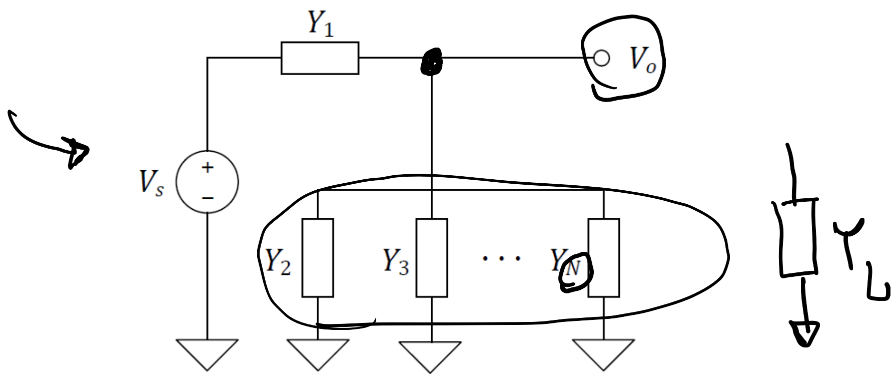
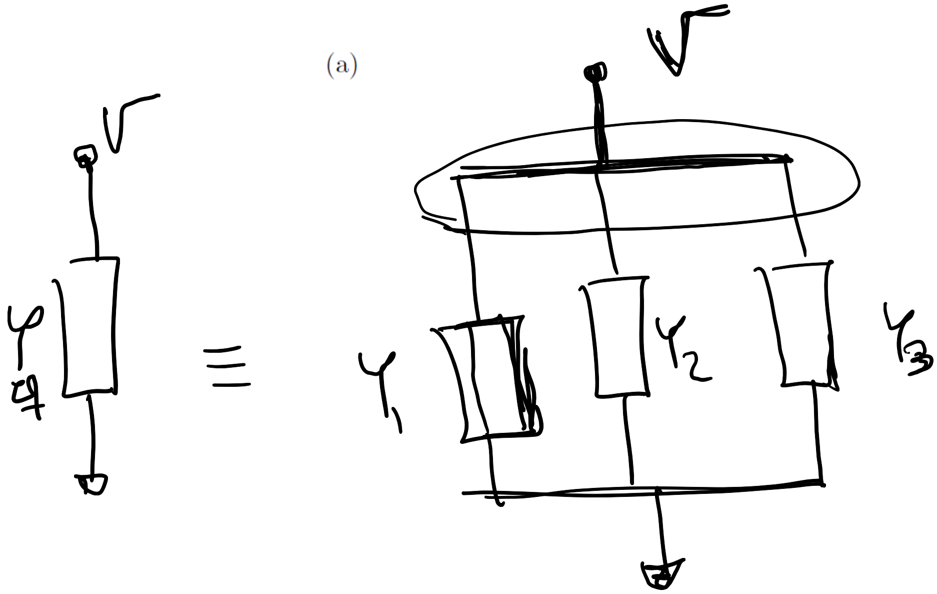


(a)

$Z \equiv \frac{V}{I}$

$Y \equiv \frac{I}{V}$



$Y_1 V + Y_2 V + Y_3 V = Y_{eq} V$

$\Rightarrow Y_{eq} = Y_1 + Y_2 + Y_3$

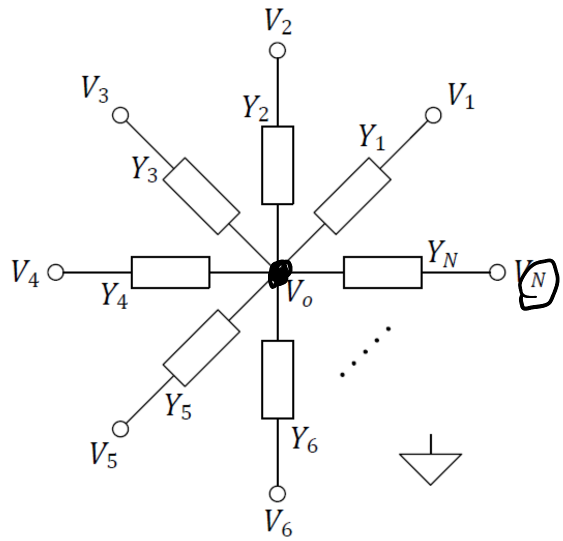
$V_o(V_s, Y_1, Y_L) = ?$

$(V_o - V_s) Y_1 + (V_o - 0) Y_L = 0$

$\Rightarrow (Y_1 + Y_L) V_o = Y_1 V_s$

$\Rightarrow \boxed{V_o = \frac{Y_1}{Y_1 + Y_L} V_s}$

$$\boxed{V_0 = \frac{\psi_1}{\sum_{i=}^{N} \psi_i}}$$



(b)

