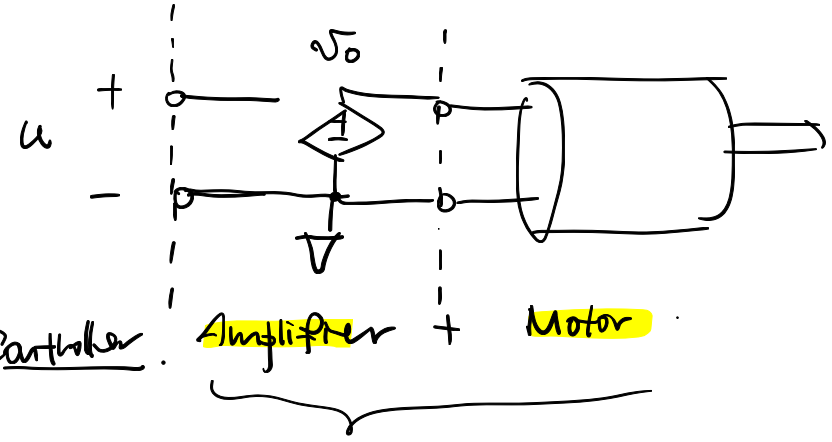
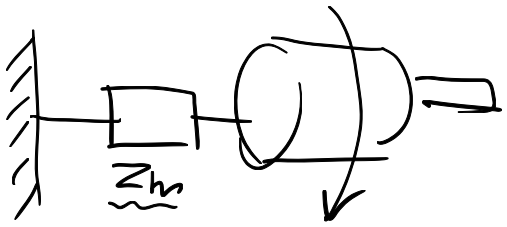
L9 – Current-controlled DC Motor



Actuator.

$$G_V(s) = \frac{V_o}{U} \quad [V/V].$$

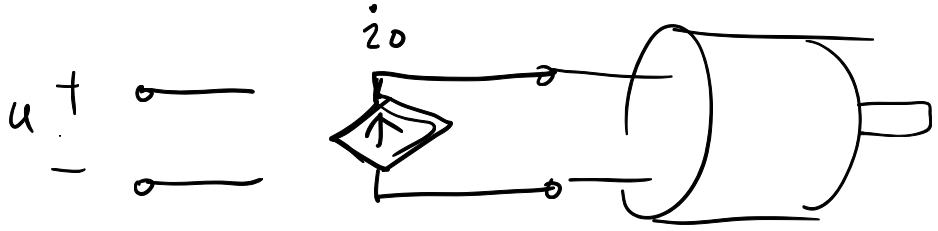
High B.W.



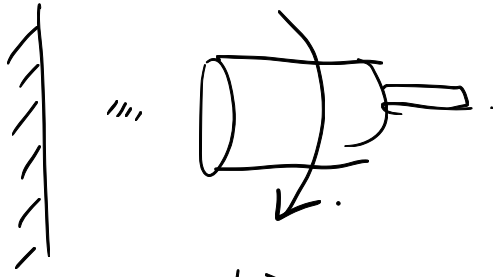
$$\tau_{th} = \frac{K}{Ls+R} V_o$$

$$Z_m = \frac{K^2}{Z_e} = \frac{K^2}{Ls+R} \simeq \frac{K^2}{R}$$

- What if



High B.W



$$\tau_{th} = K i_o.$$

$$Z_m = \frac{K^2}{Z_e} \to \frac{K^2}{\infty} \to 0$$

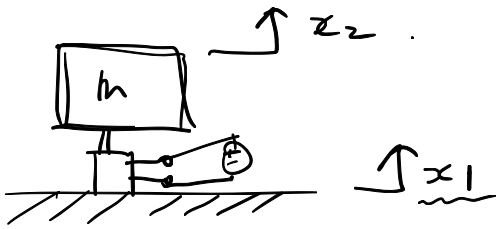
$$G_i(s) = \frac{I_o}{U} \quad [A/V].$$

"Transconductance Amp" : VCCS.

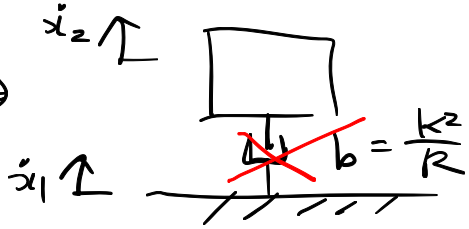
① Fast torque resp : $\tau = K \cdot i$.

② Low output impedance .

$\Rightarrow$ Ideal torque source (force) .



