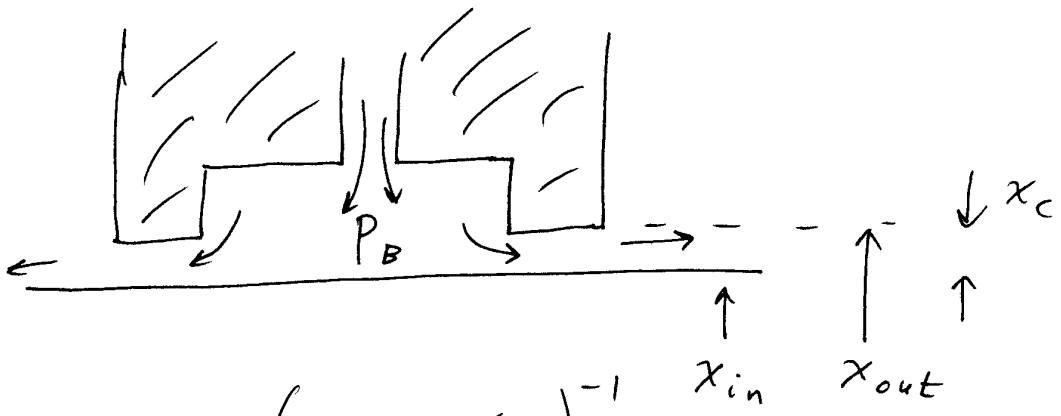
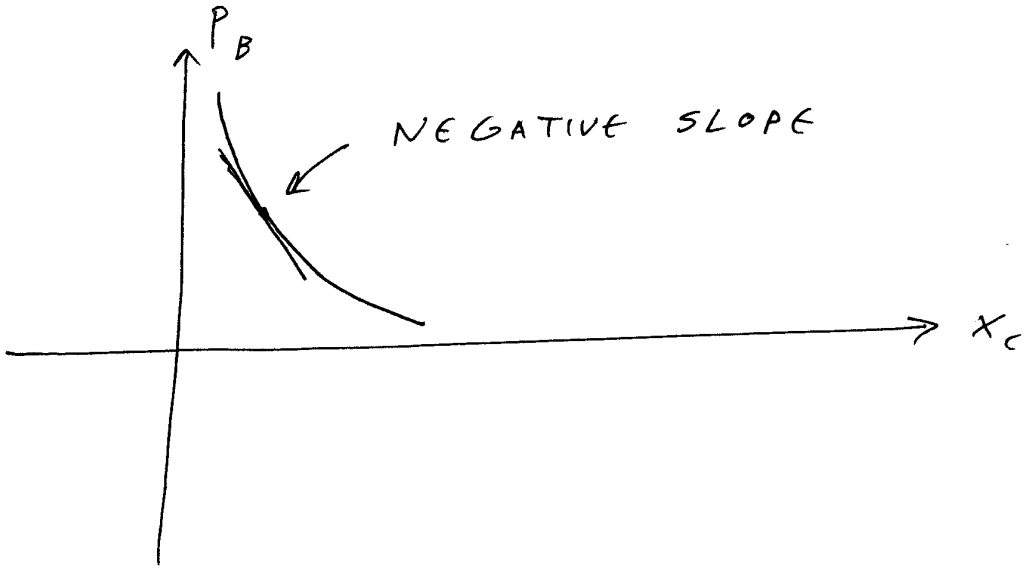
HYDROSTATIC BEARING WITH SPRING PRE LOAD



