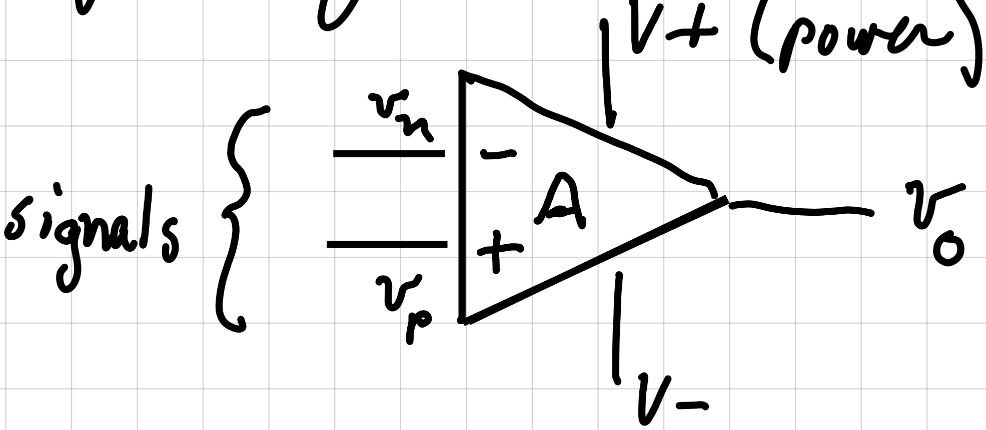
OPERATIONAL AMPLIFIERS

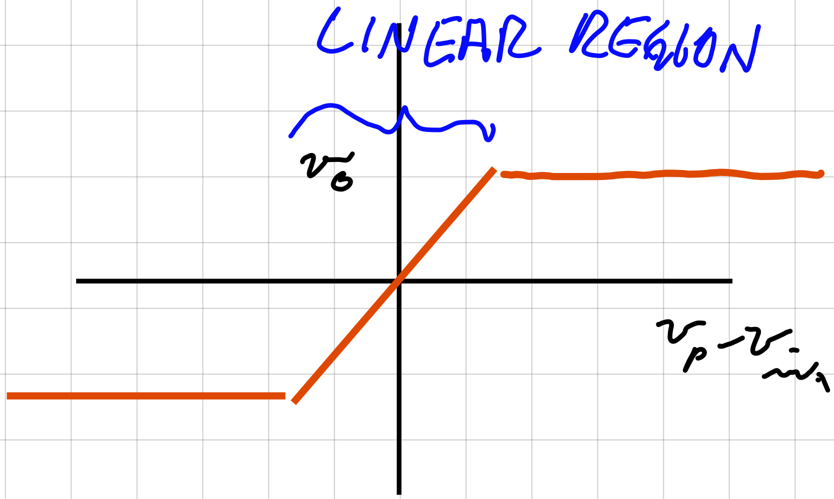
Highly useful & complex. "Black boxes."

