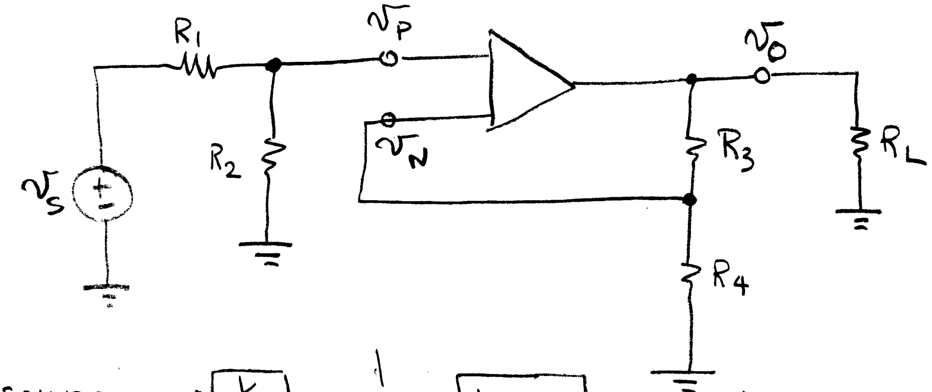
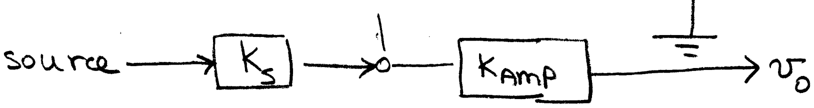
4-5 OP AMP circuit analysis

Example 4-13 Find the input-output relationship for the circuit below.





Break circuit into two parts: (1) K_S, the proportionality constant of the source circuit

(2) K_{AMP}, the gain of the non-inverting amplifier

Since the output resistance of the non inverting amplifier is zero, the load R_L has no effect on v_o.

We know the closed loop gain of the amplifier to be

$$K_{Amp} = \frac{v_o}{v_p} = \frac{R_3 + R_4}{R_4}$$

The input current i_p to the amplifier is zero, so

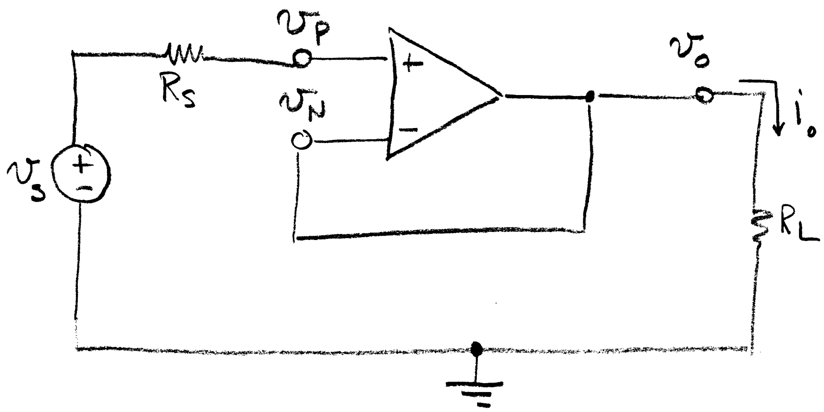
$$v_p = \frac{R_2}{R_1 + R_2} v_s$$ by voltage divider.

The overall circuit gain is given as

$$K_{CIRCUIT} = K_S K_{AMP}$$

$$K_{CIRCUIT} = \left[\frac{R_2}{R_1 + R_2}\right]\left[\frac{R_3 + R_4}{R_4}\right]$$

Voltage Follower



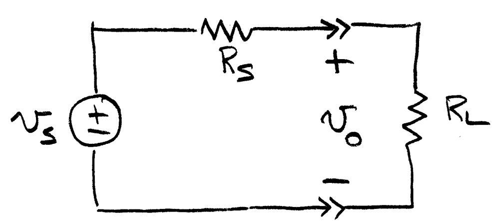
Consider the above circuit where there is a direct connection from the output back to the input.

By inspection $v_P = v_N$, $v_o = v_N$. and $v_P = v_s$

Substituting $v_o = v_s$

Since the output exactly follows the input this circuit is called a voltage follower.

