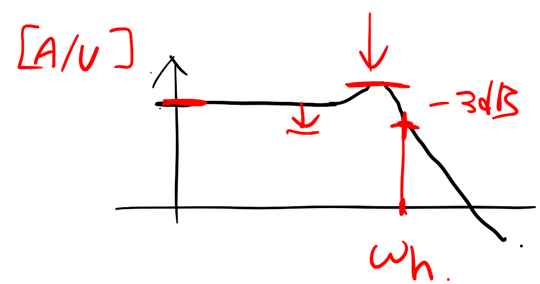





Need to select "Design parameters"

to meet "Design Specs"

"Detail"




< Desig Spec >

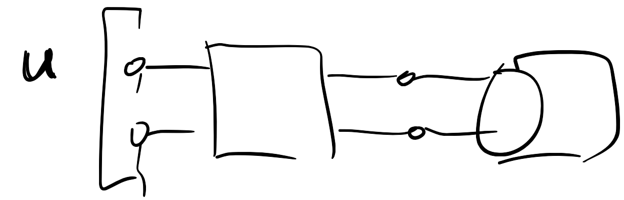
I { • DC Gain.

II { • Bandwidth. $\longleftrightarrow$ $\omega_c$ } Loop shaping.
• Resonance Peak $\longleftrightarrow$ $\phi_m$.

I. DC gain design.

DAC [-10 V, 10 V]

[-10A, 10A].




- $-1$ [A/V].
- max current of motor.

  DAC output range

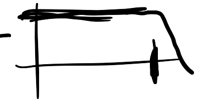
- Assume $L(j\omega)\Big|_{\omega\to 0} \to \infty$, $\dfrac{I_o}{V_{Ir}}\Big|_{\omega=0} = -\dfrac{1}{R_3}\cdot\dfrac{R_6}{R_s} = -1$

- If $R_s = 0.2\Omega$, $\to$ Pick R5 such that $R_5 \gg R_s$: $R_5 = 1K\Omega$

  Pick R3 $\to \dfrac{1}{R_3}\dfrac{R_5}{R_s} = 1 \to R_3 = 5K\Omega$

# V. Loop Shaping.

$\frac{L_p}{1+L_p}$ 1



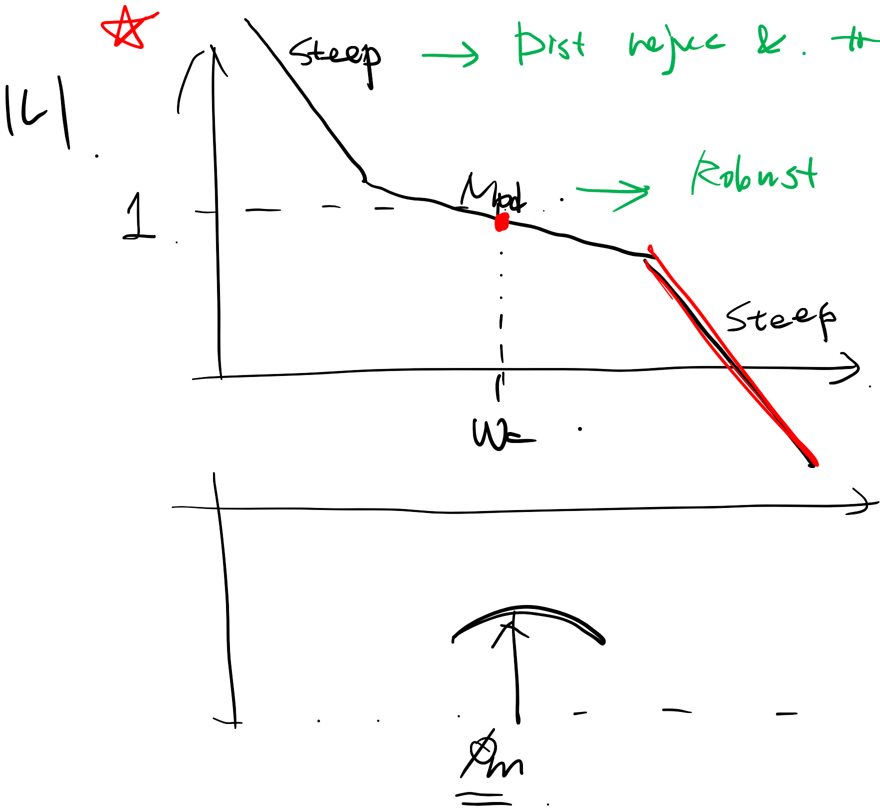
$$L(s) = \underbrace{Z_t(s)}_{C(s)} \cdot \underbrace{T_p(s)\left(\frac{R_1+R_2}{R_1}\right)\left(\frac{1}{L_m s+R_m+R_s}\right)\left(\frac{R_s}{R_5}\right)}_{P(s)}.$$

