Thursday, March 3, 2016

This is similar to the inverting amplifier, except V_{in} is moved to the non-inverting terminal (+)

Summing-point constraints: $i_n = i_p = 0$

$V_a = V_{in}$ (both '+' and '−' terminals at V_{in})

Node equation at a.

Node a: $$\frac{V_a}{R_1} + \frac{V_a - V_o}{R_f} + \cancel{i_n}^{\,0} = 0$$

and $V_a = V_{in}$, so $$\frac{V_{in}}{R_1} + \frac{V_{in} - V_o}{R_f} = 0$$

$$\frac{R_f}{R_1} V_{in} + V_{in} - V_o = 0$$

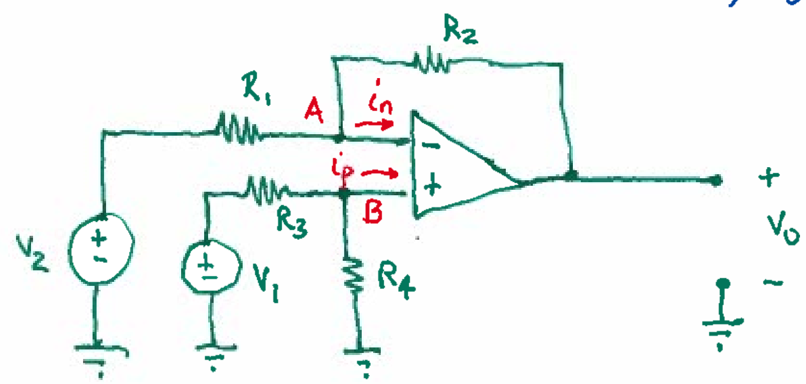
$$\text{so } V_o = \left(1 + \frac{R_f}{R_1}\right) V_{in}$$

which we may write as

$$\underset{\text{closed-loop gain}}{A_v} = \frac{V_o}{V_{in}} = \underbrace{1 + \frac{R_f}{R_1}}_{\text{note positive (non-inverting amplifier)}}$$

The differential amplifier

This is another very important and very common configuration.



Combines both an inverting and non-inverting amplifier.

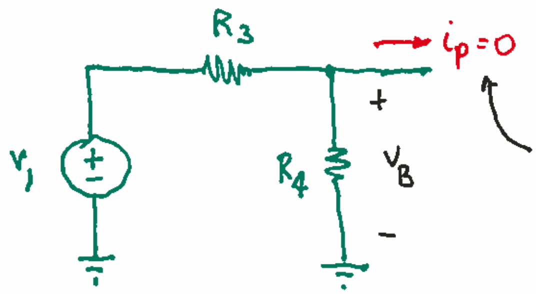
From node equations at A and B

Node A: $$\frac{V_A - V_2}{R_1} + \frac{V_A - V_0}{R_2} + \cancelto{0}{i_n} = 0 \qquad (1)$$

Node B: $$\frac{V_B}{R_4} + \frac{V_B - V_1}{R_3} + \cancelto{0}{i_p} = 0 \qquad (2)$$

From (2), $$\frac{V_B}{R_4} + \frac{V_B}{R_3} = \frac{V_1}{R_3}, \quad \text{so} \quad V_B\left(\frac{1}{R_4} + \frac{1}{R_3}\right) = \frac{V_1}{R_3}$$

$$V_B = \underbrace{V_1\left(\frac{R_4}{R_3 + R_4}\right)}_{\text{note this is a voltage divider equation!}} \qquad (3)$$



Since no current can flow here (virtual open circuit), then R_3 and R_4 are in <u>series</u>!

$$V_B = \frac{R_4}{R_3 + R_4} V_1$$

Now, $V_A = V_B = V_1\left(\frac{R_4}{R_3 + R_4}\right)$. Substitute into (1).

$$\frac{V_A - V_2}{R_1} + \frac{V_A - V_0}{R_2} = 0$$

$$\frac{V_A}{R_1} + \frac{V_A}{R_2} - \frac{V_2}{R_1} = \frac{V_0}{R_2}$$

$$V_0 = V_A\left(\frac{1}{R_1} + \frac{1}{R_2}\right)R_2 - \frac{V_2 R_2}{R_1}$$

$$V_0 = \left(\frac{R_2 + R_1}{R_1}\right)V_A - \frac{V_2 R_2}{R_1}$$

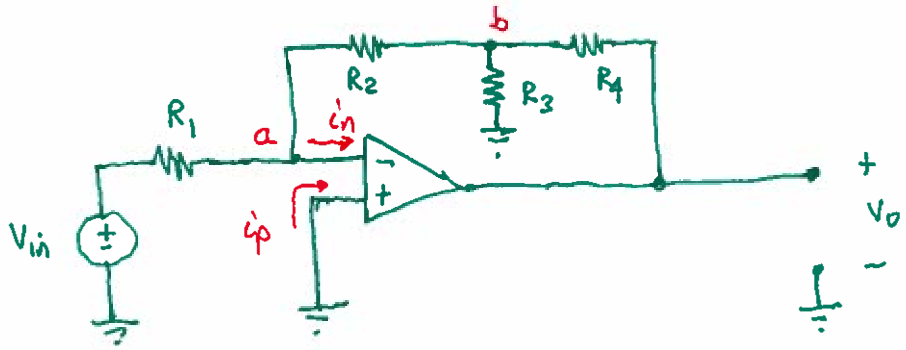
$$= \left(\frac{R_2 + R_1}{R_1}\right)\left(\frac{R_4}{R_3 + R_4}\right)V_1 - \left(\frac{R_2}{R_1}\right)V_2$$

If we let $\frac{R_2}{R_1} = \frac{R_4}{R_3}$, then it can be shown that

$$V_o = \frac{R_2}{R_1}(V_1 - V_2)$$ } amplified voltage difference.

Examples of other op-amp circuits

Example 1: More practice — another inverting amplifier circuit



Node a: $$\frac{V_a - V_{in}}{R_1} + \cancel{i_n}^{\,0} + \frac{V_a - V_b}{R_2} = 0$$

With $V_a = 0$,
$$-\frac{V_{in}}{R_1} - \frac{V_b}{R_2} = 0 \qquad (1)$$

Node b: $$\frac{V_b - V_a}{R_2} + \frac{V_b}{R_3} + \frac{V_b - V_o}{R_4} = 0$$

$$V_o = R_4\left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right)V_b \qquad (2)$$

From (1),
$$V_b = -\frac{R_2}{R_1}V_{in}, \quad \text{so}$$

$$V_o = -\frac{R_4 R_2}{R_1}\left(\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}\right)V_{in}$$