El amplificador operacional

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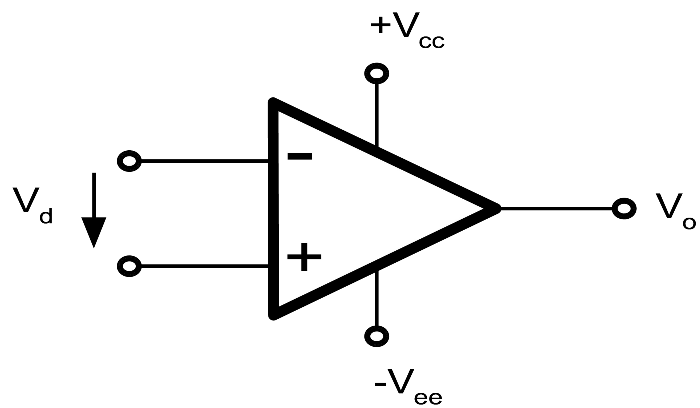
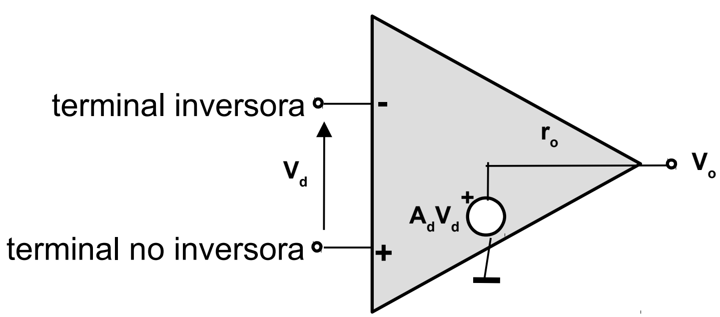
El amplificador operacional

Amplificador operacional ideal





$$v_d = v_+ - v_-$$

$$v_o = A_d v_d$$

$$-V_{ee} \leq v_o \leq +V_{cc}$$

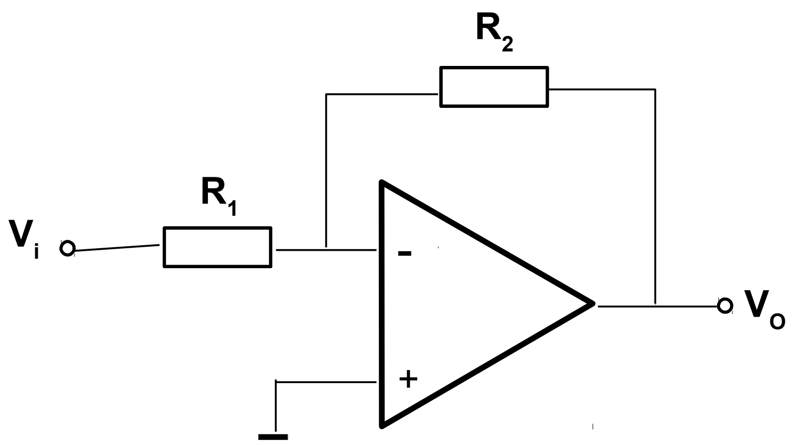
A_d → Ganancia en lazo abierto (sin realimentación) > 100 dB

El amplificador operacional simplificaciones para modelado

- Capacidad de carga infinita
- Impedancia de entrada infinita
- Offset nulo
- Ancho de banda infinito
- Ganancia infinita

