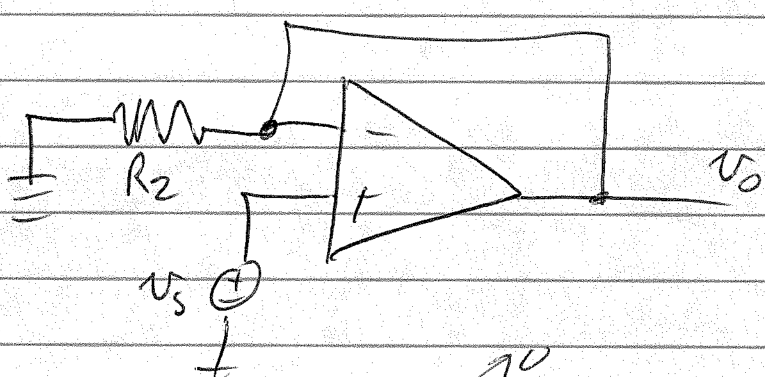
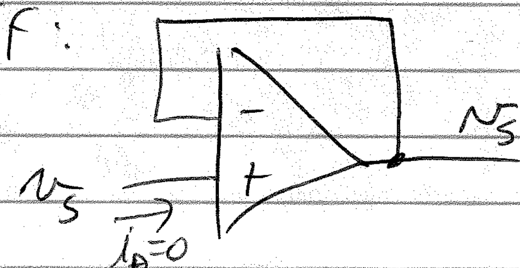
In important special case of the NonInverting Configuration is for $R_1 = 0$:



$$v_o = \left(1 + \frac{\overset{0}{R_1}}{R_2}\right) v_s = (1) v_s = v_s$$

$$v_o = v_s \quad \text{(Voltage Follower)}$$

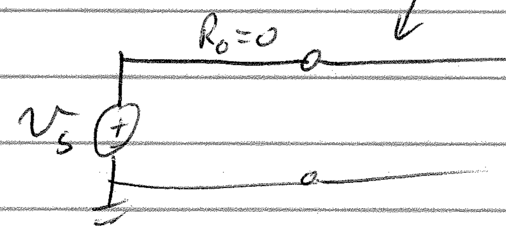
We do not need R_2 to determine gain, so leave it off:



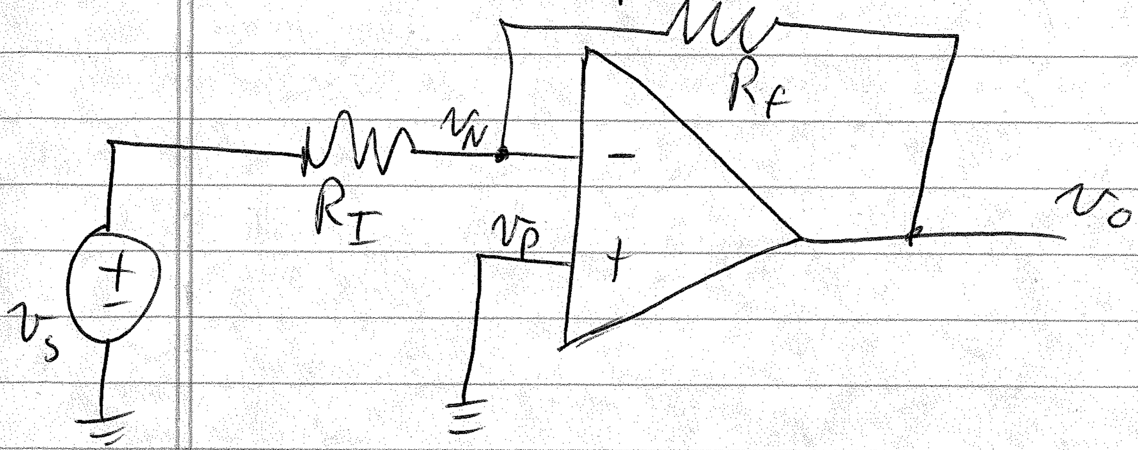
<u>Voltage Follower</u>

Takes a voltage with no current

Turns it into a voltage with (possibly) huge current.



