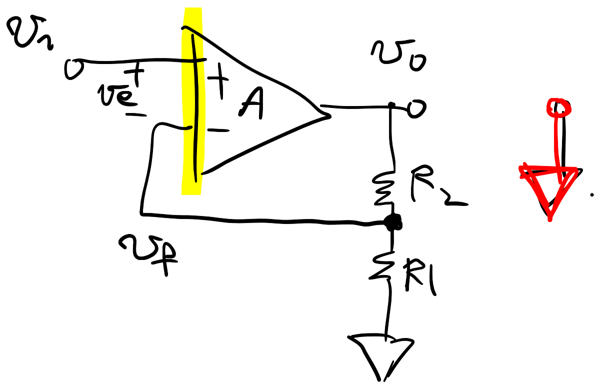
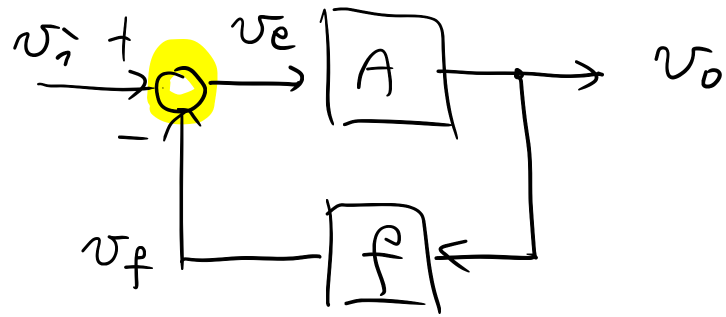
L5 – Op-Amp (Statics)





$$f = \frac{R_1}{R_1 + R_2}.$$

$$\frac{v_o}{v_i} \triangleq G = \frac{A}{1 + Af}$$

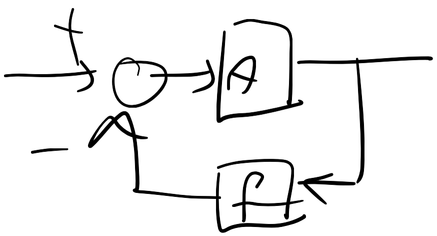
① $Af \to \infty \quad \Rightarrow \quad G = \dfrac{A}{1+Af} \simeq \dfrac{A}{Af} = \dfrac{1}{f}.$ • $\underline{\underline{G}}$ is not affected by A

② $Af \not\to \infty$. $A =$ constant. Op27. $|A(j\omega)|_{\omega \to 0} \simeq \underline{125\text{ dB}}$

$$10^{\frac{125\text{ dB}}{20\text{ dB}}} = 10^{6.xx}$$
$$= \boxed{10^6}$$

How to quantify $\frac{dA}{A} \approx 10\%$ $\longrightarrow$ $\frac{dG}{G}$?

"Gain sensitivity"



① $f=0$. $\Rightarrow$ $dA = dG$.

$$\frac{dG}{G} = \frac{dA}{A} = 10\%$$

② $f \neq 0$ $\Rightarrow$ $G = \frac{A}{1+Af}$

$$dG = \frac{dA(1+Af) - A(dA \cdot f)}{(1+Af)^2}.$$

$$= \frac{dA + \cancel{dA\,A f} - \cancel{A\,dA \cdot f}}{(1+Af)^2}.$$

$$= \frac{dA}{(1+Af)^2}.$$

$$G = \frac{A}{1+Af}. \qquad \frac{dG}{G} = \frac{\cancel{1+Af}}{A} \cdot \frac{dA}{(1+Af)^{\cancel{2}}}. = \underbrace{\left(\frac{1}{1+Af}\right)}_{\triangleq S} \frac{dA}{A}.$$