$$P_B = \alpha \left(x_{out} - x_{in} \right)^{-1}$$

$$P_B = \alpha \, x_c^{-1}$$

$$\frac{d P_B}{d x_c} = - \alpha \, x_c^{-2}$$



PRE LOAD

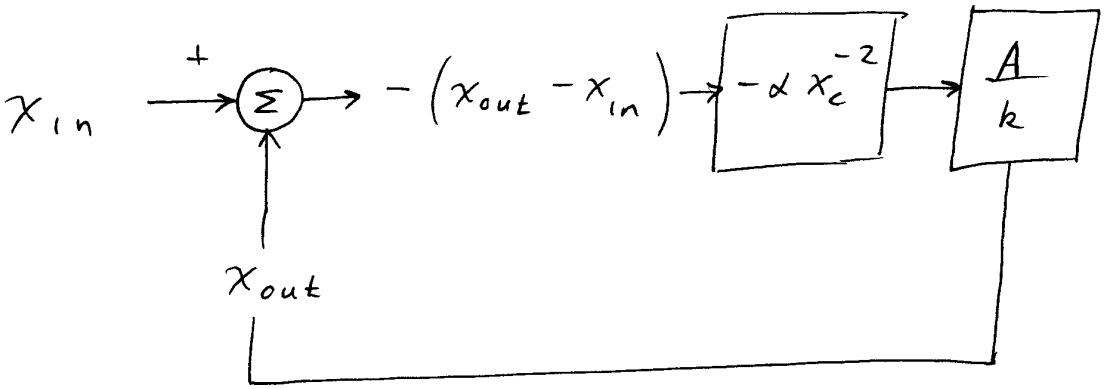
$$F = F_0 + k\, x_{out}$$

$$x_c = \frac{1}{k}\left(F - F_0\right)$$

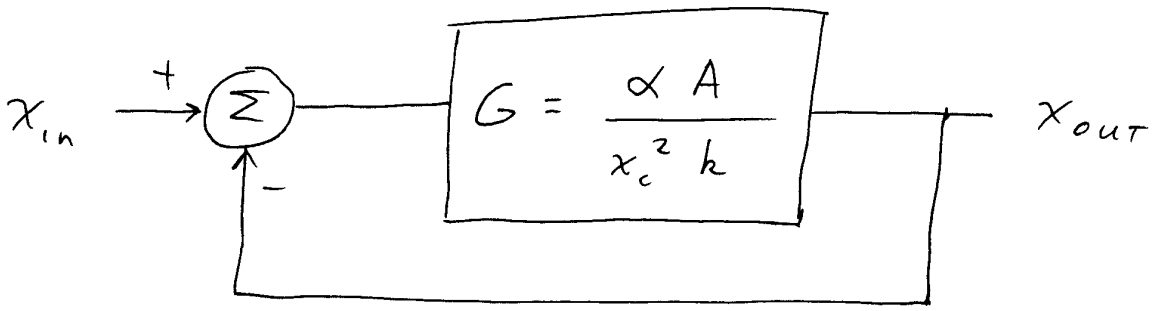
← LARGE FOR SOFT SPRING

NEGATIVE FEEDBACK LOOP

A: BEARING AREA



SIMPLIFIED FEEDBACK LOOP



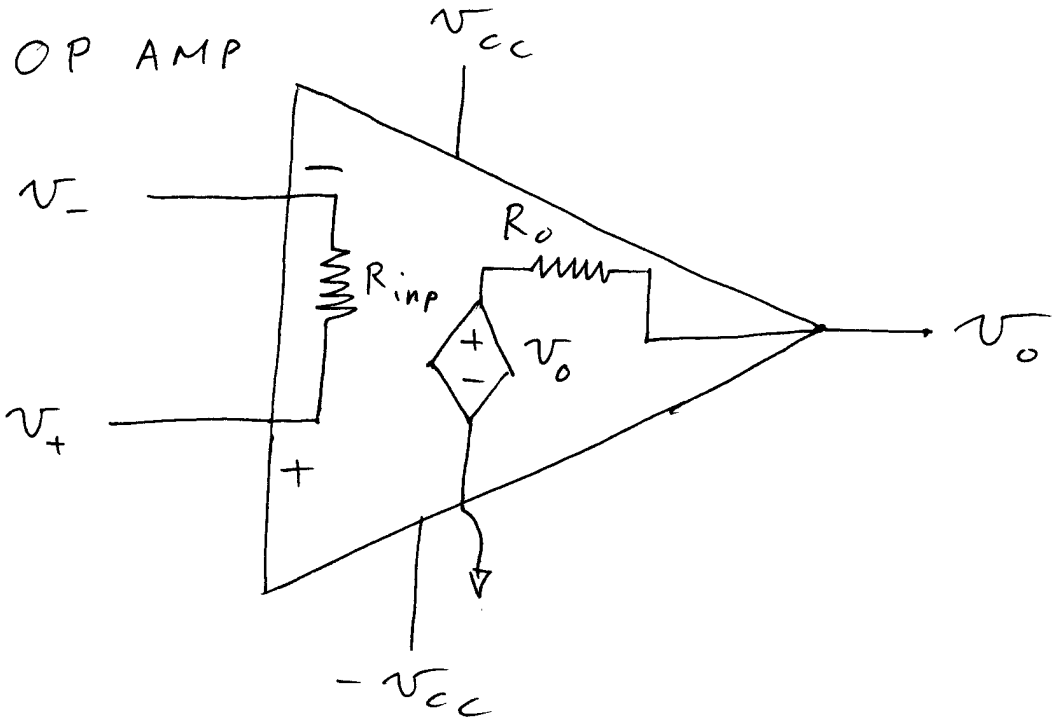
$$x_{out} = G\left(x_{in} - x_{out}\right)$$

