Op Amp Configurations

The name “operational amplifier” stems from the fact that by adding various external components to the op amp, we can make it perform a variety of useful mathematical operations including:

- Addition
- Multiplication
- Linear combinations
- Differentiation
- Integration

The next few slides illustrate a few of these configurations that can be achieved with purely resistive circuitry.

For this course, it is not necessary that you memorize these configurations. Rather, just take these as examples of op amp circuits and make sure that you understand how these configurations are analyzed.

In all cases, we start the analysis from the ideal op amp equations.

Inverting Amplifier

This configuration produces an output which is a negative multiple of the input signal.

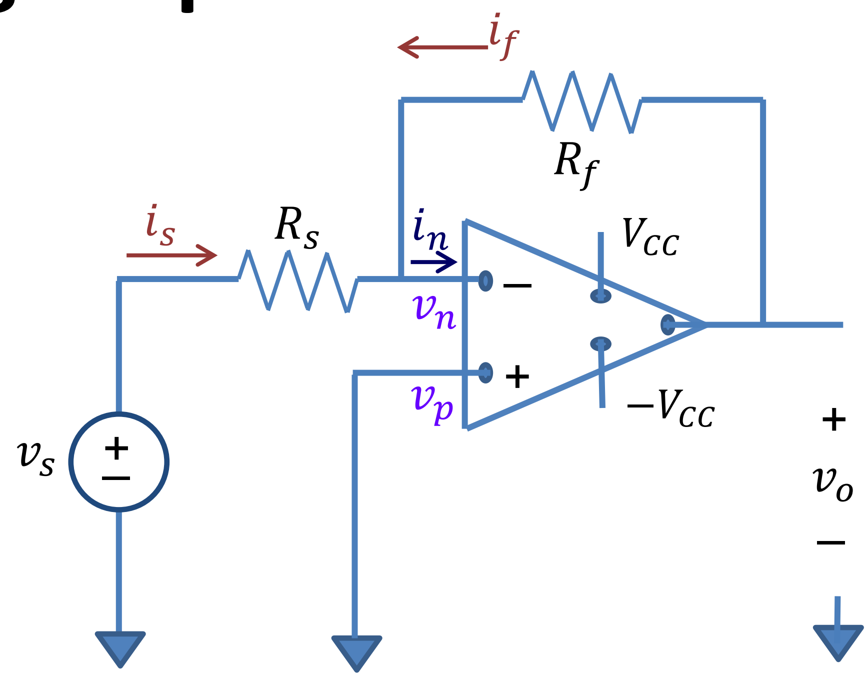
$$v_p = v_n = 0.$$

$$i_s = {}^{v_s}/_{R_s}, \;\; i_f = {}^{v_o}/_{R_f}.$$

$$i_n = i_s + i_f = 0.$$

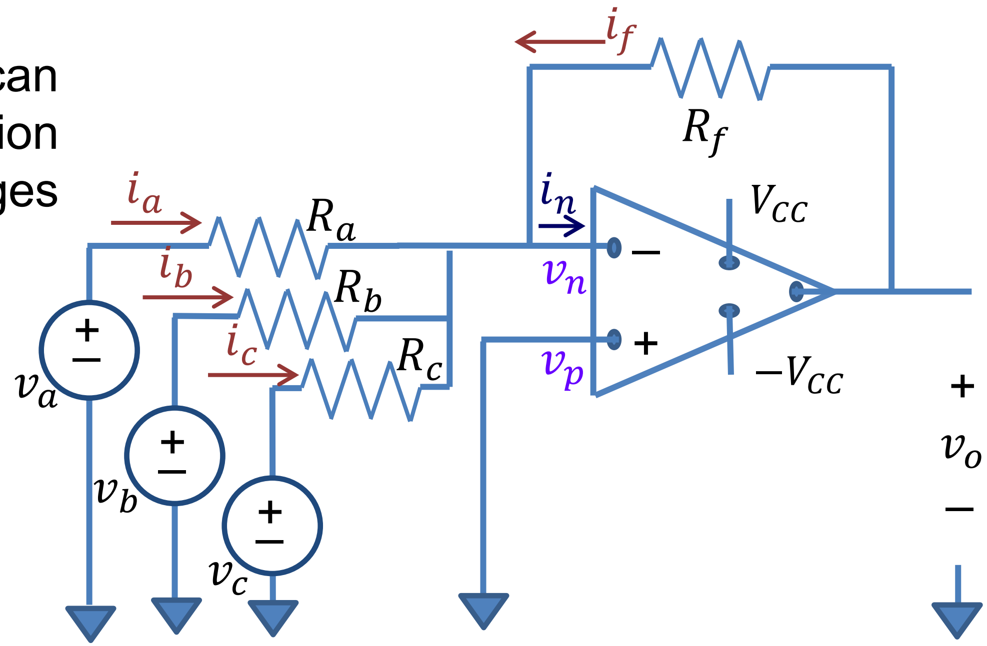
$$\frac{v_s}{R_s} + \frac{v_o}{R_f} = 0.$$

