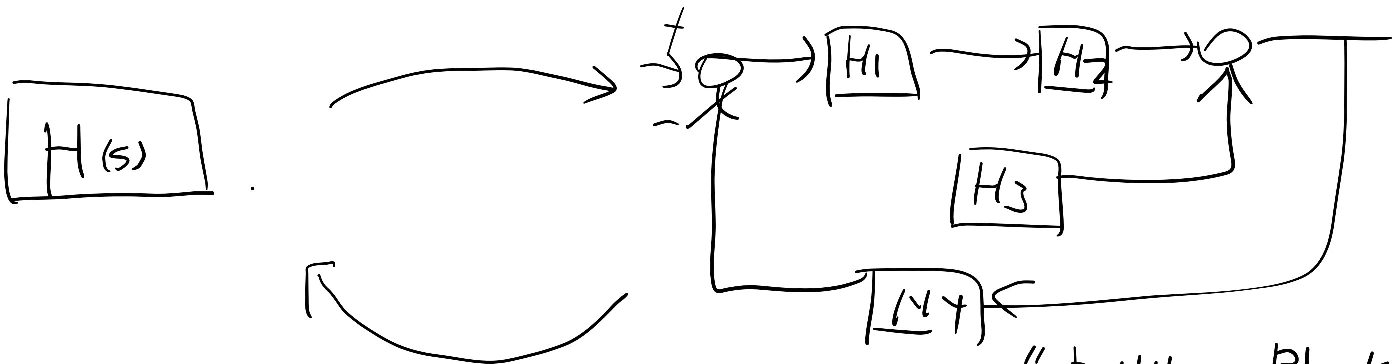
L4 – Operational Amplifier

Control = "Design" of the system dynamics.

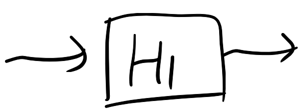
Analysic. { Decompose: "+" ; Factorization: "×"



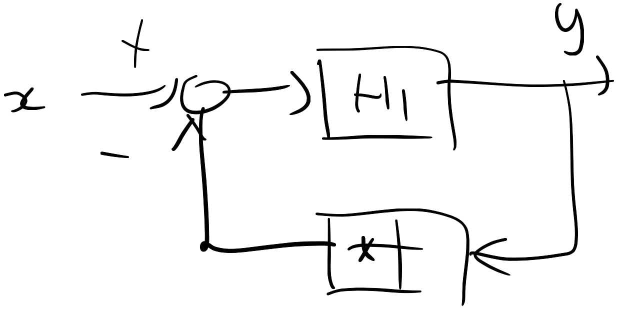
"Building Block"

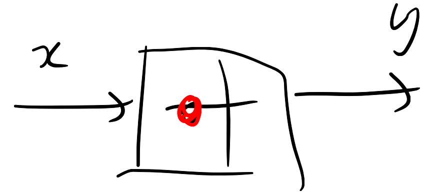
Synthesis (design)

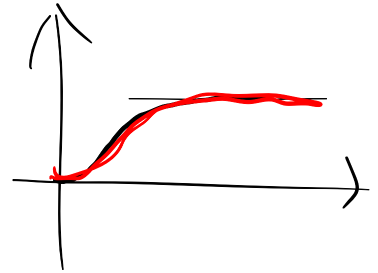
time { Imp, Step. sinusoid.