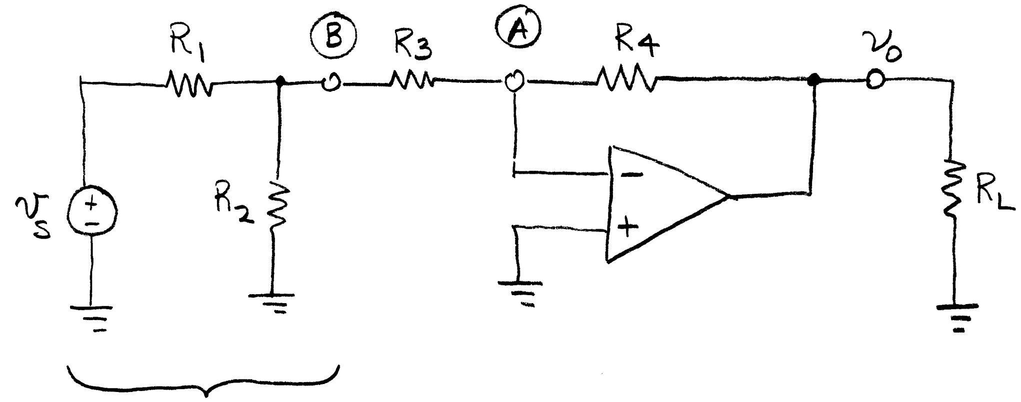
This circuit is also called a buffer because it isolates the source and load circuits. Without this circuit you would have

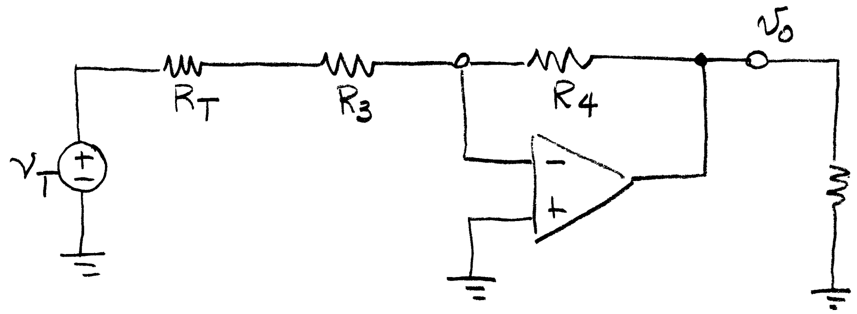


There would be a voltage divider relationship between the input and output circuits.

$$v_o = \frac{R_L}{R_L + R_S} v_s$$

Example 4-34 Find the input-output relationship for this circuit.





where $v_T = \dfrac{R_2}{R_1+R_2} v_s$

$$R_T = \frac{R_1 R_2}{R_1+R_2}$$

The reduced circuit is precisely that of an inverting amplifier where

$$v_o = -K_1 v_T = -\frac{R_4}{R_T+R_3} v_T = -\frac{R_4}{\frac{R_1R_2}{R_1+R_2}+R_3} v_T$$

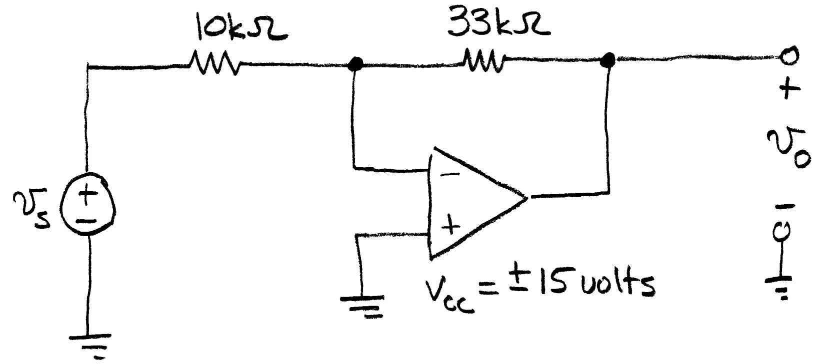
$$v_o = -\frac{R_4(R_1+R_2)}{R_1R_2+R_1R_3+R_2R_3} v_T$$

