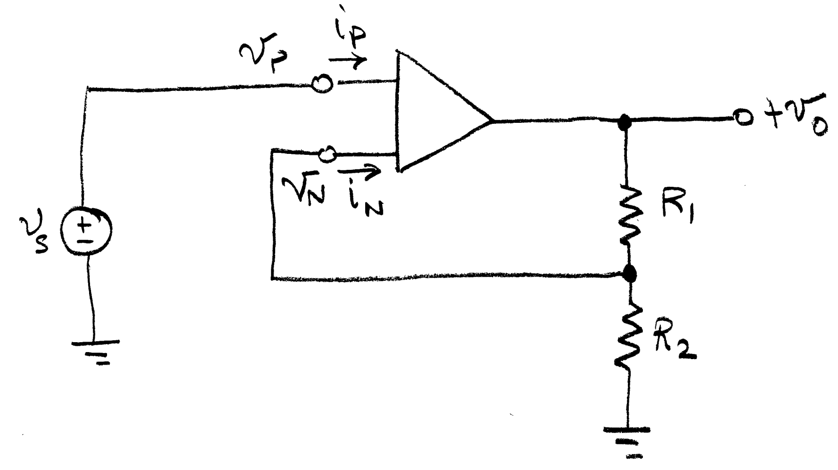
Non-inverting OP-AMP (assume ideal OP AMP)



Since $i_P = i_N = 0$ we can find v_N by voltage division

$$v_N = \frac{R_2}{R_1+R_2} v_o$$

Since the OP AMP is ideal ($A \to \infty$) $v_P = v_N$

By inspection $v_P = v_S$

$$\therefore \; v_S = \frac{R_2}{R_1+R_2} v_o$$

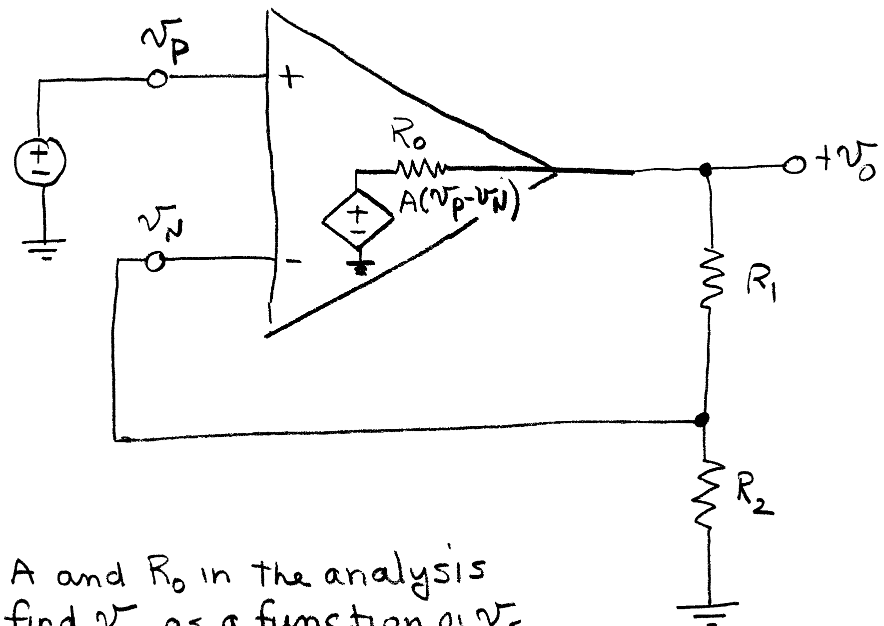
or

$$v_o = \underbrace{\frac{R_1+R_2}{R_2}}_{\text{constant of proportionality } K} v_S$$

constant of proportionality K – sometimes called the closed-loop gain

Since v_o is of the same sign as v_s this is called a non-inverting amplifier.

Effects of finite OP AMP gain.