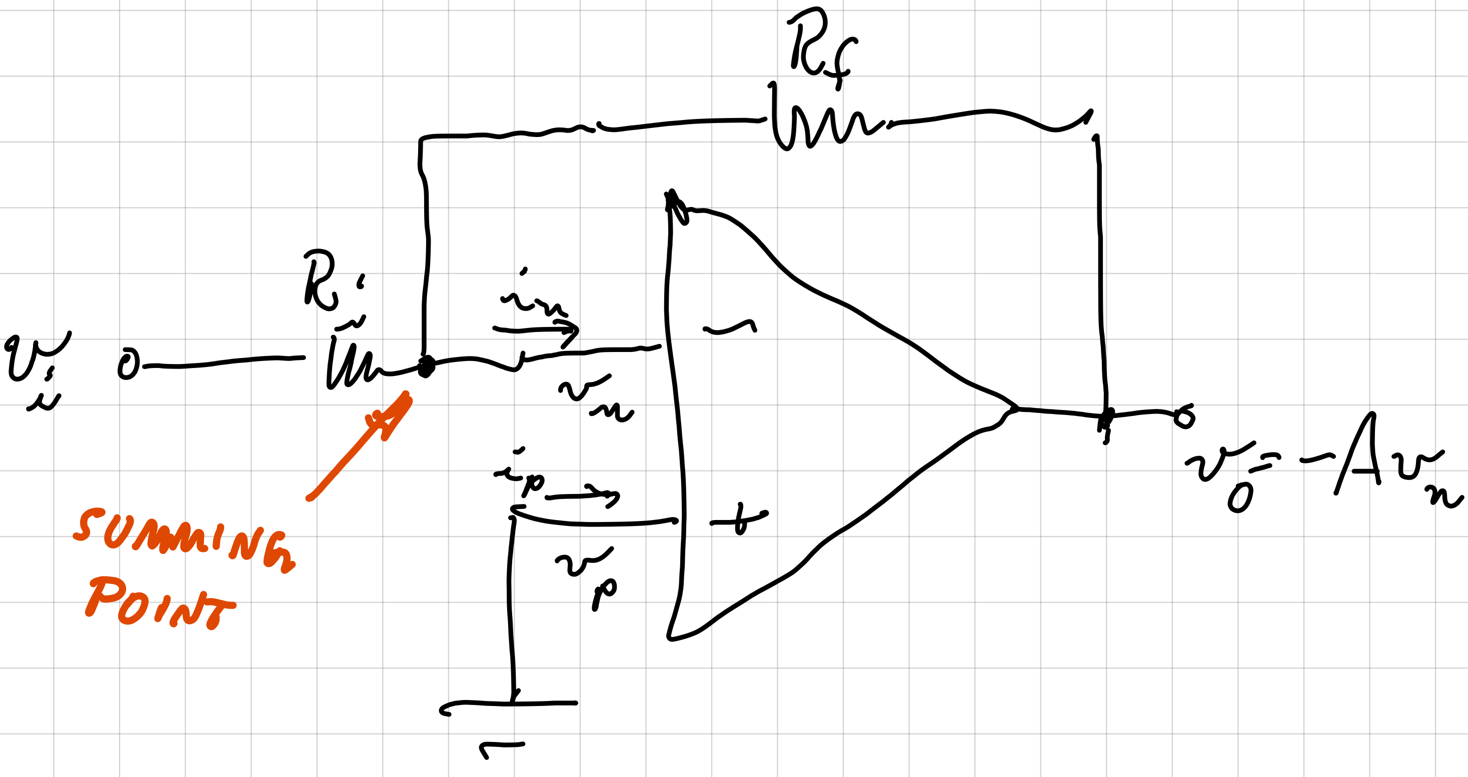


$$v_0 = A(v_p - v_n)$$

Characteristics: A is very large ($>10^5$)
(Design)
Z_{in} is very large ($\sim 1 M\Omega$)
Z_{out} is rather small