$\Rightarrow$



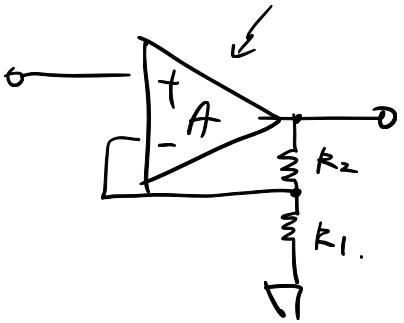
"Seismic short"

with Trans Amp

- power Amp
- Transconductance
- Motor drive
- Current drive
- ⋮

Q. How can we make a controlled current source ?

Recall .



v_o .

"To measure v_o" .

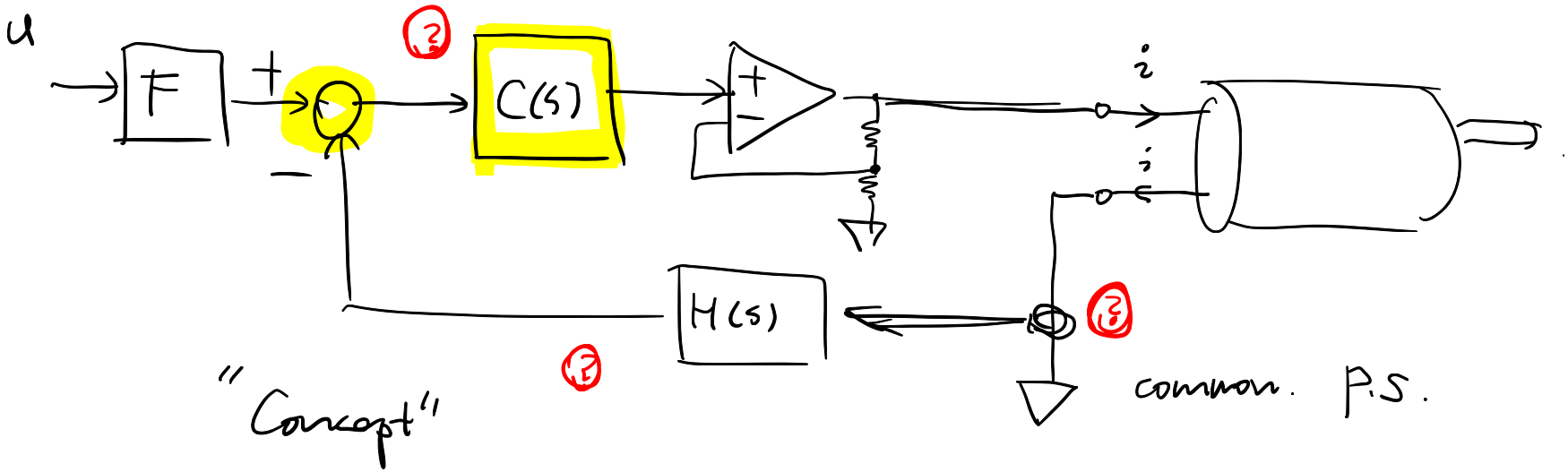
"Measurand"

R_2 & R_1 high enough .

$\Rightarrow$ do not affect measurand .

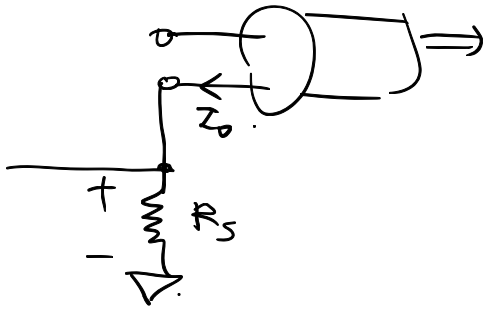
- Measure I_o "strategy"
- Feed it back.

"Design question"
1. How to measure I_o ?
2. How to design a feedback cont ?
3. How to implement a controller ?