$$\boxed{v_o = -\frac{R_f}{R_s} v_s.}$$



Summing Amplifier

By adding multiple inputs we can produce a linear combination (inverted) of the source voltages at the output.



$$v_p = v_n = 0.$$

$$i_a = {}^{v_a}/_{R_a},$$
$$i_b = {}^{v_b}/_{R_b},$$
$$i_c = {}^{v_c}/_{R_c},$$
$$i_f = {}^{v_o}/_{R_f}.$$

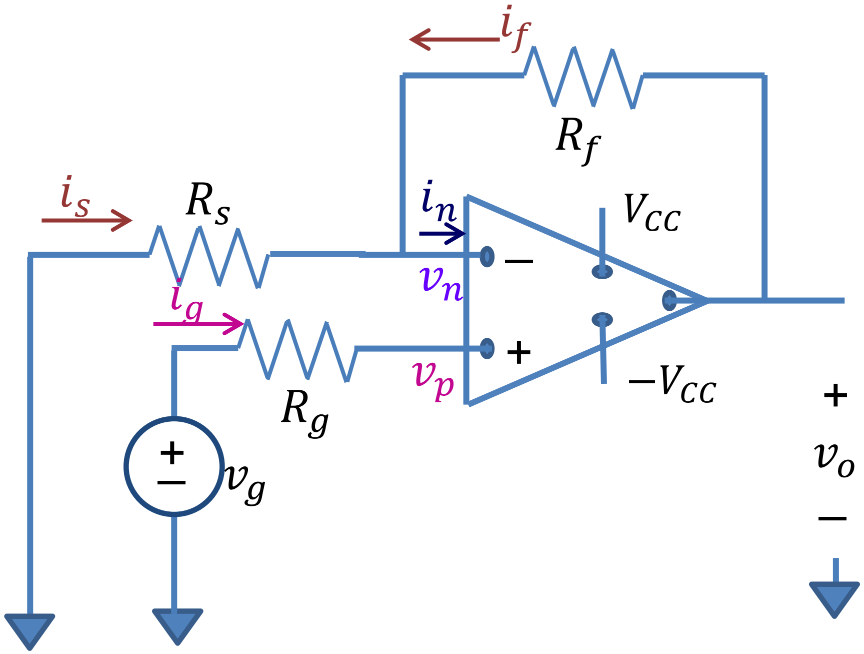
$$i_n = i_a + i_b + i_c + i_f = 0.$$

$$\frac{v_a}{R_a} + \frac{v_b}{R_b} + \frac{v_c}{R_c} + \frac{v_o}{R_f} = 0.$$

$$\boxed{v_o = -\left(\frac{R_f}{R_a}v_a + \frac{R_f}{R_b}v_b + \frac{R_f}{R_c}v_c\right).}$$