Another example:



1.) Resistor between $v_o + v_N$, so GR 1 applies.

$$v_N = v_p$$

but $v_p = 0$, so $v_N = 0$.

2.) Apply KCL at Inverting Input:

$$\frac{v_N - v_S}{R_I} + \frac{v_N - v_o}{R_F} = 0$$

but $v_N = 0$, so $-\frac{v_S}{R_I} - \frac{v_o}{R_F} = 0$

$$\frac{v_o}{R_F} = -\frac{v_s}{R_I}$$

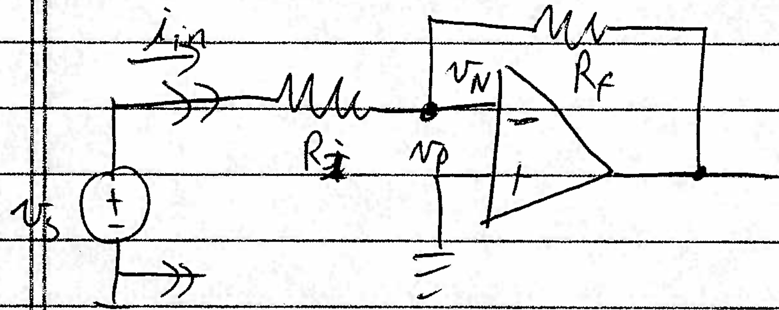
$$v_o = -\frac{R_F}{R_I} v_S = G\, v_S$$

$$G = -\frac{R_F}{R_I}$$

Inverting Amplifier

Input R?

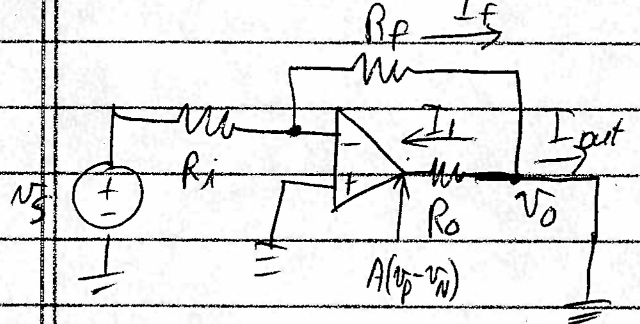
~~Output is same as before, R_s...~~



$$i_{in} = \frac{v_s - v_N}{R_i} = \frac{v_s}{R_i}$$

$$\text{So } R_{in} = \frac{v_s}{i_{in}} = \frac{v_s}{v_s/R_i} = R_i$$

Output Equiv?



~~Dependent Src will be negative, "pulling" all the current from R_f in through R_o through the VCVS, to ground. v_N will not be zero, although the OpAmp tries.~~

$$\cancel{\frac{v_N - v_s}{R_i} + \frac{v_N - 0}{R_f} = 0}$$

$$\cancel{\left(\frac{1}{R_i} + \frac{1}{R_f}\right) v_N = \frac{1}{R_i} v_s}$$

$$\cancel{v_N = \frac{R_f}{R_i + R_f} v_s}$$

$$\cancel{I_f = \frac{v_N}{R_f} = \frac{1}{R_i + R_f} v_s}$$ ~~must be taken in by dep. src~~

$$\cancel{I = \frac{A(v_p - v_N)}{R_o} - \frac{v_s}{R_i + R_f} = 0}$$

$$\cancel{\frac{A v_N}{R_o} = \frac{v_s}{R_i + R_f} \Rightarrow v_N = \frac{R_o}{(R_i + R_f) A} v_s}$$

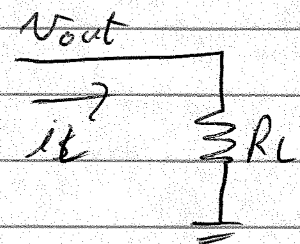
Several contradictory things: $\underline{v_N = 0 + v_{out} = 0}$

No current thru R_F.