$V_o(V_j, Y_i)$

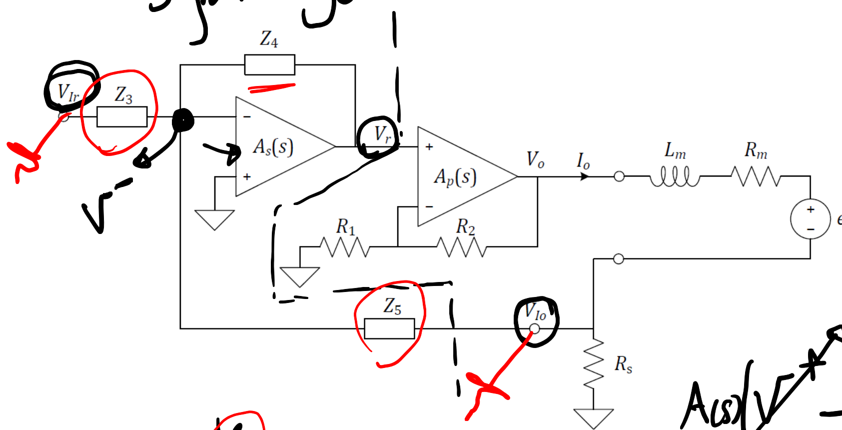
$$(V_o - V_1)Y_1 + (V_o - V_2)Y_2 + (V_o - V_3)Y_3 = 0$$

$$(Y_1 + Y_2 + Y_3)V_o - Y_1V_1 - Y_2V_2 - Y_3V_3 = 0$$

$$\Rightarrow V_o = \frac{Y_1V_1 + Y_2V_2 + Y_3V_3}{Y_1 + Y_2 + Y_3}$$

$$\boxed{V_o = \frac{\sum_{i=1}^{N} Y_i \cdot V_i}{\sum_{j=1}^{N} Y_j}}$$

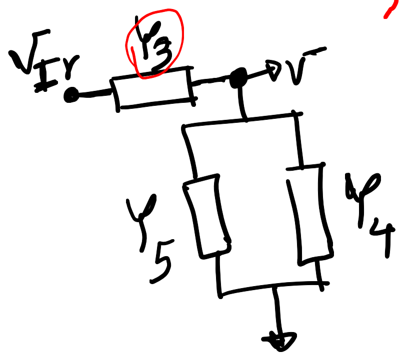
signal stage



V_{Ir}, V_{Io}, V_r

superposition :

