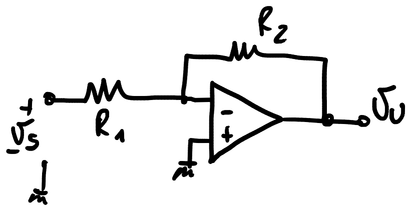
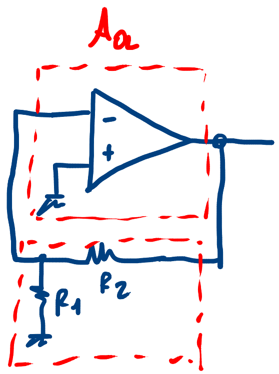
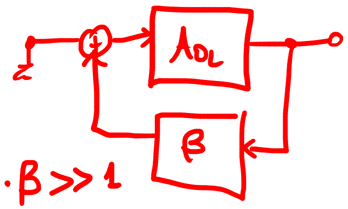


$$V_U = - \frac{\frac{A R_2}{R_1+R_2}}{\underbrace{1 + A\frac{R_1}{R_1+R_2}}_{A_f}} \cdot V_S$$

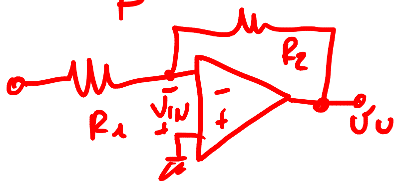
per $A \to +\infty \Rightarrow A_f \to -\frac{R_2}{R_1}$





$A_{OL} \cdot \beta >> 1$

$$\boxed{A = A_{VOL\phi}}$$



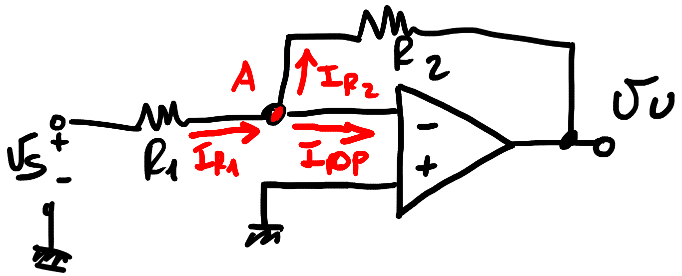
$V_U = A_{VOL\phi} \cdot V_{IN}$

$V_{IN} = \frac{V_U}{A_{VOL\phi}}$

$$V_U = - \frac{\frac{A R_2}{R_1+R_2}}{1 + A\frac{R_1}{R_1+R_2}} V_S$$

$$V_{IN} = - \frac{\frac{\cancel{A} R_2}{R_1+R_2}}{1 + A\frac{R_1}{R_1+R_2}} \cdot \frac{1}{\cancel{A}} V_S$$

$$\lim_{A \to +\infty} V_{IN} = \phi$$

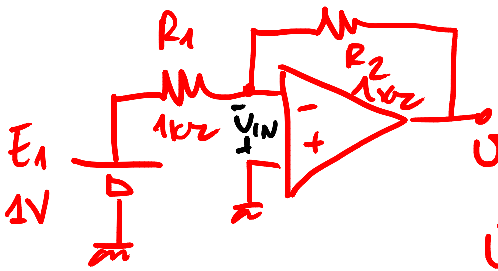


$V^+ = 0 \qquad V^+ \simeq V^- \simeq 0V \Rightarrow V_A \simeq 0V$

$I_{R_1} = I_{OP} + I_{R_2} \qquad I_{OP} = 0 \Rightarrow I_{R_1} \simeq I_{R_2}$

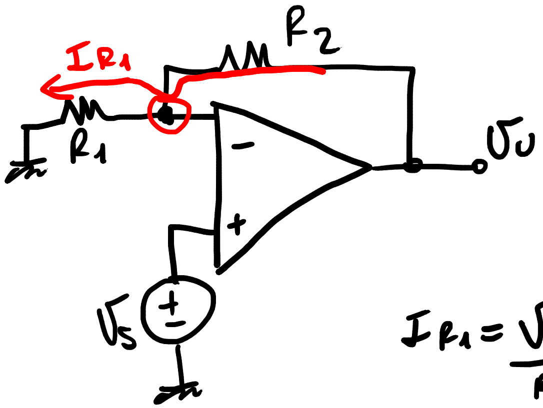
$$I_{R_1} = \frac{V_S - V_A}{R_1} = \frac{V_S}{R_1} = I_{R_2}$$

$$V_U = V_A - R_2 I_{R_2} = -R_2 \cdot \frac{V_S}{R_1} = \underbrace{-\frac{R_2}{R_1}}_{A_f} V_S$$