Freq. { · Bode. · pole, $H_1(s)$



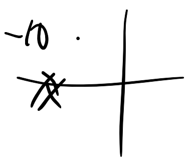




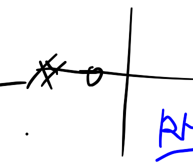
$$G_1 = \frac{1}{s^2+20s+100}$$

$$= \frac{1}{(s+10)^2}$$

-10

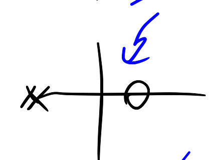


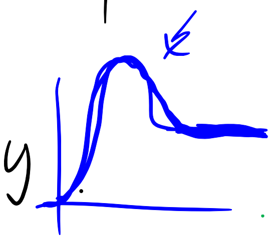
$$G_2 = \frac{1+s}{s^2+20s+100}$$



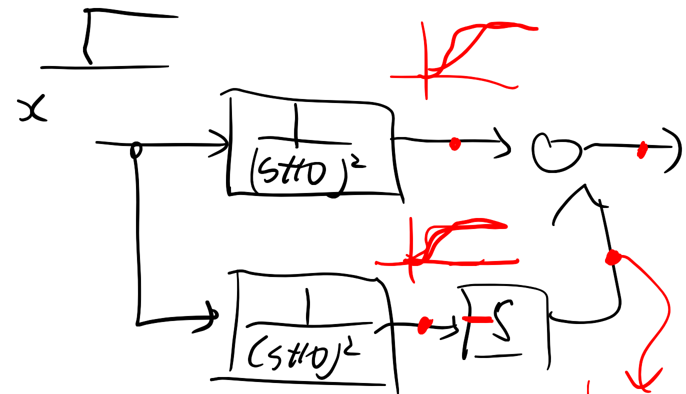
RHP zero

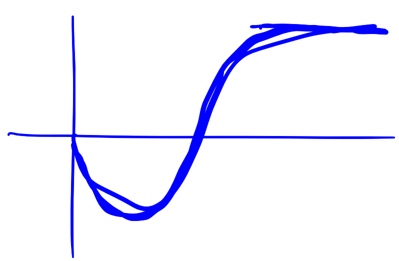
$$G_3 = \frac{1-s}{s^2+20s+100}$$



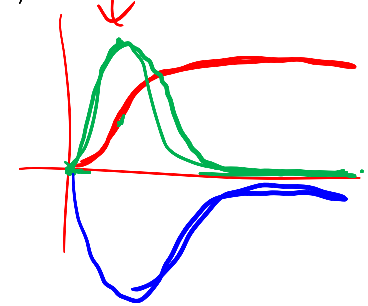


$$G_2 = \frac{1}{(s+10)^2} + \frac{s}{(s+10)^2}$$



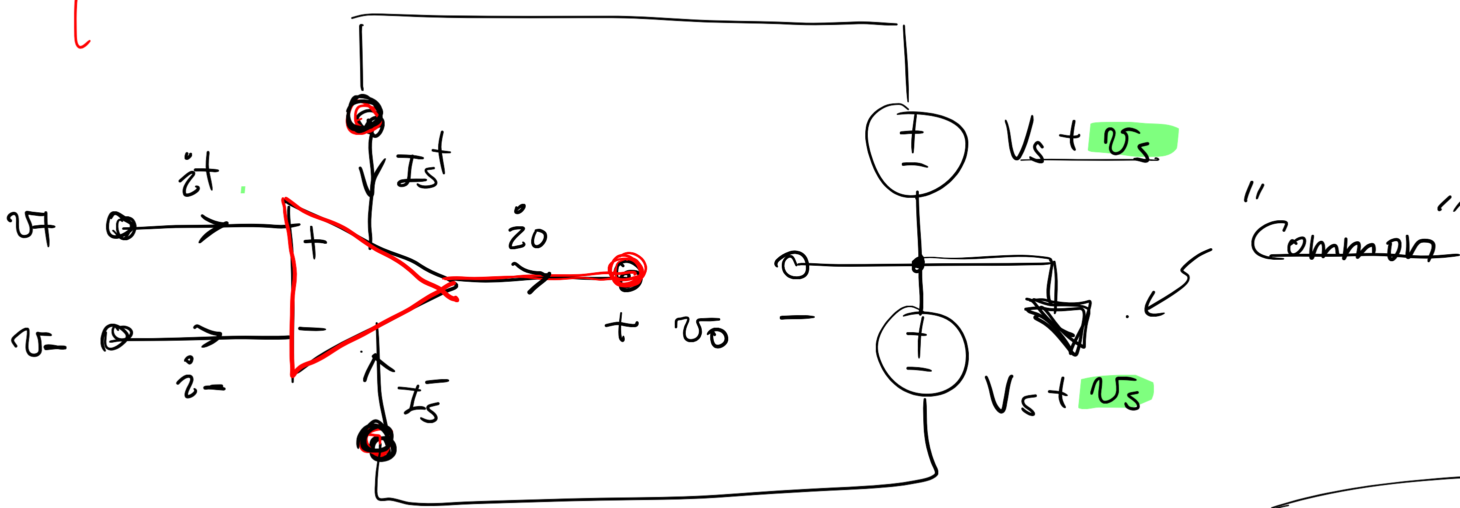


G_3



Input {

"object"



trans. cap. res. . . .