G LARGE, VARIABLE

$$x_{out} = \frac{G}{1+G} x_{in} \simeq x_{in}$$

FOR BIG G

OP AMP



IDEAL OP AMP

$$v_o = G(v_+ - v_-) \qquad G \to \infty$$

$$R_i \to \infty \qquad R_o \to 0$$

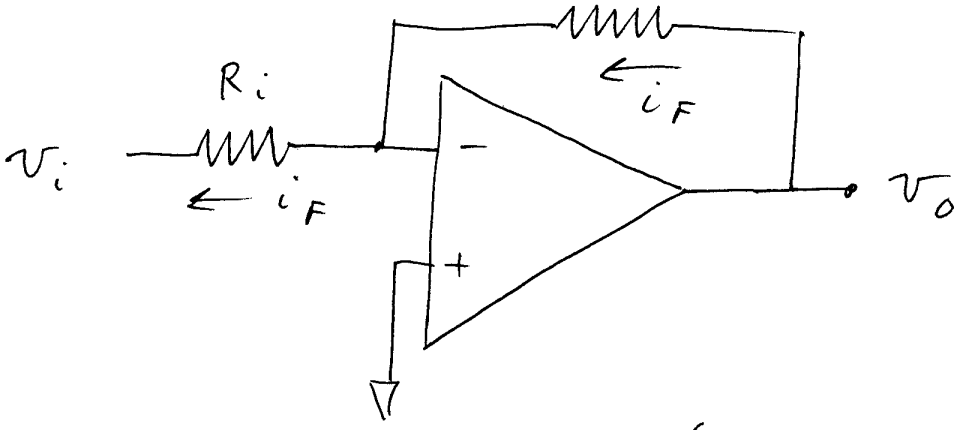
SATURATION

$$-v_{cc} < v_o < v_{cc}$$

v_{cc} TYPICALLY 10 - 15 VOLTS

OUR FIRST OP-AMP CIRCUIT

INVERTING AMP R_F



ASSUME $R_{inp} \to \infty$ (NO CURRENT IN OR OUT OF − OR + INPUTS)

$$v_+ = 0 \qquad i_F = \frac{v_o - v_i}{R_i + R_F}$$

$$v_- = v_i + i_F R_i$$

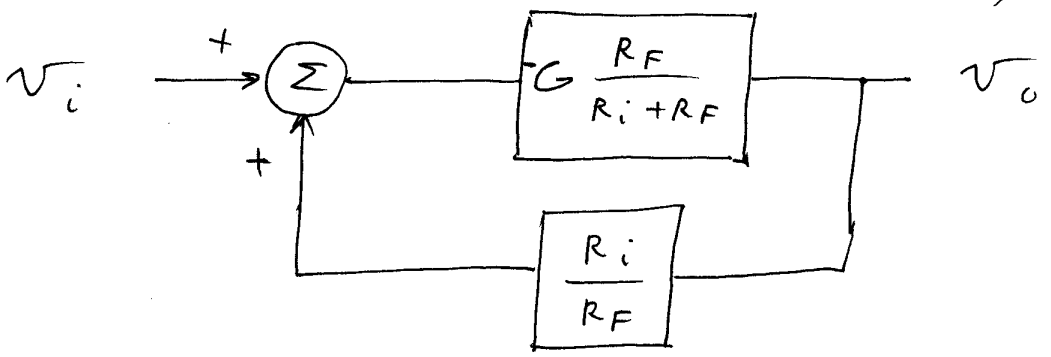
$$= v_i + \left(\frac{R_i}{R_i + R_F}\right)(v_o - v_i)$$

$$v_o = G(v_+ - v_-)$$

$$= G\left(-v_i + \left(\frac{R_i}{R_i + R_F}\right)(v_o - v_i)\right)$$

$$v_o = -G\left(\frac{R_i}{R_i+R_F}\,v_o + \frac{R_F}{R_i+R_F}\,v_i\right)$$

$$= -G\,\frac{R_F}{R_i+R_F}\left(\frac{R_i}{R_F}\,v_o + v_i\right)$$



$$v_o = -G'\left(v_i + \frac{1}{\beta}\,v_o\right)$$

$$G' = G\,\frac{R_F}{R_i+R_F} \qquad \beta = \frac{R_F}{R_i}$$

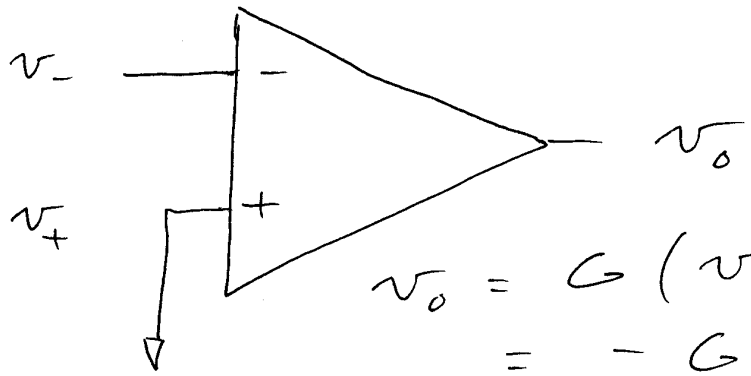
$$v_o = \frac{-G'}{1+\frac{G'}{\beta}}\,v_i$$