(I) Current sensing

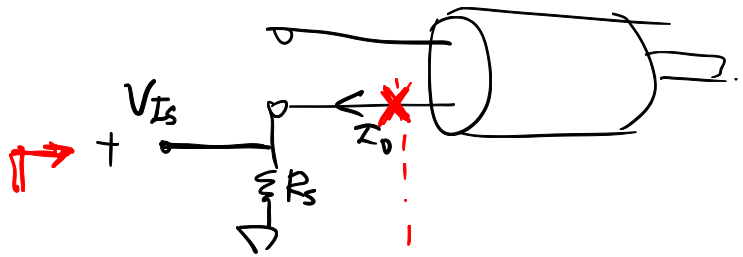
1. Minimally affect I_o. → $R_s \ll R_m$.
2. High bandwidth. → ✓
3. Low noise. → ✓ (trade-off)
4. Low interference. →
5. Low cost →

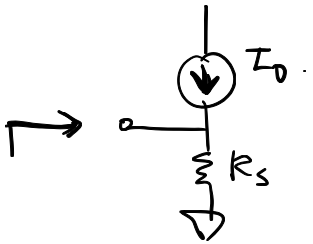


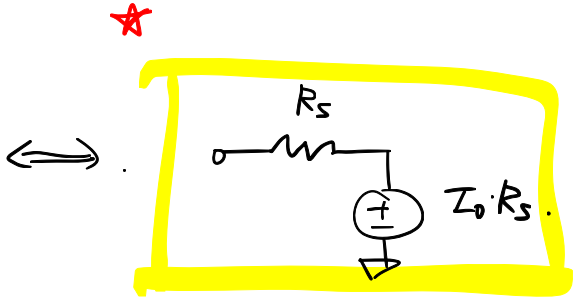
two common solutions
1. (Current-sensing) shunt resistor.
2. Hall effect sensor.

- T.C.R $[K^{-1}] \triangleq \frac{dR}{dT}\frac{1}{R}$.
- $P_{max} = R_s I^2_{max}$

< Equivalent Circuit Model >

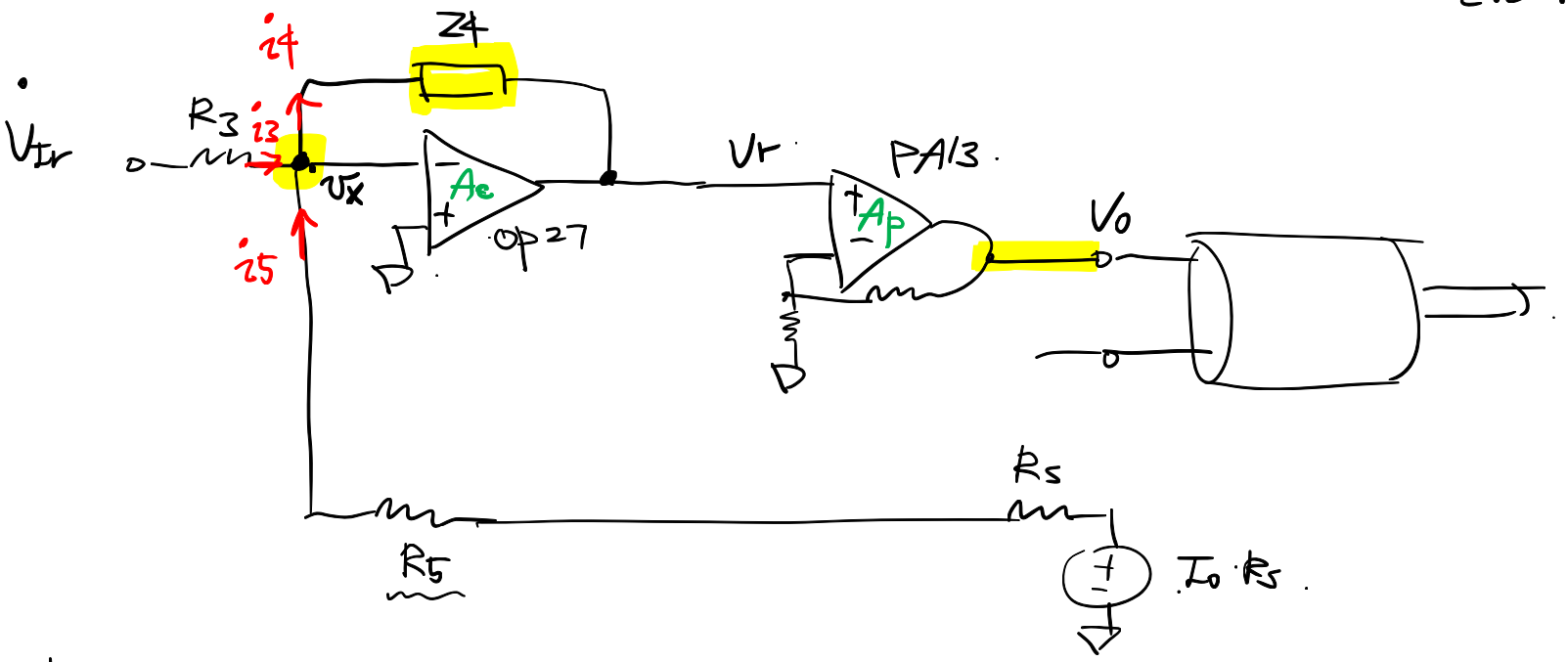






(II) Controller Implementation.