Keep A and R_o in the analysis and find v_o as a function of v_s

v_o is given by the voltage divider as

$$v_o = \frac{R_1 + R_2}{R_o + R_1 + R_2} A(v_P - v_N)$$

but $v_P = v_S$

and also using a voltage divider

$$v_N = \frac{R_2}{R_1 + R_2} v_o$$

Substituting

$$v_o = \frac{R_1 + R_2}{R_o + R_1 + R_2} A \left[v_s - \frac{R_2}{R_1 + R_2} v_o \right]$$

$$v_o + \frac{R_2 A}{R_o + R_1 + R_2} v_o = \frac{R_1 + R_2}{R_o + R_1 + R_2} A v_s$$

$$v_o \left[R_o + R_1 + R_2 + R_2 A \right] = (R_1 + R_2) A v_s$$

$$v_o = \frac{A(R_1 + R_2)}{R_o + R_1 + R_2(1 + A)} v_s$$

As $A \to \infty$ this reduces to

$$v_o = \frac{R_1 + R_2}{R_2} v_s = K v_s$$

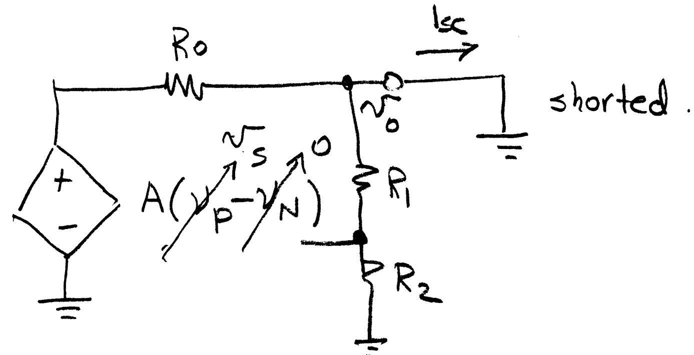
To see the effects of A ignore R_o since $R_o \ll R_1 + R_2$

$$v_o \cong \frac{A(R_1+R_2)}{R_1+R_2(1+A)} v_s = \frac{R_1+R_2}{\frac{R_1+R_2}{A} + R_2} v_s = \frac{\frac{R_1+R_2}{R_2}}{\frac{R_1+R_2}{R_2 A}+1} v_s$$

$$v_o = \frac{K}{\frac{K}{A}+1} v_s$$

Clearly as the open loop gain $A \to \infty$ the closed loop gain reduces to K, the closed loop gain. This is the effect of feedback.

Another effect of feedback occurs at the output. Short circuit the output to zero. This forces v_o and v_N to zero, but $v_p = v_s$.



By inspection

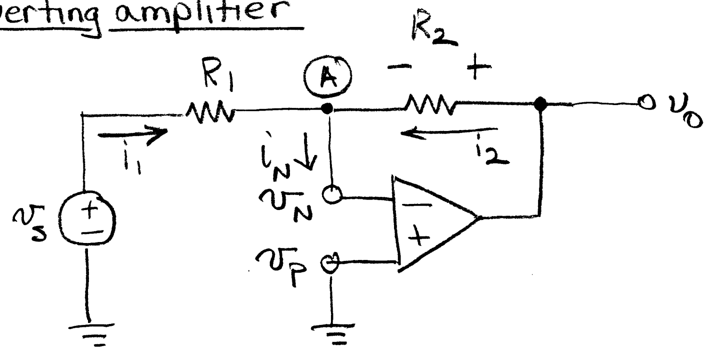
$$i_{sc} = \frac{A v_s}{R_o}$$

The Thevenin output resistance is given by

$$R_T = \frac{v_{oc}}{i_{sc}} = \frac{\frac{K}{1+K/A} v_s}{\frac{A\, v_s}{R_o}} = \frac{K/A}{1+K/A} R_o$$

As $A \to \infty$ $R_T \to 0\,\Omega$

The inverting amplifier



This is probably the most common OP AMP circuit.

For an ideal OP AMP $i_N = 0$ and $v_N = v_P = 0$

Applying KCL at node A.

$$\sum_{+in} i = 0 \qquad + \frac{v_S - v_A}{R_1} + \frac{v_o - v_A}{R_2} = 0$$

but $v_A = v_N = 0$.

$$\frac{v_S}{R_1} + \frac{v_o}{R_2} = 0$$

$$v_o = -\frac{R_2}{R_1} v_S$$

For this ideal OP AMP

$$R_{in} = \frac{v_S}{i_1} = \frac{v_S}{\frac{v_S - 0}{R_1}} = R_1$$