$V_U = -1V$

$V_U = A_{vol} \cdot V_{IN}$



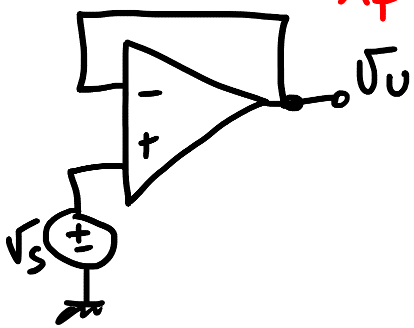
$$V^+ \simeq V^-$$

$$V^+ = V_s \Rightarrow V^- \simeq V_s$$

$$I_{R1} = \frac{V_s}{R_1}$$

$$V_u = V^- + R_2 I_{R2} = V_s + R_2 \frac{V_s}{R_1} =$$

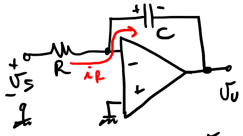
$$= \underbrace{\left(1 + \frac{R_2}{R_1}\right)}_{A_f} V_s$$



$$V_u = V^-$$

$$V^+ \simeq V^-$$

$$V_s = V^+ \Rightarrow V_u \simeq V_s$$



$0 = v^+ \simeq v^- \simeq 0$

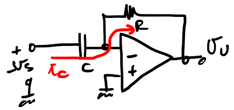
$i_R = \frac{v_S}{R}$

$$v_U = -\frac{1}{C}\int i_C(t)\,dt = -\frac{1}{C}\int \frac{v_S(t)}{R}\,dt =$$

$$= -\frac{1}{RC}\int v_S(t)\,dt$$

$\Updownarrow$

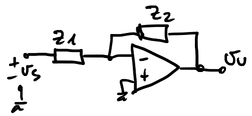
$i_R = \frac{v_S}{R}$ $\quad v_U = -\frac{1}{Cs} i_R = -\frac{1}{RCs} v_S$



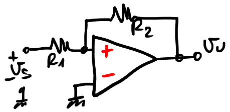
$v_U = -R i_C$

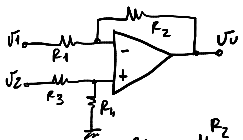
$i_C = \frac{v_S}{1/Cs} = Cs \cdot v_S$

$v_U = -RCs\,v_S$

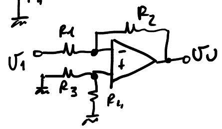


$v_U = -\frac{Z_2}{Z_1} v_S$



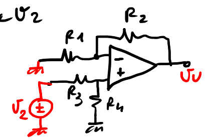


Se agisce v_1



$v_U = -\frac{R_2}{R_1} v_1$

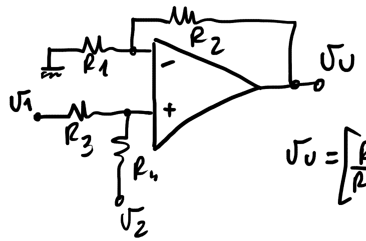
Se agisce v_2



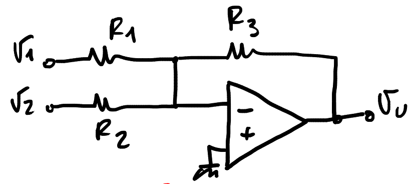
$v_U = \left(1+\frac{R_2}{R_1}\right)\frac{R_4}{R_3+R_4} v_2$

$$v_U = -\frac{R_2}{R_1}v_1 + \left(1+\frac{R_2}{R_1}\right)\frac{R_4}{R_3+R_4}v_2 = -\frac{R_2}{R_1}v_1 + \left(1+\frac{R_2}{R_1}\right)\frac{\frac{R_4}{R_3}}{1+\frac{R_4}{R_3}}v_2$$

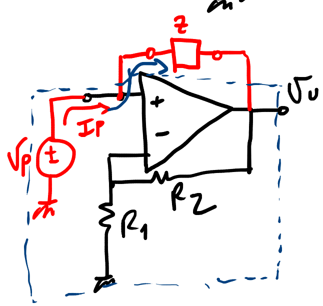
Se $\frac{R_2}{R_1} = \frac{R_4}{R_3} \Rightarrow v_U = -\frac{R_2}{R_1}(v_1 - v_2)$



$$V_U = \left[\frac{R_4}{R_3+R_4} V_1 + \frac{R_3}{R_3+R_4} V_2\right]\left(1+\frac{R_2}{R_1}\right)$$