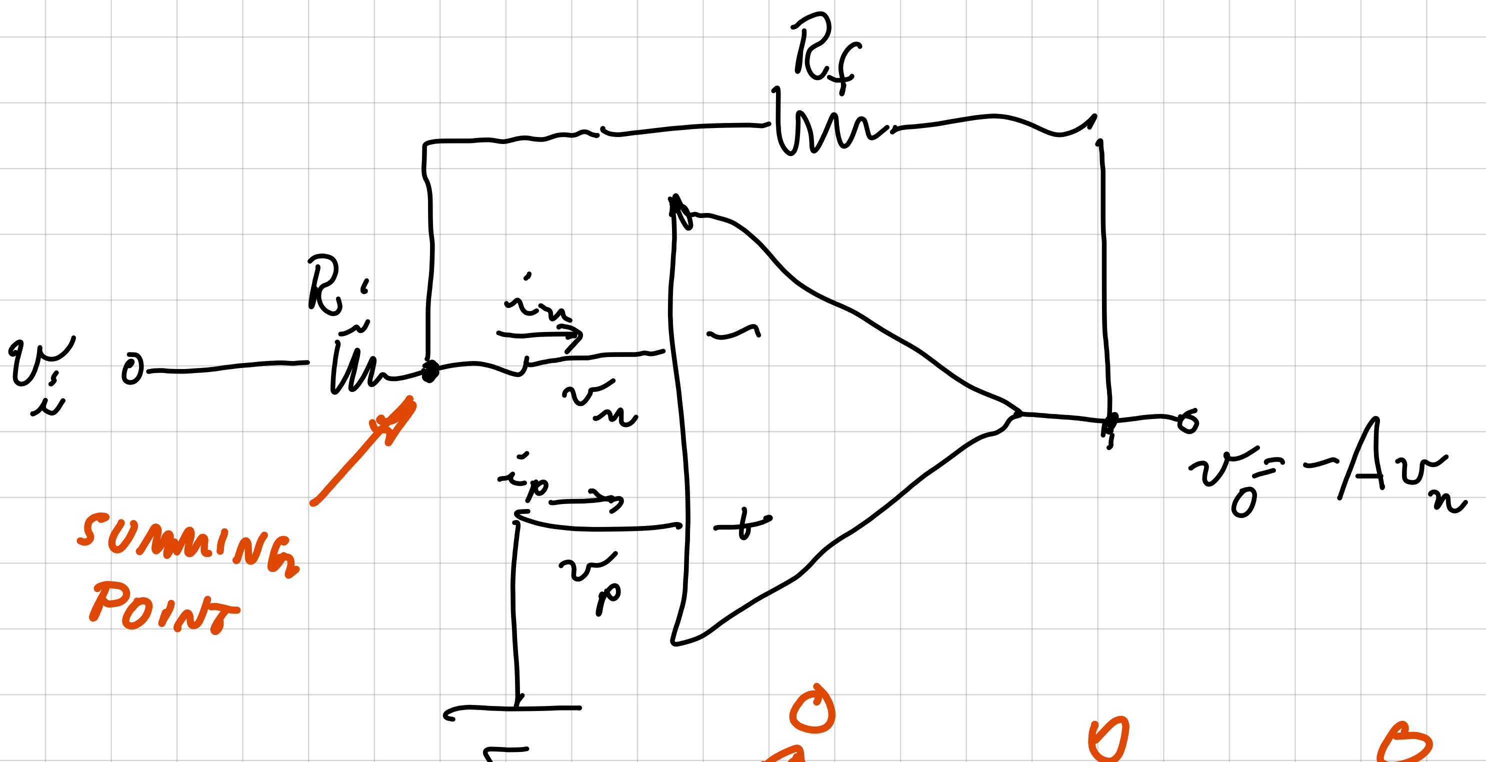
move this! "virtual short" betw v_p & v_n (with -ve feedback).





Operational Chars: "virtual short" $v_n = v_p$

(summing point constraints) → $i_n = 0 = i_p$

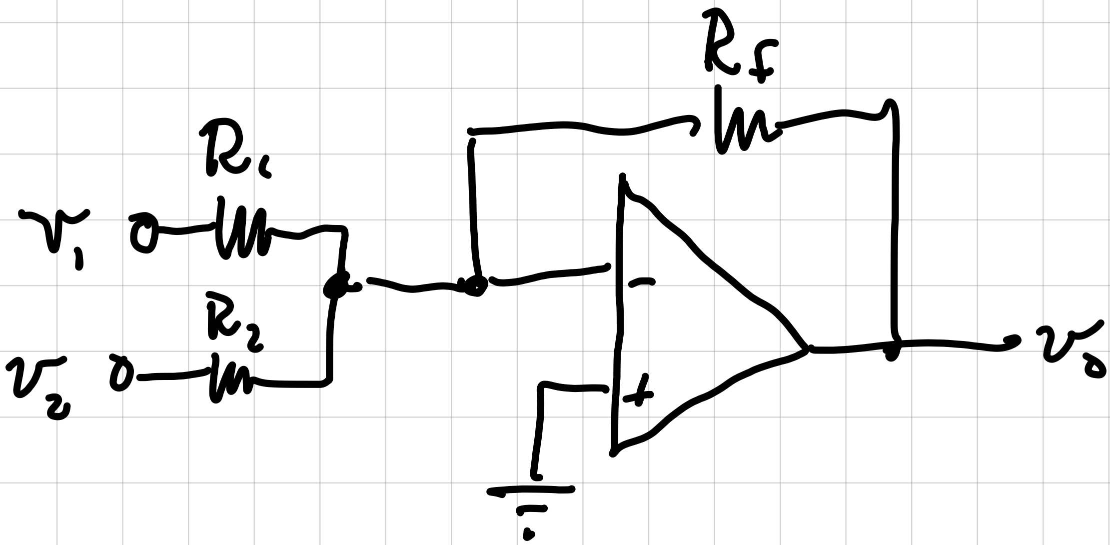


$$v_o = f(v_i, R's) = \frac{\cancelto{0}{v_n} - v_o}{R_f} + \frac{\cancelto{0}{v_n} - v_i}{R_i} + \cancelto{0}{i_n} = 0$$

$$v_o \doteq -\frac{R_f}{R_i} v_i \quad \text{[inverting op amp ckt]}$$

Load does not figure into the analysis,

cuz Zout w/ nve f.b. is very small.