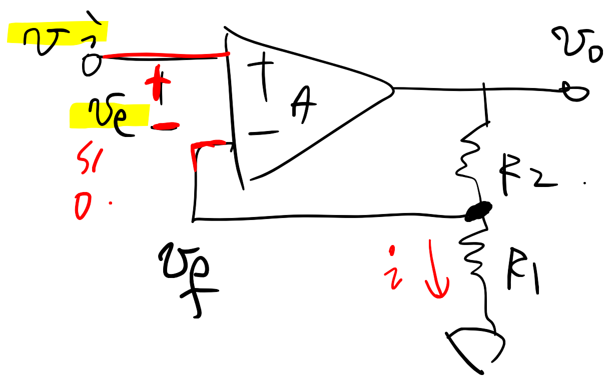
$\frac{dA}{A} \downarrow 10\%..$

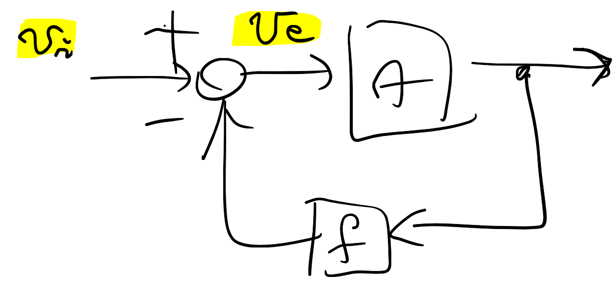
$$\text{OP27}: \quad A \simeq 10^6, \quad f = \frac{1}{10}$$

$$Af \simeq 10^5. \longrightarrow \frac{1}{1+Af} = \frac{1}{1+10^5} = \frac{10^{-5}}{10^{-5}+1} \simeq 10^{-5}.$$

- Sensitivity function : $S(s) \triangleq \frac{1}{1+L(s)}$.

① - Feedback makes the system "Insensitive" to change in A.

②. 



$$\frac{v_e}{v_i} = \frac{1}{1 + Af} = S(s).$$

- When $Af = L \to \infty$. $S \to 0$.

$$\cancel{v_e} = S \cdot v_i$$ $\to 0$.

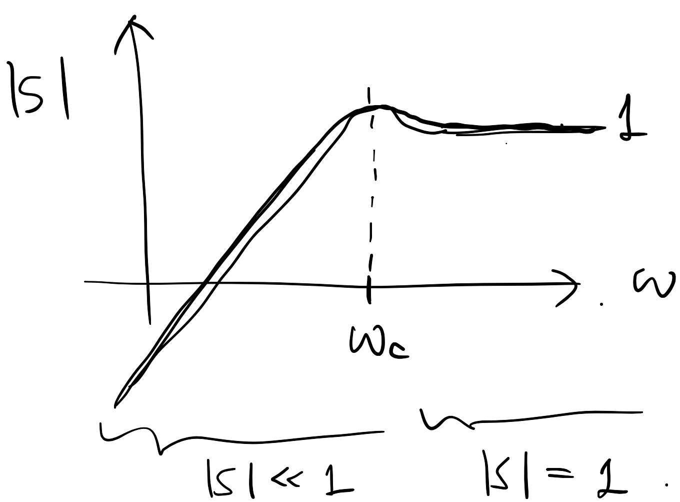
"Feedback syst. reject dist."

As $Af \to \infty$.

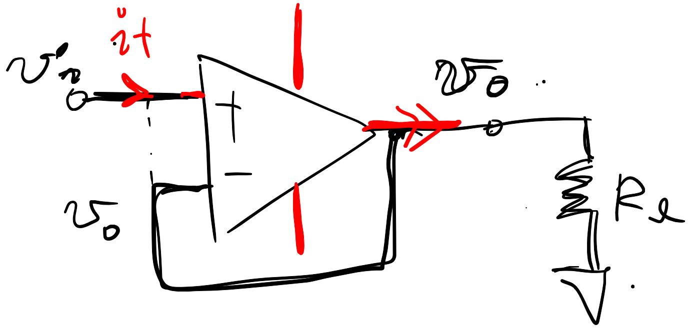
- As long as $Af \gg 1$, $\boxed{v_e \simeq 0}$ "virtual short"