$$V_U = -\left(\frac{R_3}{R_1} V_1 + \frac{R_3}{R_2} V_2\right)$$



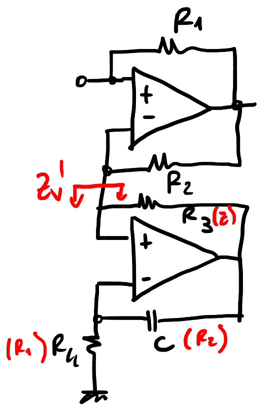
$$V^+ = V_P$$

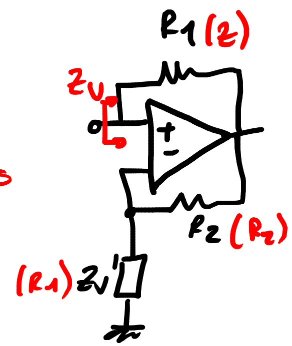
$$V^+ \simeq V^- \simeq V_P$$

$$V_U = \left(1+\frac{R_2}{R_1}\right) V_P$$

$$I_P = \frac{V_P - V_U}{Z} = \frac{V_P - \left(1+\frac{R_2}{R_1}\right) V_P}{Z}$$

$$\frac{V_P}{I_P} = Z_V = -Z\frac{R_1}{R_2}$$

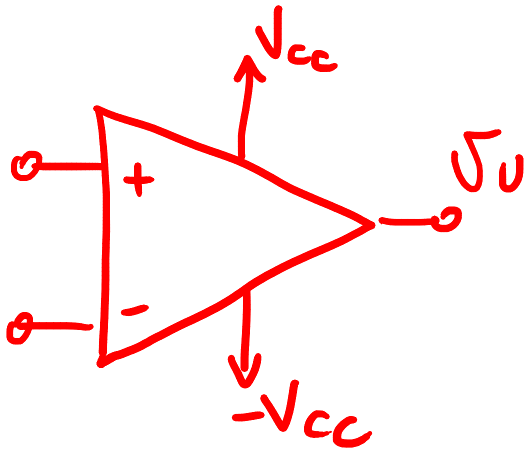


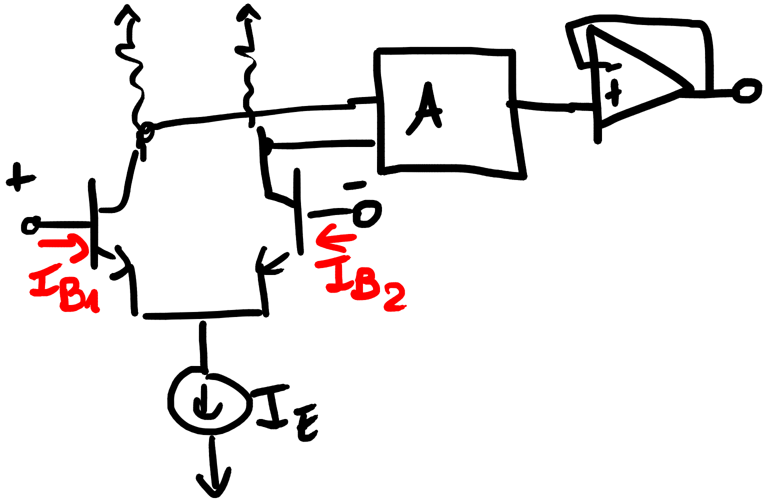


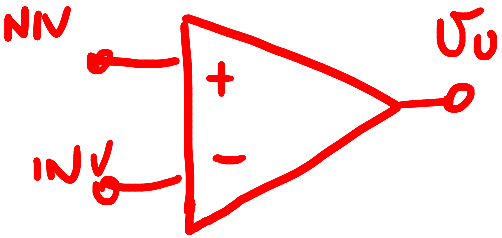
$$Z_V' = -R_3 R_4 C s$$

$$Z_V = -\frac{R_1 Z_V'}{R_2}$$

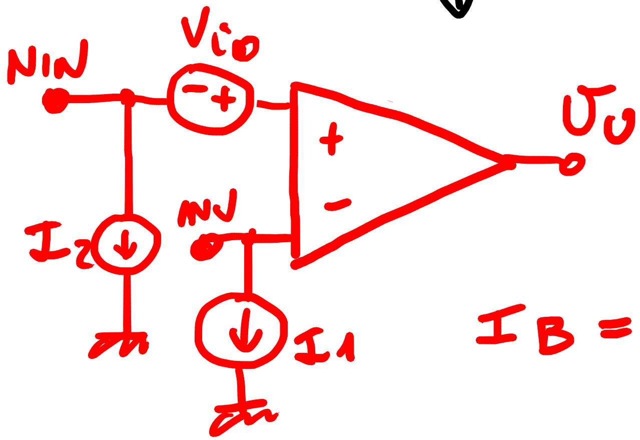
$$Z_V = \frac{R_1 R_3 R_4 C s}{R_2}$$







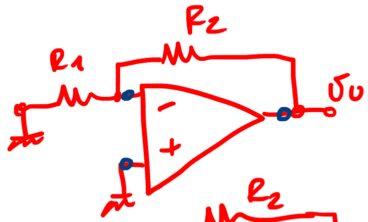
OP AMP
NON IDEALE

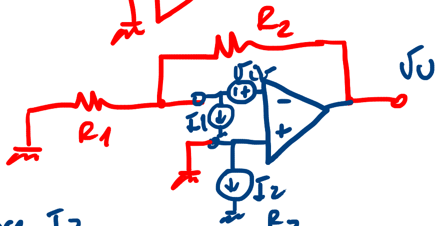


$$I_B = \frac{I_1 + I_2}{2}$$

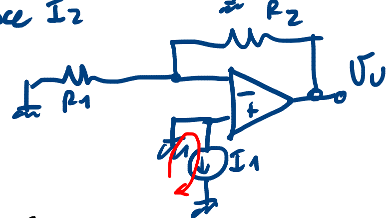