Put on load + calculate $i_{\cancel{out}}$:

No way to calculate i_{sc}.

$$v_{out} = G v_s$$

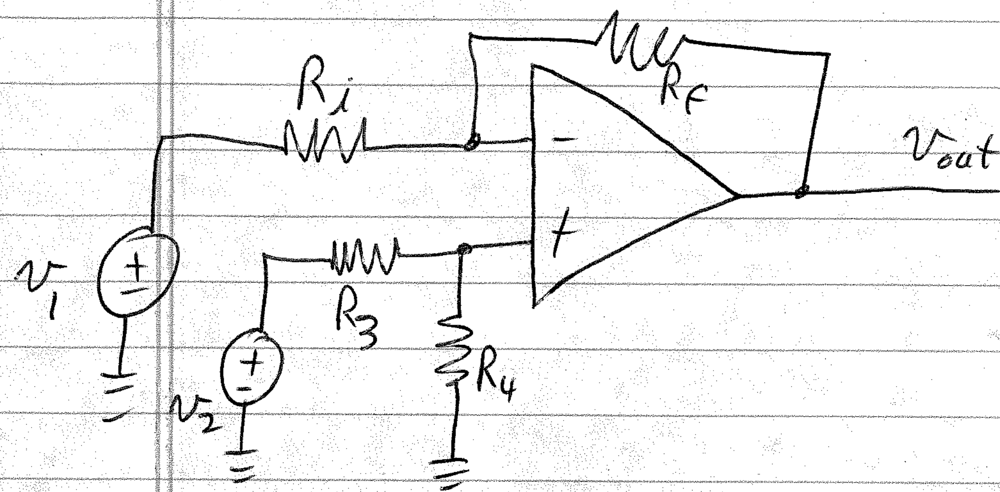


$$i_L = \frac{v_{out}}{R_L}$$

Find i_{sc}: $\lim_{R_L \to 0} i_L = \infty = i_{sc}$

$$\underline{R_T = \frac{v_{oc}}{i_{sc}} = \frac{G v_s}{\infty} = 0}$$

Let's analyze the most general case we can:



Could use ~~nodal analysis~~ my general technique:

1.) Resistive Negative Feedback? ✓ Yes

$$v_N = v_P$$

v_P by Voltage Division: $v_P = \frac{R_4}{R_3+R_4} v_2 = v_N$

2.) KCL @ inverting input:

$$\frac{v_N - v_1}{R_i} + \frac{v_N - v_{out}}{R_F} = 0$$

$$\left(\frac{1}{R_i} + \frac{1}{R_F}\right) v_N - \frac{1}{R_i} v_1 - \frac{1}{R_F} v_{out} = 0$$

$$v_{out} = \cancel{R_F}\left(\frac{R_F+R_i}{R_i \cancel{R_F}}\right) v_N - \frac{R_F}{R_i} v_1$$

$$v_{out} = \left(\frac{R_F+R_i}{R_i}\right)\left(\frac{R_4}{R_3+R_4}\right) v_2 - \frac{R_F}{R_i} v_1$$

(Differential Amp)

Special Case: Let $R_3 = R_i$; $R_4 = R_f$,

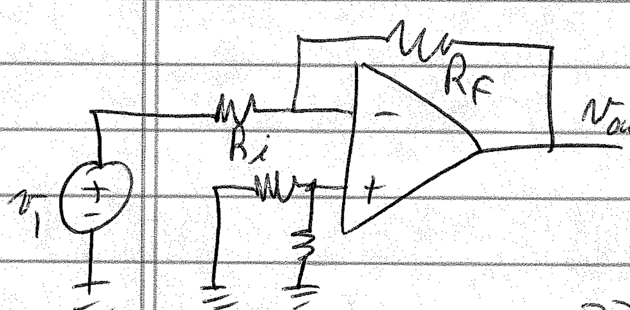
then $v_{out} = \left(\frac{\cancel{R_f + R_i}}{R_i}\right)\left(\frac{R_f}{\cancel{R_f + R_i}}\right) v_2 - \frac{R_f}{R_i} v_1$

$$v_{out} = \frac{R_f}{R_i}(v_2 - v_1)$$ (called a True Differential Configuration.)