- Design $C(s) = Z_t(s)$. such that $L(s) = C \cdot P$. achieves a "desired loop shape"

- $C(s)$ "Compensator"

  Compensates ( $L(s)$. ) for ( mag & phase ) deficiencies.

- Desired Loop shape.

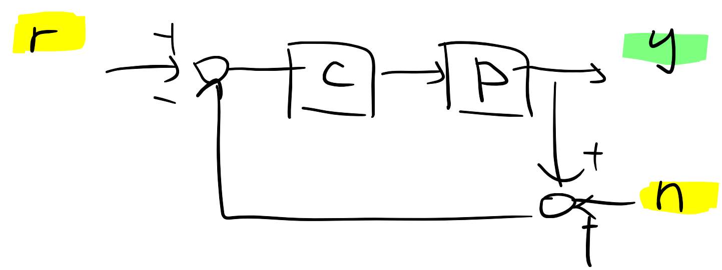


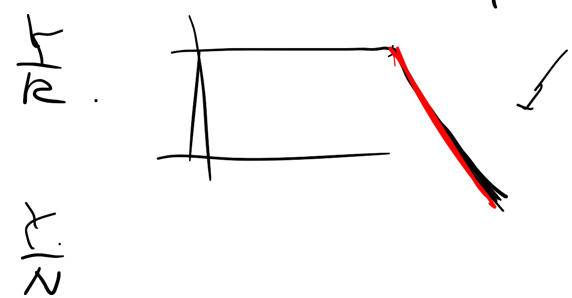

→ Dist reject & tracking.

→ Robust stability.

→ Noise attenuation.

$\phi \simeq 90^\circ$ n. ✓



• Loop shape before comp.

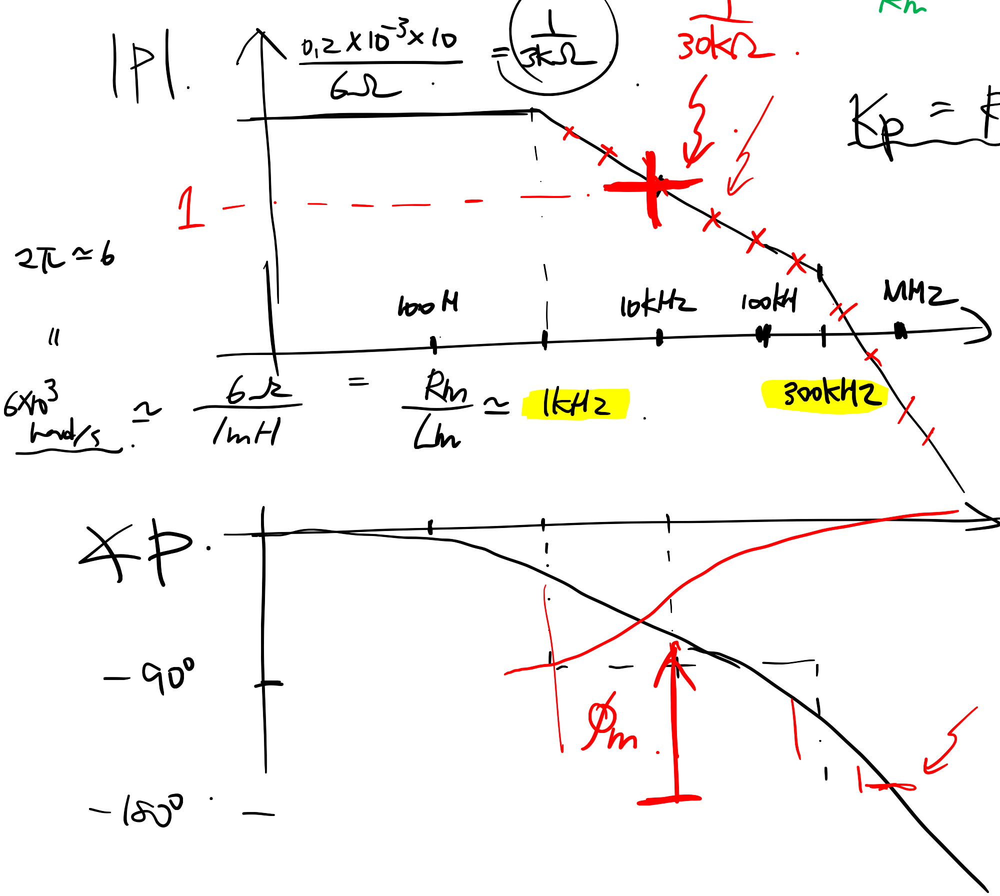
$$P(s) = \cancel{T_p(s)}\,\underbrace{\frac{R_1+R_2}{R}}_{10}\,\underbrace{\left(\frac{1}{L_m s + R_m + R_s}\right)}_{\frac{1}{R_m} = \frac{1}{6\Omega}}\cdot\underbrace{\frac{R_s}{R_5}}_{\frac{0.2\Omega}{1k\Omega} = 0.2\times10^{-3}}$$