$$= \frac{1}{\frac{1}{G'}+\frac{1}{\beta}}\,v_i = \frac{-1}{\frac{1}{\beta}}\,v_i$$

$$= -\beta\,v_i$$

As $G' \to \infty$ $\quad \frac{1}{G'} \to 0$

VIRTUAL REFERENCE VOLTAGE

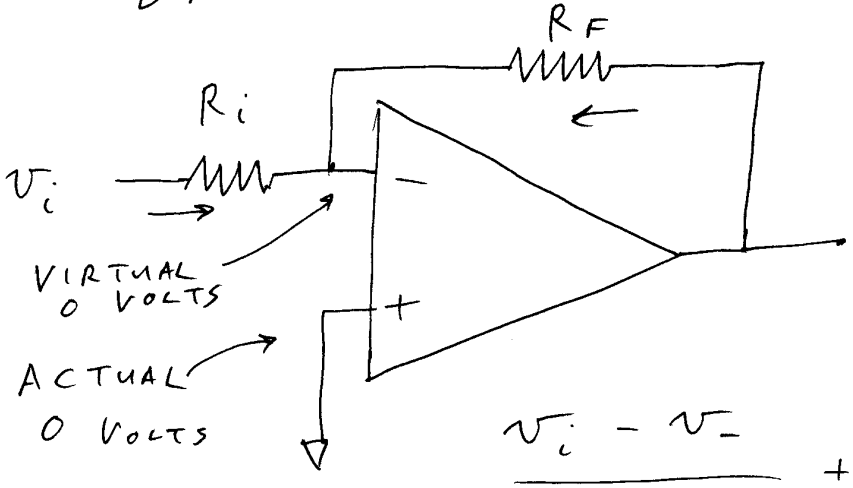


$$v_o = G(v_+ - v_-)$$

$$= -Gv_-$$

$$v_- = -\frac{1}{G} v_o \simeq 0 !$$

BACKWARDS NODE EQ

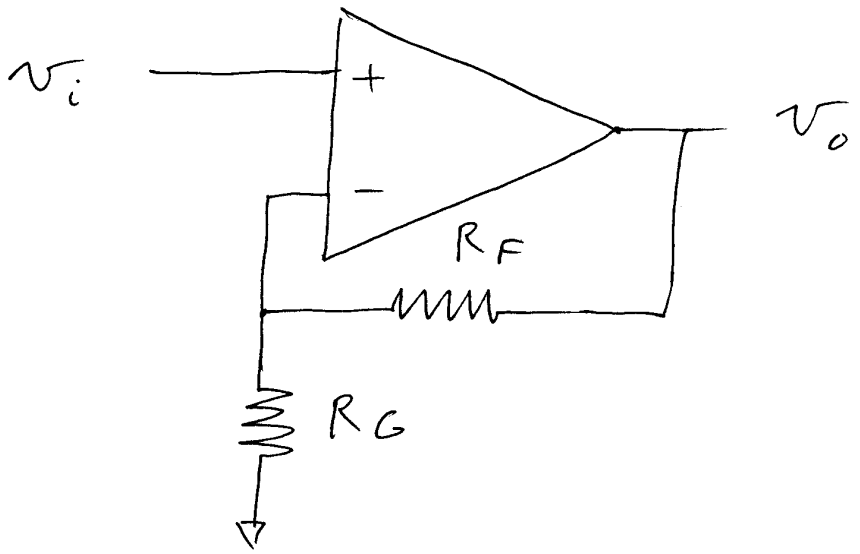


$$\frac{v_i - v_-}{R_i} + \frac{v_o - v_-}{R_F} = 0$$

$$v_- = v_+ = 0$$

$$v_o = -\frac{R_F}{R_i} v_i$$

NON-INVERTING OP AMP



VOLTAGE DIVIDER

$$V_- = \frac{R_G}{R_G + R_F} V_o$$

VIRTUAL REFERENCE VOLTAGE

$$V_- = V_+ = V_i$$

$$V_i = \frac{R_G}{R_G + R_F} V_o$$

$$V_o = \frac{R_G + R_F}{R_G} V_i = \left(1 + \frac{R_F}{R_G}\right) V_i$$