- Analog circuits. — Higher B.W. — Lower noise. vs. Digital implementation (MCU & switching electronics)



Key ideas

① Summing junction: KCL at x $\Rightarrow$ $\dot{i}_4 = \dot{i}_3 + \dot{i}_5$

② Controller t.f.: $Z_4(s)$.

Virtual short approx : $v_x \simeq 0$

$$V_r \simeq -Z_f i_f$$ Virtual short

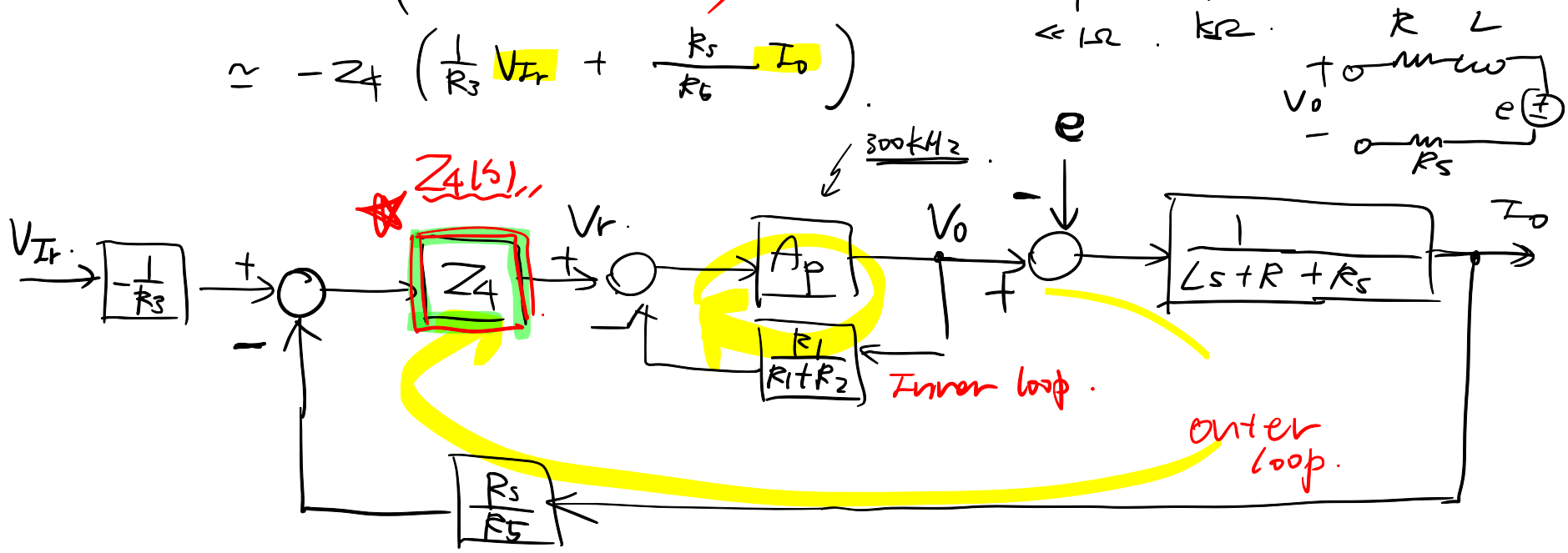
$$= -Z_f (i_3 + i_5)$$ KCL.

$$= -Z_f \left(\frac{1}{R_3} V_{Ir} + \frac{1}{R_5 + R_S} R_S I_o \right)$$

$R_S \ll R_5$

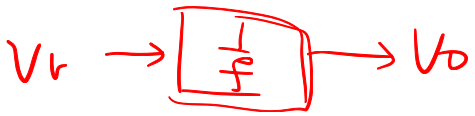
$\ll 1\Omega$. $k\Omega$.

$$\simeq -Z_f \left(\frac{1}{R_3} V_{Ir} + \frac{R_S}{R_5} I_o \right)$$



- Back-emf e : disturbance

- "Nested Loop" : Outer loop B.W. < Inner loop B.W. ,,


Vi
1/f
Vo