V_{Ir} ✓
V_r ✗
V_{Io} ✗



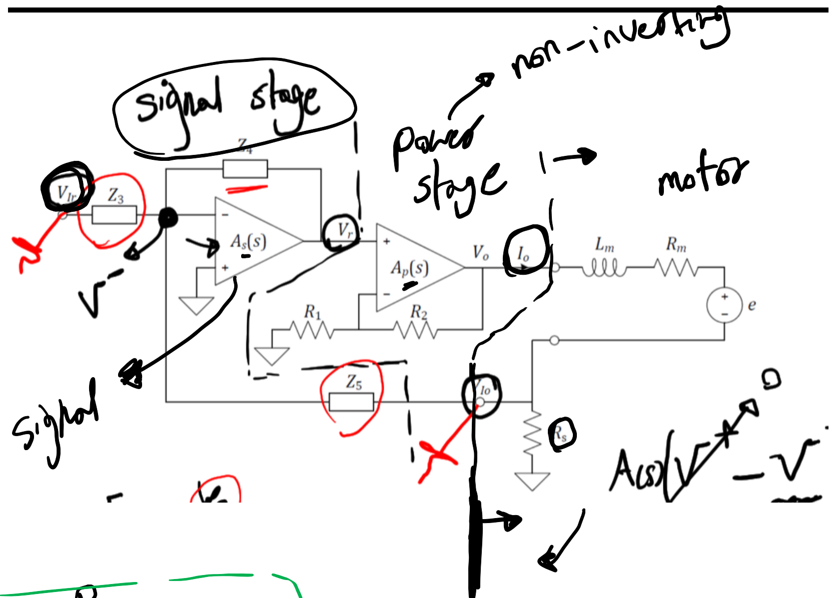
$$A(s)(\cancel{V^+} - V^-) = V_r$$

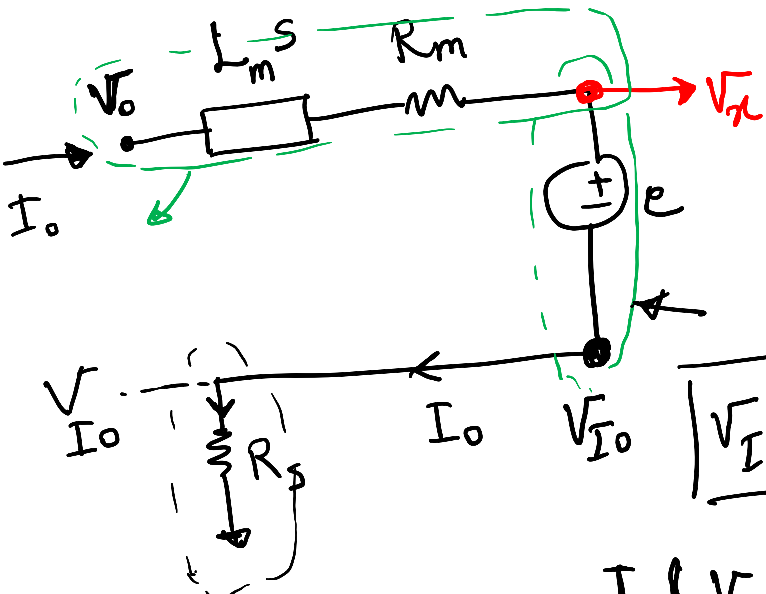
$$\boxed{V_r = -A(s)V^-}$$

$$Y_3 = \frac{1}{Z_3}$$

$$V_1^- = \frac{Y_3}{Y_4 + Y_5 + Y_3} V_{Ir}$$

V_r ✓
V_{Ir} ✗
V_{Io} ✗

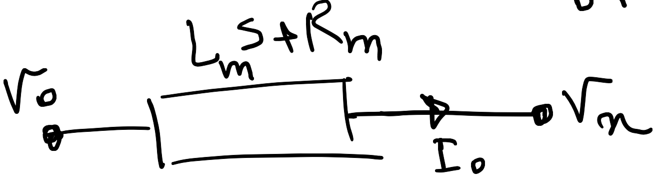




$$V_{Io}(I_o) = ?$$

$$\boxed{V_{Io} = R_s I_o}$$

$$I_o(V_o) = ?$$

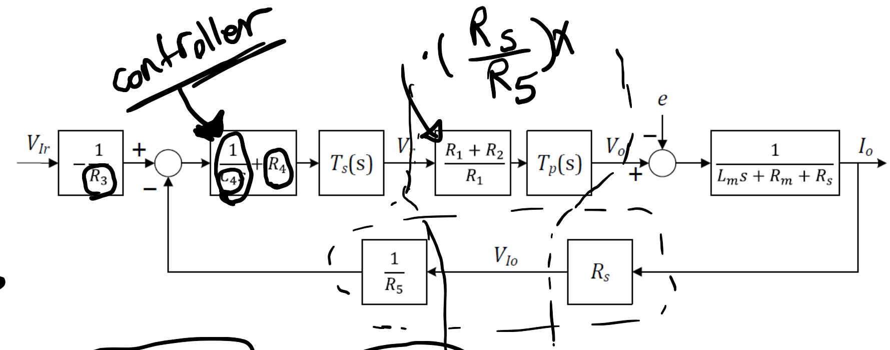


$$\begin{cases} \dfrac{V_o - V_n}{R_m + L_m s} = I_o \quad (*) \\ V_n - V_{Io} = e \Rightarrow V_n - R_s I_o = e \Rightarrow \boxed{V_n = e + R_s I_o} \end{cases}$$

(*) $V_0 - (e + R_s I_0) = I_0 (R_m + L_m s)$

$$V_0 - e = I_0 (R_m + L_m s + R_s)$$

$$\Rightarrow \boxed{I_0 = \frac{1}{R_m + R_s + L_m s}(V_0 - e)}$$



$A_s(s) = \frac{5 \times 10^7}{s}$ $\quad A_p(s) = \frac{10^7}{s}$ $\quad R_1 = 1\,\mathrm{k\Omega}$ $\quad R_2 = 9\,\mathrm{k\Omega}$