<u>Example</u>. As $Af \to \infty$, $v_f \simeq v_i$ $\quad v_o = v_f \frac{1}{R_1}(R_1 + R_2)$.

$$\simeq v_i \frac{1}{R_1}(R_1 + R_2)$$



$$\boxed{v_o = \frac{R_1 + R_2}{R_i} v_i}$$



$$\boxed{v_o \simeq v_i} \qquad \underset{\sim\sim\sim}{G = 1}.$$

Q. Amplifier?

A. Yes.

Q. What does it amplify?

A. Power.

$$P_{in} = v_i \cancel{i_t}^{\simeq 0} \simeq 0.$$

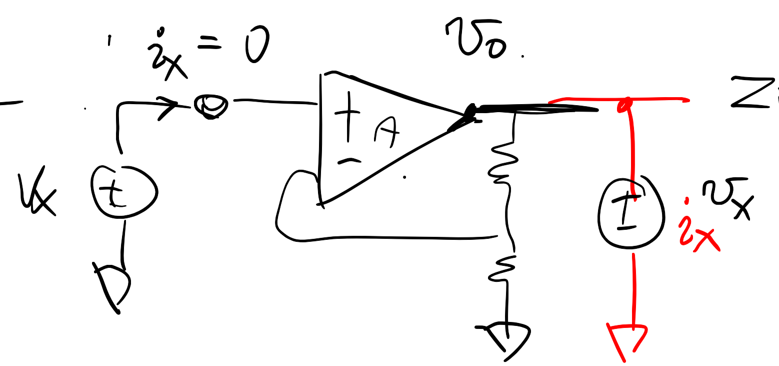
$$P_{out} = v_o i_o = \frac{v_o^2}{R} \qquad \underline{100\,W}!$$

$\boxed{\text{"Power Amplifier"}}$

Input impedance

"port"

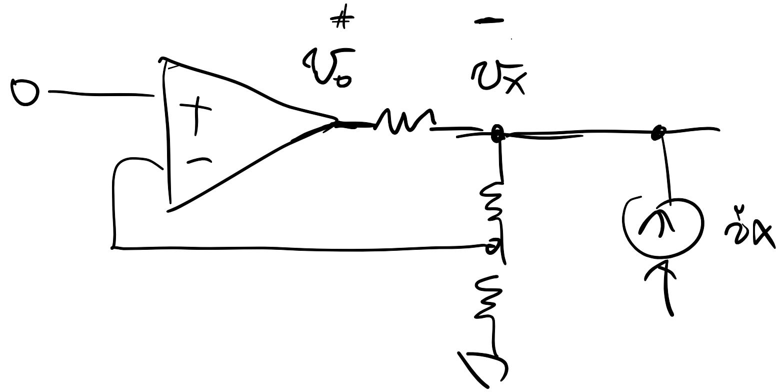
$i_x = 0$



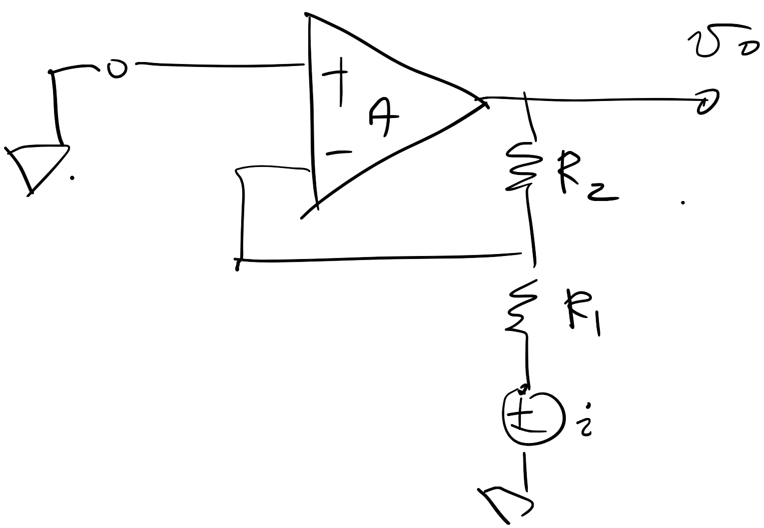
$$Z_{in} = \frac{v_x}{i_x} \to \infty.$$