Go back to original ckt + think "2 Indep. Srcs."

<u>Superposition</u> %

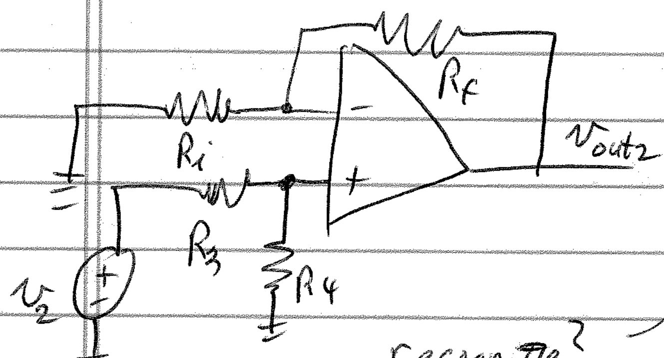
Turn off 2:



recognize??

$v_{out\,1} = -\frac{R_f}{R_i} v_1$

Turn off 1:



recognize?

$v_{out2} = \left(1 + \frac{R_f}{R_i}\right) v_p$

Voltage Div. $v_p = \frac{R_4}{R_3 + R_4} v_2$

so $v_{out2} = \left(1 + \frac{R_f}{R_i}\right)\left(\frac{R_4}{R_3 + R_4}\right) v_2$

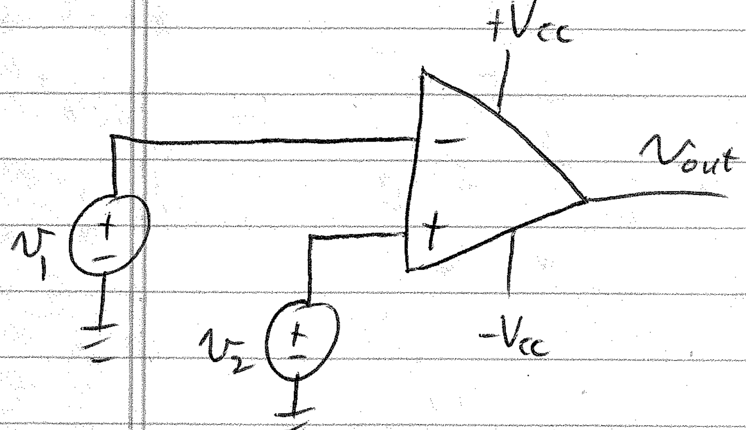
Both on: $v_{out} = v_{out\,2} + v_{out\,1}$

$$v_{out} = \left(1 + \frac{R_f}{R_i}\right)\left(\frac{R_4}{R_3+R_4}\right)v_2 - \frac{R_f}{R_i}v_1$$

$$= \left(\frac{R_f+R_i}{R_i}\right) \quad \text{"} \quad \text{"} \quad \text{"} \quad \text{"}$$

Same as before.

Sometimes we do not use the linear region, but want to go straight to saturation:



$v_{out} = A(v_2 - v_1)$

$\lim_{A\to\infty}$ but output limited to $\pm V_{cc}$

$v_{out} = V_{cc}\,\mathrm{sgn}(v_2 - v_1)$ ← "Signum" or "sign" function "sign of $(v_2 - v_1)$"

or $v_{out} = V_{cc}\dfrac{(v_2 - v_1)}{|v_2 - v_1|}$ ← absolute value

$$v_{out} = \begin{cases} +V_{cc} & \text{if } v_2 > v_1 \\ -V_{cc} & \text{if } v_2 < v_1 \\ 0 & \text{if } v_2 = v_1 \end{cases}$$

Called a Comparator that compares v_2 & v_1