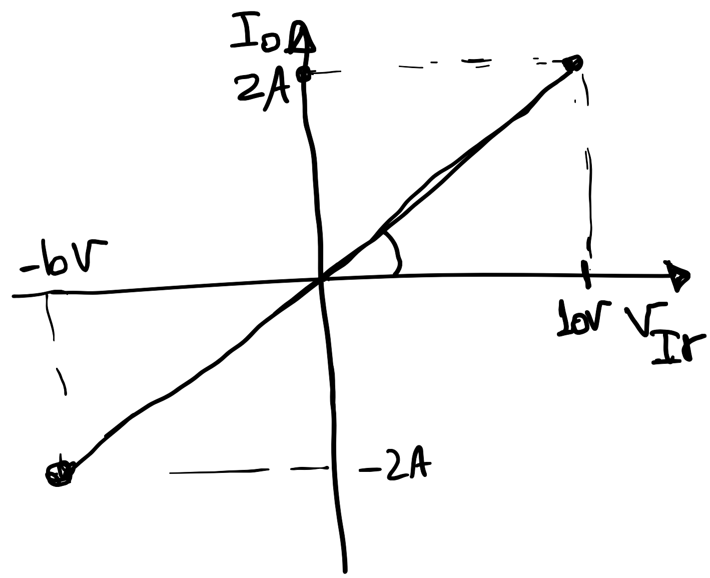
$L_m = 1\,\mathrm{mH}$ $\quad R_m = 5.8\,\Omega$ $\quad R_s = 0.2\,\Omega$ $\quad R_5 = 1\,\mathrm{k\Omega}$.

select R_3:

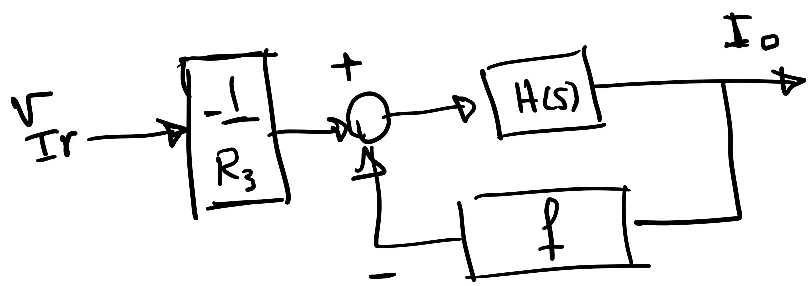
DAC V_{Ir}

DAC $\rightarrow \pm 10V \rightarrow V_{Ir} \rightsquigarrow I_o \rightarrow$ motor

$\pm 2A$



$L(j\omega)\Big|_{\omega=0} \rightarrow \infty$



$H(s)$

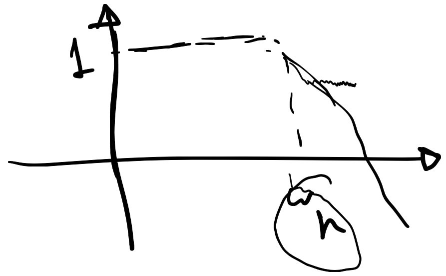
$f = \frac{R_s}{R_5}$

$$G = \frac{I_o}{V_{Ir}} = \frac{\left(-\frac{1}{R_3}\right)(H(s))}{1 + f\,H(s)}$$

@ $\omega = 0$ $\quad \frac{I_o(j\omega)}{V_{Ir}(j\omega)}\Big|_{\omega=0} = \frac{-1/R_3}{f}$

Selecting R_4:

$T_s(s) = 1$

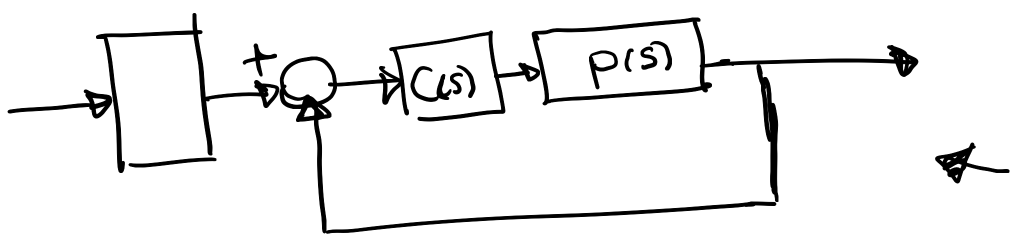


$C_4 \to \infty$

$R_4 = ?$

$$T_p(s) = \frac{L_p(s)}{1 + L_p(s)}$$

- $L(s)$ have largest crossover frequency (ω_c) while $\phi_m \geq 90^\circ$



$$C(s) = \cancel{\frac{1}{C_4 s}} + R_4$$

$$P(s) = \left(\frac{R_1 + R_2}{R_1}\right)\left(\frac{1}{L_m s + R_m + R_s}\right)\left(\frac{R_s}{R_5}\right) T_p(s)\, \cancel{T_s(s)}^{\,1}$$

$$T_p(s) = \frac{L_p(s)}{L_p(s) + 1}, \quad L_p(s) = f_p A_p(s),$$

$$f_p = \frac{R_1}{R_1 + R_2}$$

$$L(s) = C(s)P(s) = R_4 \underbrace{P(s)}_{\text{phase}}$$