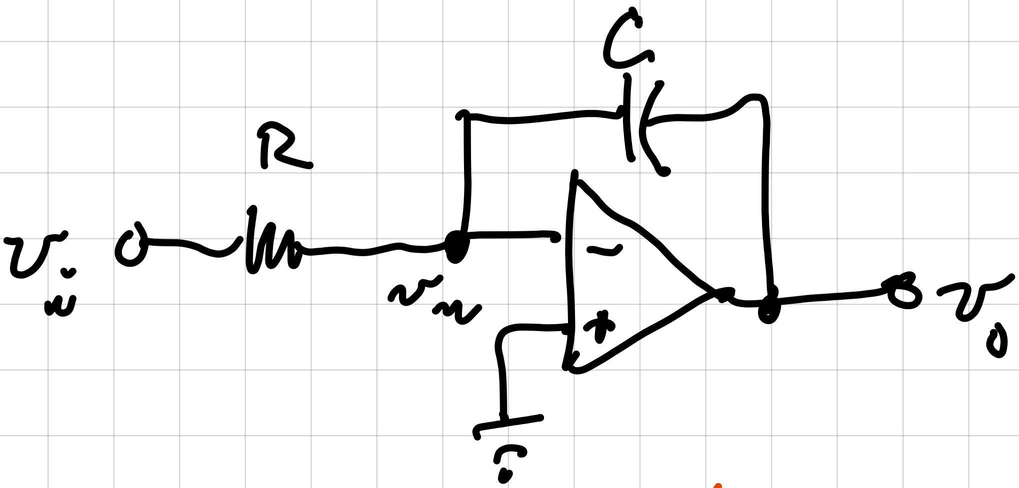


$$\frac{v_n - v_1}{R_1} + \frac{v_n - v_2}{R_2} + \frac{v_n - v_0}{R_f} = 0$$

$$\frac{v_0}{R_f} = -\left[\frac{v_1}{R_1} + \frac{v_2}{R_2}\right] \Rightarrow v_0 = -R_f\left[\frac{v_1}{R_1} + \frac{v_2}{R_2}\right]$$

if $R_1 = R_2 = R_i$

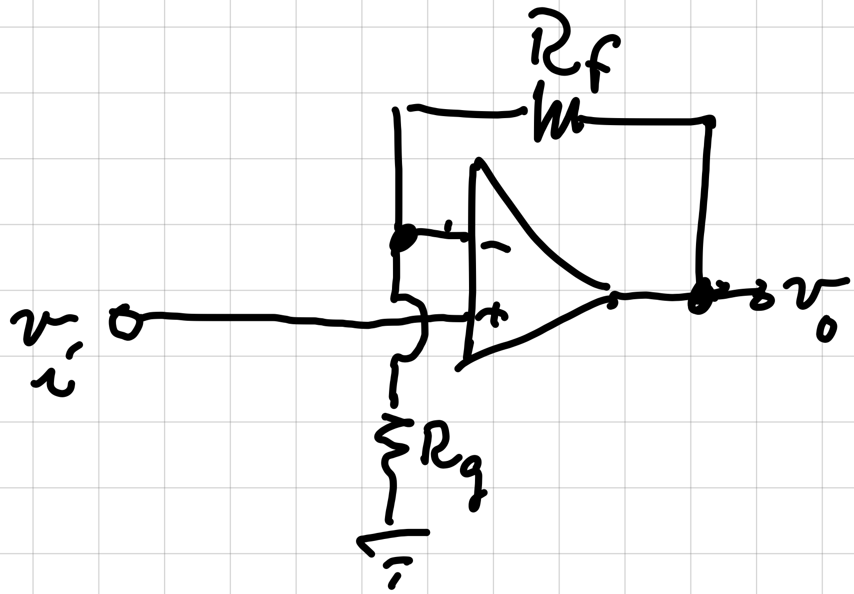
$$v_0 = -\frac{R_f}{R_i}\left(v_1 + v_2\right)$$