$$I_{off} = |I_1 - I_2|$$

$$I_1 = \begin{cases} I_B + \frac{I_{off}}{2} \\ I_B - \frac{I_{off}}{2} \end{cases} \wedge \; I_2 = \begin{cases} I_B - \frac{I_{off}}{2} \\ I_B + \frac{I_{off}}{2} \end{cases}$$



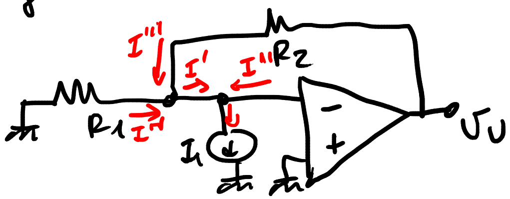


Se agisce I_2



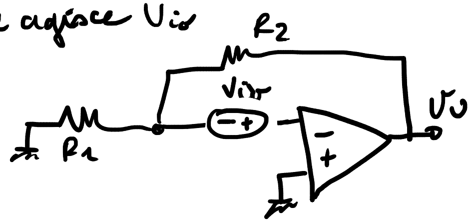
$$V_{U_{I_2}} = 0V$$

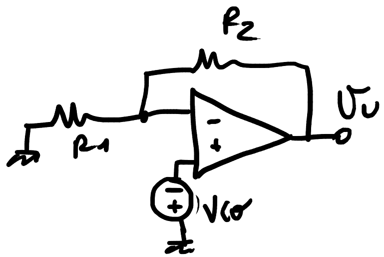
Se agisce I_1



$$V_{U_{I_1}} = R_2 I_1$$

Se agisce V_{io}

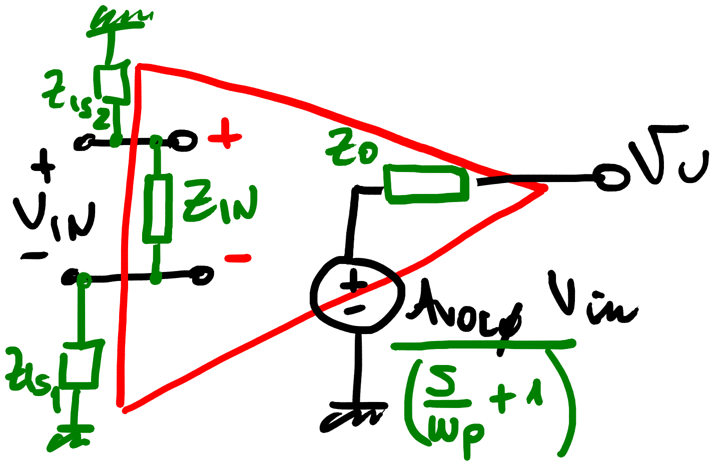




$$V_{U_{V_{io}}} = -V_{io}\left(1+\frac{R_2}{R_1}\right)$$

$$V_{U_{TOT}} = R_2 I_1 - V_{io}\left(1+\frac{R_2}{R_1}\right)$$

$$\begin{cases} V_{io} < 0 \\ I_1 = I_B + \frac{I_{off}}{2} \end{cases}$$



$$A_d = \frac{A_{VOL0}}{1+\frac{s}{\omega_p}}$$

$$CMRR = \frac{A_d}{A_c}$$

$$V_U = A_d V_d + A_c V_c = A_d \left(V_d + \frac{V_c}{CMRR} \right)$$