In terms of the original v_s

$$v_o = -\frac{R_4(R_1+R_2)}{R_1R_2+R_1R_3+R_2R_3} \frac{R_2}{R_1+R_2} v_s = -\underbrace{\frac{R_2R_4}{R_1R_2+R_1R_3+R_2R_3}}_{K_{CIRCUIT}} v_s$$

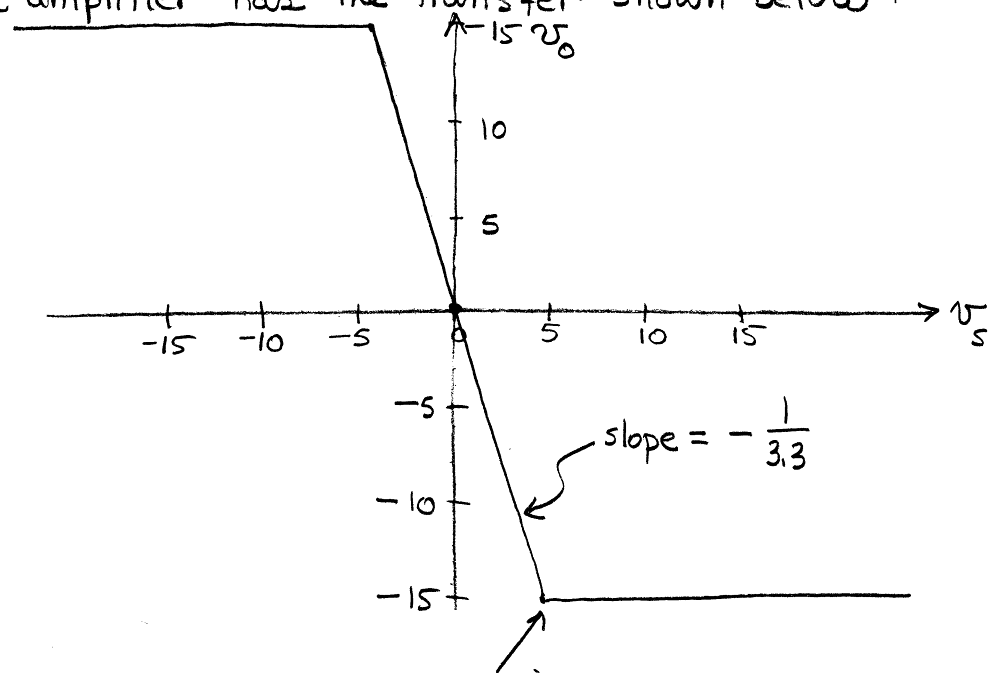
Exercise 4-11

Sketch the transfer characteristic of the OP AMP circuit shown below for $-10 < v_s < 10$ volts.



This is an inverting amplifier where $K = -\frac{33k}{10k} = -3.3$

The amplifier has the transfer shown below.

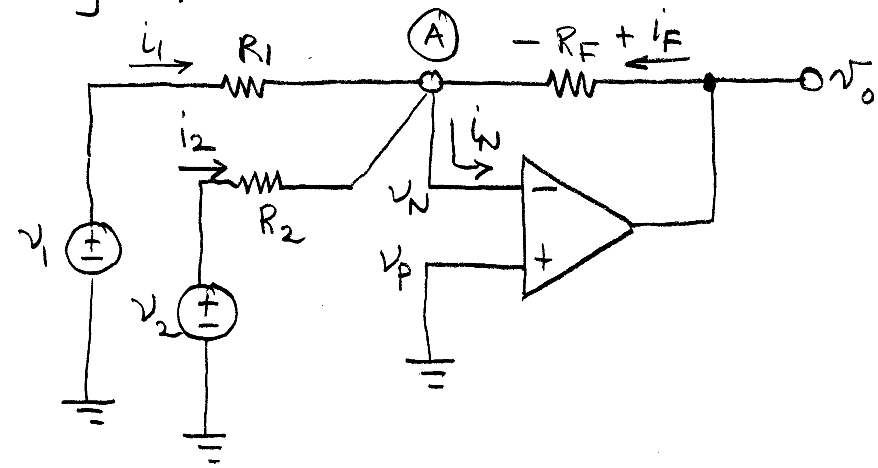


amplifier output saturates at ±15 volts corresponding to inputs given by.

$$\pm 15 = K v_s = -3.3 \; v_s$$

$$v_s = \mp 4.54 \text{ volts.}$$

The summing amplifier



By inspection $i_N = 0$ and $v_A = v_N = v_P = 0$

Using KCL @ node A.