$$\frac{\cancelto{0}{v_n} - v_i}{R} + C\frac{d}{dt}(\cancelto{0}{v_n} - v_o) = 0$$

$$C\frac{dv_o}{dt} = -\frac{v_i}{R} \Rightarrow \frac{dv_o}{dt} = -\frac{1}{RC}v_i$$

$$v_o = -\frac{1}{RC}\int v_i\,dt$$



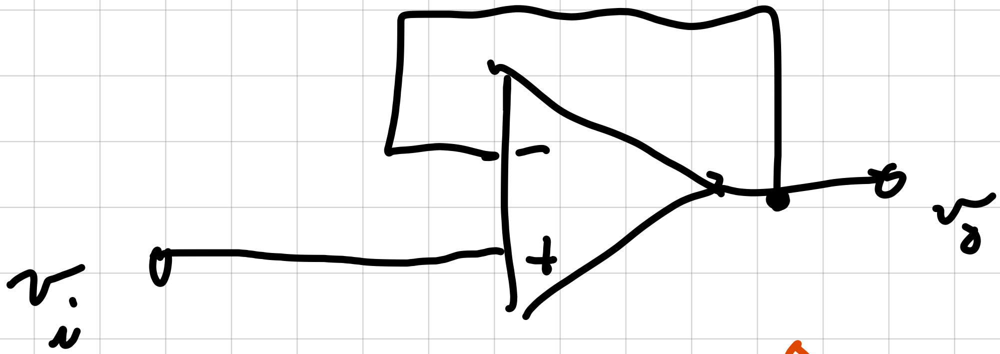
$$\frac{v_n - v_o}{R_f} + \frac{v_n}{R_g} = 0$$

$v_n = v_i$ [summing point constraint]

$$\frac{v_i - v_o}{R_f} + \frac{v_i}{R_g} = 0$$

$$\frac{v_o}{R_f} = \frac{v_i}{R_f} + \frac{v_i}{R_g} \Rightarrow v_o = v_i + \frac{R_f v_i}{R_g} = v_i\left(1 + \frac{R_f}{R_g}\right)$$

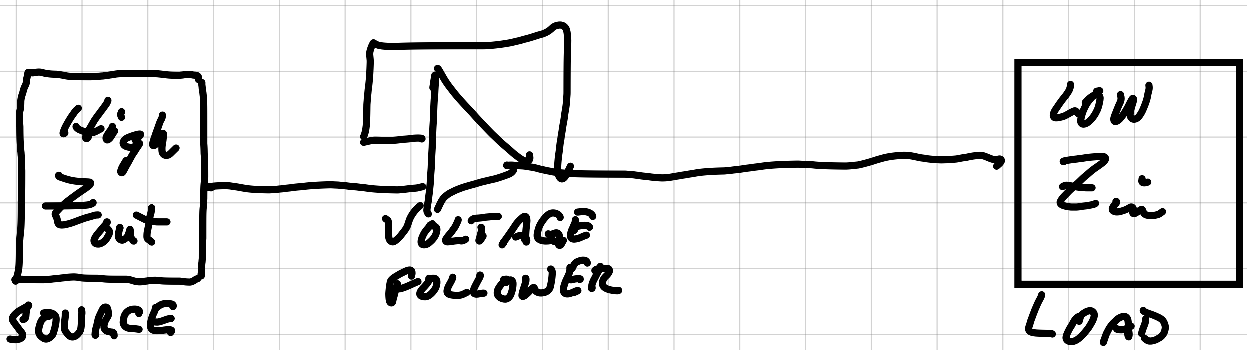
$$= v_i\left(1 + \frac{R_f}{R_g}\right)$$ [non-inverting op amp ckt]



$$v_o = ? = v_i\left(1 + \frac{\cancel{R_f}^{\,0}}{\cancel{R_g}_{\,\infty}}\right) = v_i$$

voltage follower ckt.

(Has high Z_{in} and low Z_{out})



Isolates load from source.

(without voltage follower, load would see very little voltage from source)