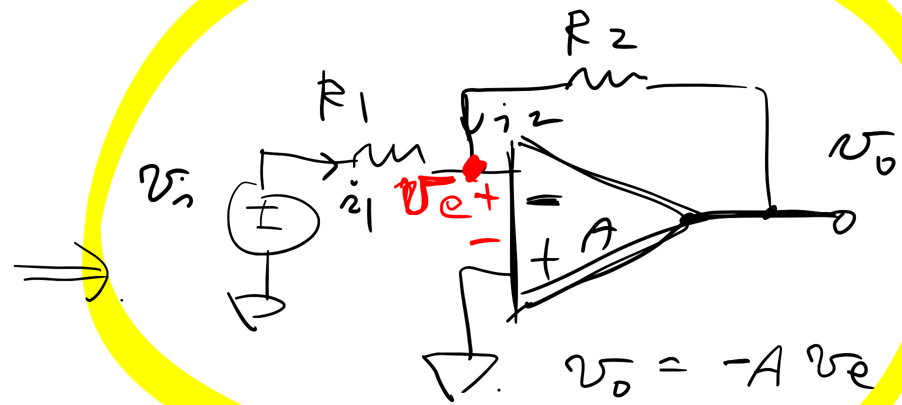
Output Z

$Z_{out} = \frac{v_x}{i_x} \simeq 0$.



Inverting Amp





$\underline{v_o = -A v_e}$

$A_f \to \infty$. $\quad v_e \simeq 0$.

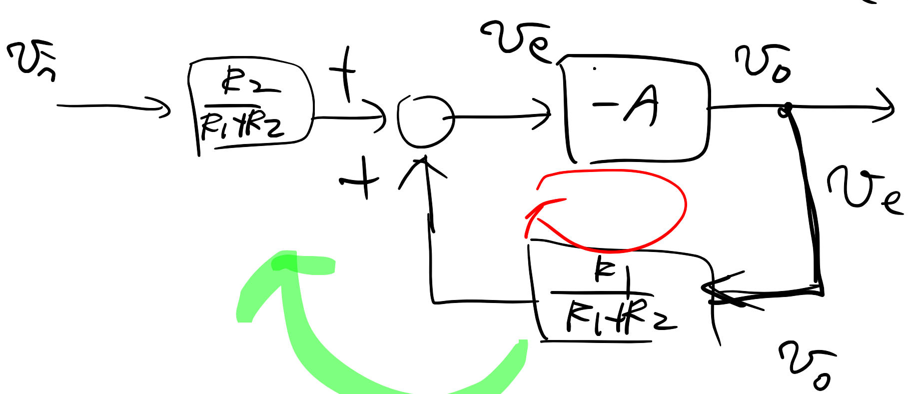
KCL: $i_1 + i_2 = 0$. $\Rightarrow$ $\quad v_i \to \boxed{\frac{1}{R_1}} \xrightarrow{i_1} \boxed{-1} \xrightarrow{i_2} \boxed{R_2} \to v_o$.

$$\boxed{A = \text{const}} \qquad \qquad \boxed{\frac{v_o}{v_i} = -\frac{R_2}{R_1}}$$

① Node Method.