$\sum_{+in} i = 0 \qquad +i_1 + i_2 - i_N + i_F = 0$

$$\frac{v_1 - 0}{R_1} + \frac{v_2 - 0}{R_2} - 0 + \frac{v_o - 0}{R_F} = 0$$

$$\frac{v_1}{R_1} + \frac{v_2}{R_2} + \frac{v_o}{R_F} = 0$$

$$v_o = -\frac{R_F}{R_1} v_1 - \frac{R_F}{R_2} v_2$$

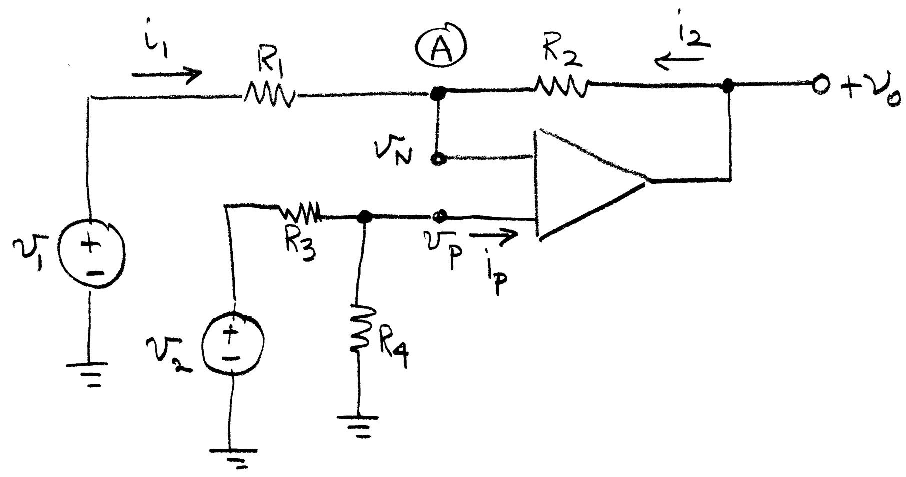
$$v_o = K_1 v_1 + K_2 v_2$$

In the case that $R_1 = R_2 = R$ this reduces

$$v_o = -\frac{R_F}{R}(v_1 + v_2)$$

This is called a summation amplifier.

The differential amplifier or subtractor



Since $i_p = 0$ $\quad v_p = \frac{R_4}{R_3+R_4} v_2$ which is the voltage at (A)

$$i_1 = \frac{v_1 - v_p}{R_1} \qquad i_2 = \frac{v_o - v_p}{R_2}$$

using KCL @ A $\quad \sum_{\text{in}} i = 0 \qquad i_1 + i_2 = 0$

$$\frac{v_1 - v_p}{R_1} = -\frac{v_o - v_p}{R_2}$$

$$\frac{v_1 - \frac{R_4}{R_3+R_4} v_2}{R_1} = \frac{\frac{R_4}{R_3+R_4} v_2 - v_o}{R_2}$$

$$\frac{R_2}{R_1} v_1 - \frac{R_4 R_2}{R_1(R_3+R_4)} v_2 = \frac{R_4}{R_3+R_4} v_2 - v_o$$

$$v_o = -\frac{R_2}{R_1} v_1 + \left[\frac{R_4 R_2}{R_1(R_3+R_4)} + \frac{R_4}{R_3+R_4}\right] v_2$$

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

$$v_o = -K_1 v_1 + K_2 v_2$$

When $\frac{R_3}{R_1} = \frac{R_4}{R_2}$ this reduces to $v_o = \frac{R_2}{R_1}(v_2 - v_1)$

a subtractor.