$T_p(s)$: 1 upto 300kHz.

$1 \quad (s \to 0)$

| |
|---|
| $L_m = 1mH$ |
| $R_m = 6\Omega$ |
| $R_1 = 1k\Omega$ |
| $R_2 = 9k\Omega$ |
| $R_s = 0.2\ \Omega$ |
| $R_5 = 1k\Omega$ |

$K_p = R_4$.




Deficiencies

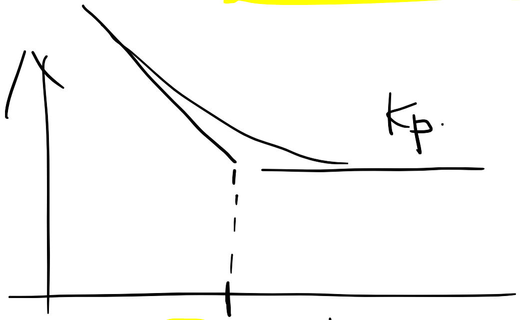
• Low loop gain.

• Flat dc loop gain

→ want "steep" slope

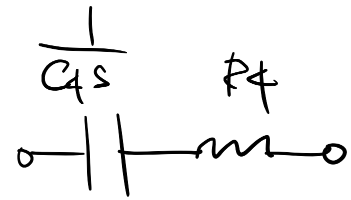
< Loop shaping steps >.

① $C(s) = K_p\left(1 + \frac{1}{T_i s}\right) = K_p\left(1 + \frac{\omega_i}{s}\right) = Z_4(s)$.



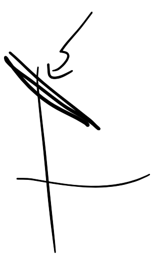

$\omega_i = \frac{1}{T_i}$

$\Rightarrow$

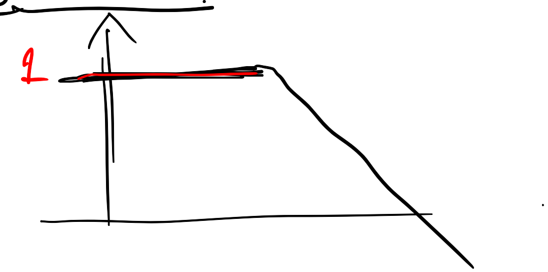



$Z_4(s) = R_4\left(1 + \frac{1}{R_4 C_4 s}\right)$

② Select $\omega_c$, by considering $\phi_m$.



$L(s)$. $\begin{cases} T = \frac{L}{1+L} \\ S = \frac{1}{1+L} \end{cases}$




e.g.) set $\phi_m > 60°$ $30°$.