Terminal variables

· 5 terminals

· 3 ports.

Terminal Relations.

Current : $i_o = I_s^+ + I_s^- + i^+ + i^-$ (KCL)

Voltage : $v_o = A\underbrace{(v_+ - v_-)}_{v_e} + A_c\underbrace{\left(\frac{v_+ + v_-}{2}\right)}_{v_{cm}} + A_s v_s - Z_o i_o$

A : open-loop (voltage) gain.

A_c : Common-mode gain.

A_s :

$\Rightarrow$

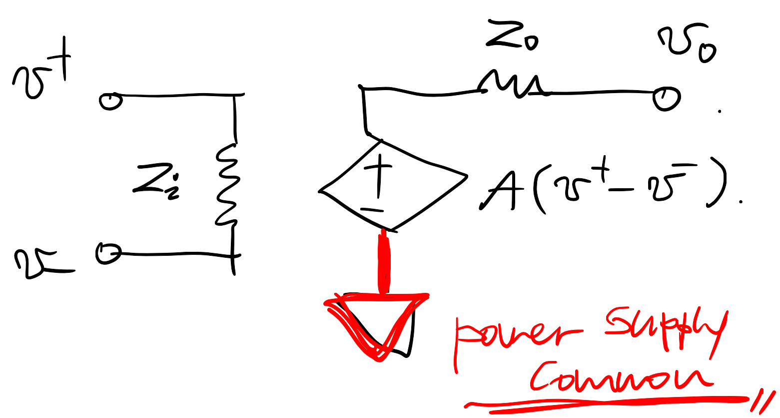
$\underline{\underline{CMRR}} \triangleq \dfrac{A}{A_c}$

$\underline{\underline{PSRR}} \triangleq \dfrac{A}{A_s}$

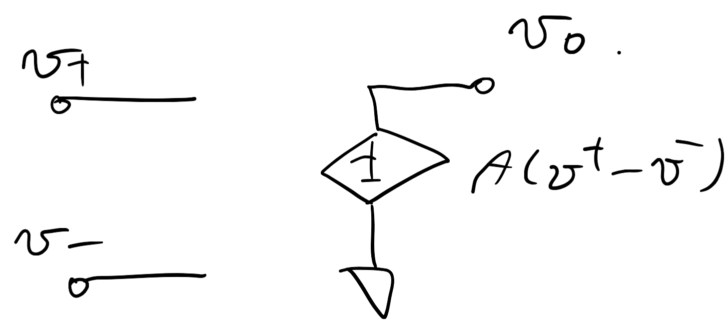
Input Z : Z_i

Output Z : Z_o

① Circuit Model.