Non-Inverting Amplifier

This configuration produces an output which is a positive multiple of the input signal.



$$i_g = 0.\ v_p = v_g.$$

$$v_p = v_n = v_g.$$

$$i_s = -{}^{v_g}/_{R_s},\ \ i_f = {}^{v_o - v_g}/_{R_f}.$$

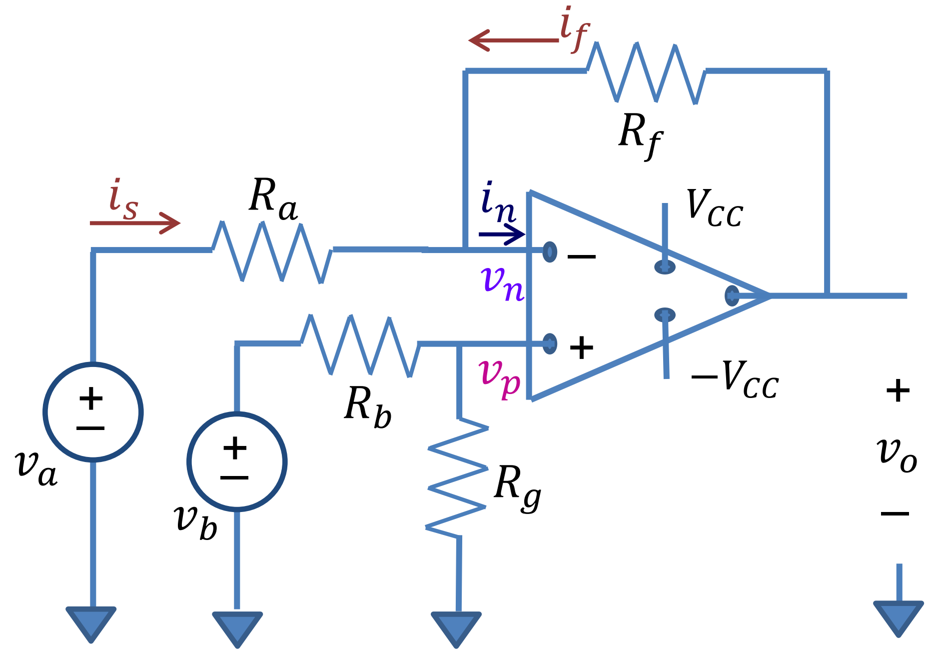
$$i_n = i_s + i_f = 0.$$

$$-\frac{v_g}{R_s} + \frac{v_o - v_g}{R_f} = 0.$$

$$\boxed{v_o = \frac{R_f + R_s}{R_s} v_g.}$$

Difference Amplifier

This configuration produces an output which is a linear combination (with opposite signs) of two input signals.



$$v_p = v_b \frac{R_g}{R_g+R_b}.$$

$$v_n = v_p = v_b \frac{R_g}{R_g+R_b}.$$

$$i_s = \frac{v_a - v_n}{R_s}, \ \ i_f = {}^{v_o - v_n}/_{R_f}.$$

$$i_n = i_s + i_f = 0.$$

$$\frac{v_a - v_n}{R_a} + \frac{v_o - v_n}{R_f} = 0.$$

$$\boxed{v_o = \frac{(R_f + R_a)R_g}{(R_g + R_b)R_a} v_b - \frac{R_f}{R_a} v_a.}$$

Voltage Comparator

Without any feedback resistor to connect the output to the input, the op amp acts as a digital logic device.

If $v_{in} > v_{ref}$, the op amp will try to produce a very large (positive) output voltage and the output will saturate at $v_o = V_{CC}$.

If $v_{in} < v_{ref}$, the op amp will try to produce a very large (negative) output voltage and the output will saturate at $v_o = -V_{CC}$.

$$v_o = \begin{cases} V_{CC}, & if\ v_{in} > v_{ref}, \\ -V_{CC}, & if\ v_{in} < v_{ref}. \end{cases}$$