Ⅰ Apply KCL: $\nabla \cdot i = 0$. $\qquad \frac{v_e - v_i}{R_1} + \frac{v_e - v_o}{R_2} = 0$

$$v_e \left(\frac{1}{R_1} + \frac{1}{R_2}\right) = +\frac{1}{R_1} v_i + \frac{1}{R_2} v_o$$



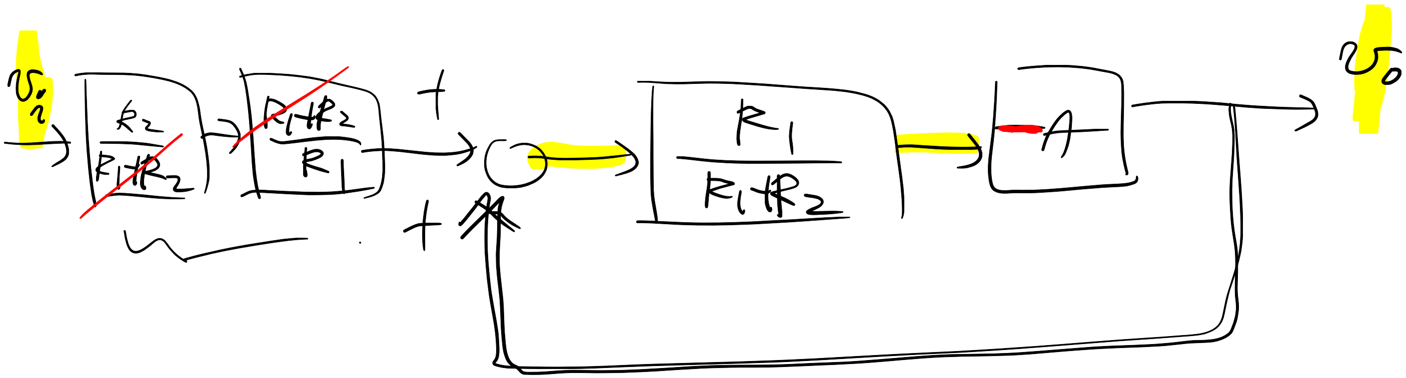
$$v_e = \left(\frac{\frac{1}{R_1}}{\frac{1}{R_1} + \frac{1}{R_2}}\right) v_i + \left(\quad\right) v_o$$

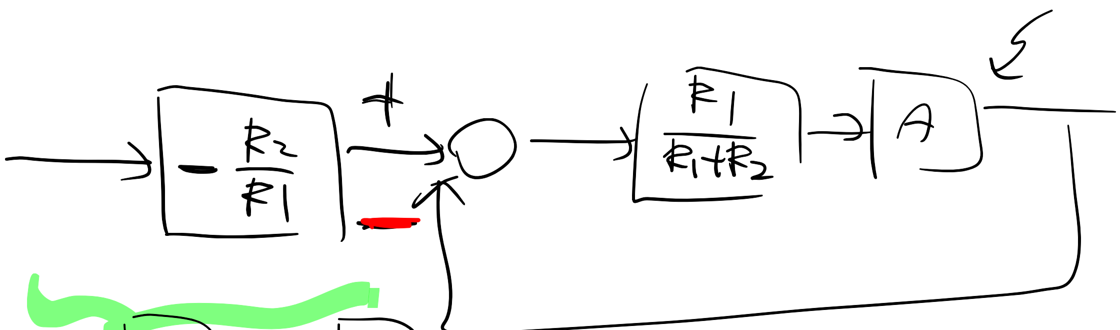
$$= \left(\frac{R_2}{R_1+R_2}\right) v_i + \left(\frac{R_1}{R_1+R_2}\right) v_o$$

Ⅱ $v_o = -A v_e$.

$L(s) = ?$

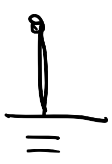
$A \cdot \underbrace{\frac{R_1}{R_1+R_2}}_{= f} \qquad Af$





① $A(s) = \frac{\omega_0}{s}$

② $A(j\omega)$



Low Impedance

V