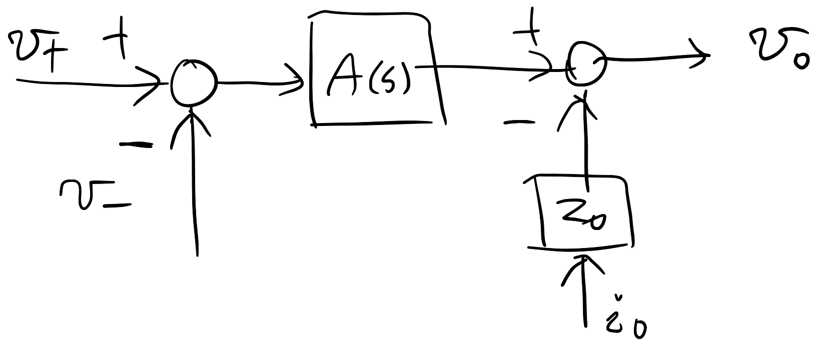
$\Rightarrow$

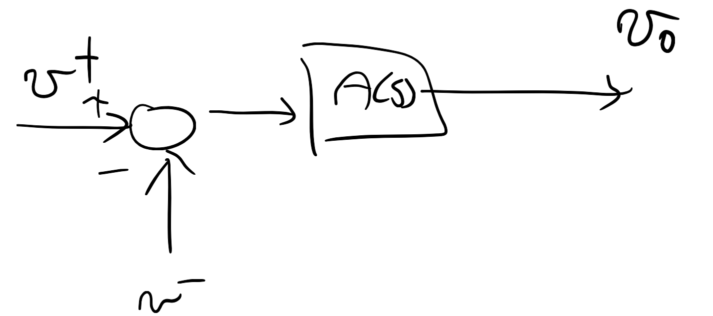


$\begin{cases} Z_i \to \infty \\ Z_o \to 0 \end{cases}$

$\underline{\underline{\text{"Ideal"}}}$.

② Block Diagram





(1) A = const

(2) $A \to \infty$

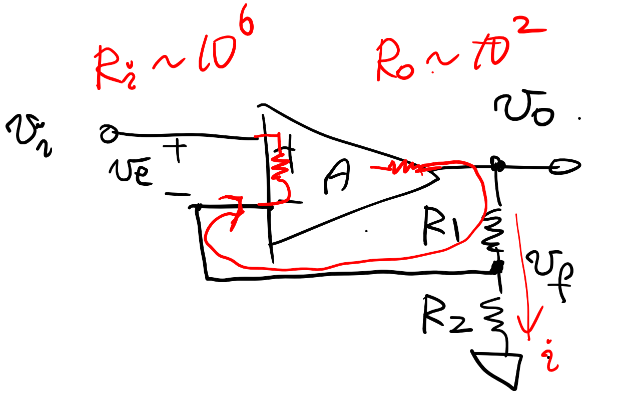
(3) $A(s) = \frac{\omega_0}{s}$

(4) $A(j\omega)$ in datasheet.

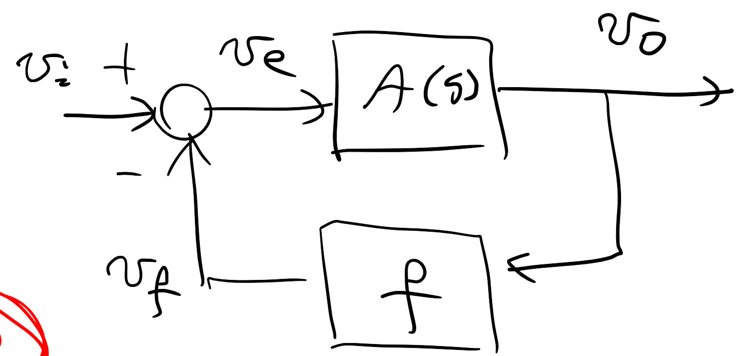
$\downarrow$

A [V/V]. = [−].

< Non-inverting Amp >.



10^4 10kΩ



Q. "A" $\left\{ \begin{array}{l} \text{hard to make it precise.} \\ \text{easy to make it "Large"} \end{array} \right.$ × 1000

Q. A → How make precise amp? → "Feed back"

$$f = \frac{v_f}{v_o} \qquad v_f = \frac{R_2}{R_1 + R_2} \cdot v_o . \qquad \boxed{f = \frac{R_2}{R_1 + R_2}} .$$

$$\frac{1\Omega}{1\Omega + 9\Omega} = \frac{1}{10} .$$

$$\frac{1k\Omega}{1k\Omega + 9k\Omega} \approx \frac{1}{10} .$$

Black's Formula.

$v_i \to v_o$:

$$\frac{A(s)}{1 + L(s)} = \frac{A(s)}{1 + A(s) \cdot f}$$

$$G = \frac{A}{1+A\beta} \qquad 1k\Omega : R_1, \quad 9k\Omega : R_2 \Rightarrow \beta = \frac{1}{10}.$$

As $A\beta \to \infty$. $G \simeq \dfrac{A}{\cancel{1+}A\beta} = \dfrac{A}{A\beta} = \boxed{\dfrac{1}{\beta}}$ $\qquad$ R $\underline{(0.005\%)}$