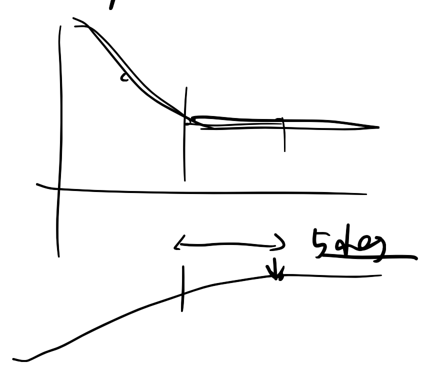
$\omega_c = 10\,kHz \longrightarrow \phi_m \doteq 90°$.

③. Raise $K_p$. $|L(j\omega)| = 1$ at $\omega = \omega_c$.

$$\frac{R_4}{30k\Omega} = 1 \Longrightarrow R_4 = 30k\Omega$$

④. Introduce the integrator. by selecting $\omega_i$

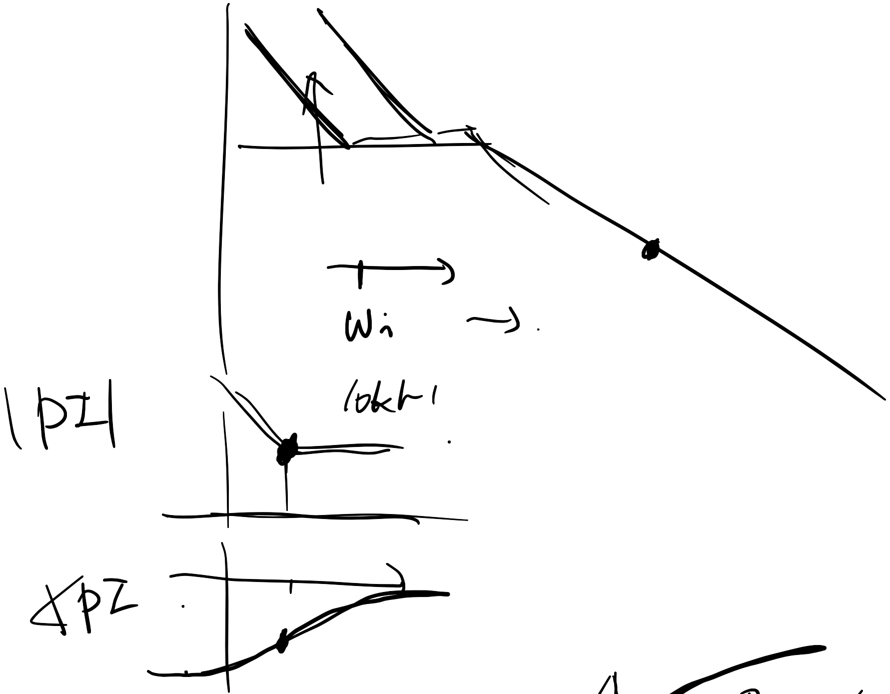
e.g. $\frac{1}{R_4C_4} \simeq 1\,kHz$ " $5°$

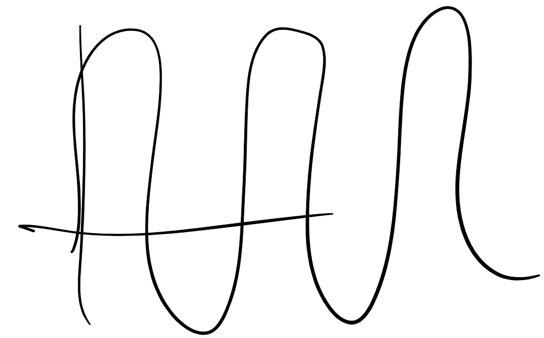



10kHz.

$$\Rightarrow \boxed{C_4 \simeq 5.5\,nF}$$

"Trade-off"
- low $\omega_i$ → weak dist reject, bad tracking.
- Low $\omega_i$ → sacrifices $\phi_m$



$\underline{90^\circ} = \phi_m$ ↓ $\underline{45^\circ \text{dec}}$ ↓ $\underline{0\ \text{deg}}$