Aplicaciones del operacional

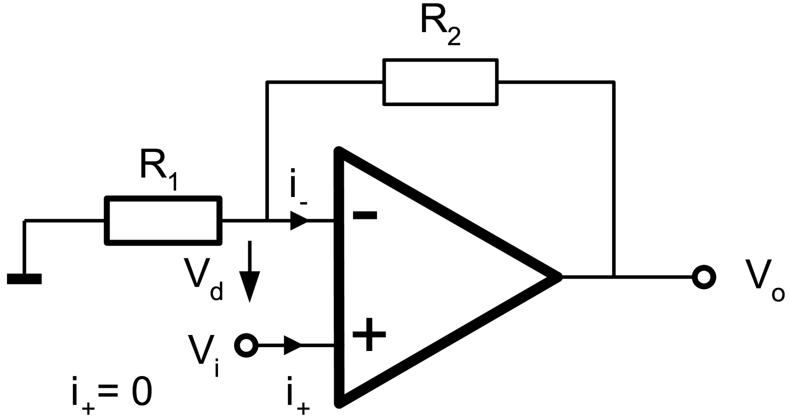
Amplificador inversor



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

Aplicaciones del operacional

Amplificador no inversor



$i_+ = 0$

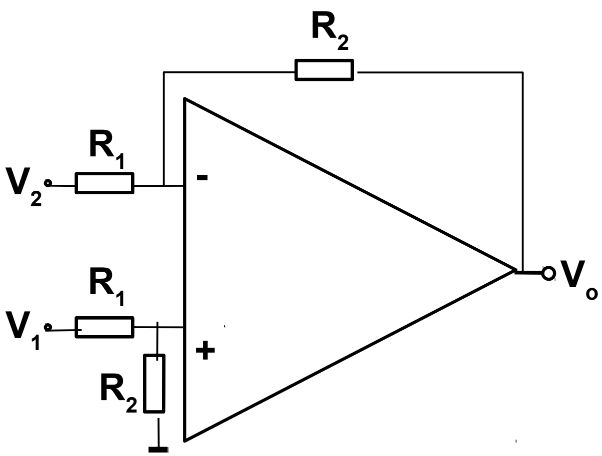
$i_- = 0$

$$v_o = \left(1 + \frac{R_2}{R_1}\right) v_i$$

Aplicaciones del operacional

Amplificador diferencial

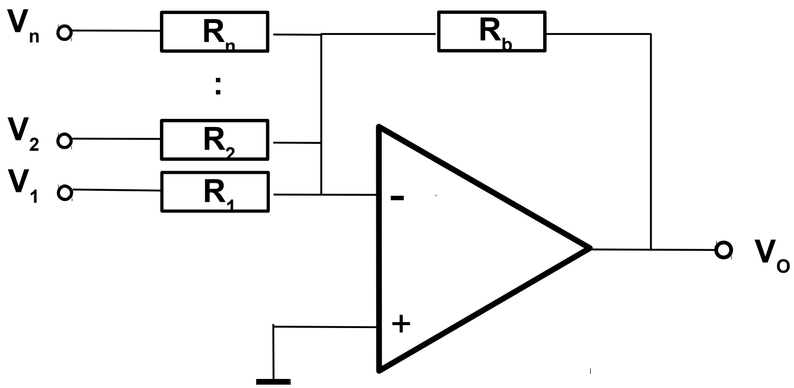
(simple restador)



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

Aplicaciones del operacional

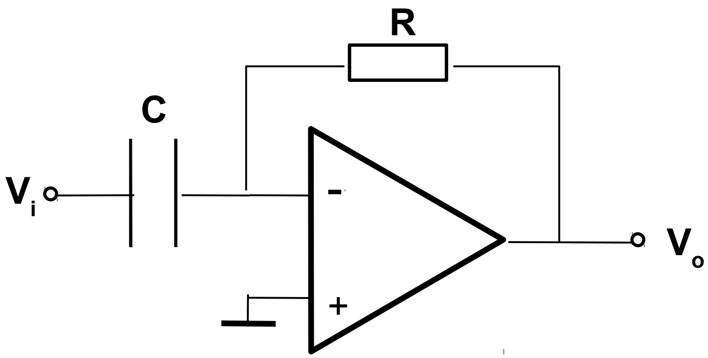
Amplificador sumador



$$v_o = -R_b\left(\frac{v_1}{R_1} + \frac{v_2}{R_2} + \ldots + \frac{v_n}{R_n}\right)$$

Aplicaciones del operacional

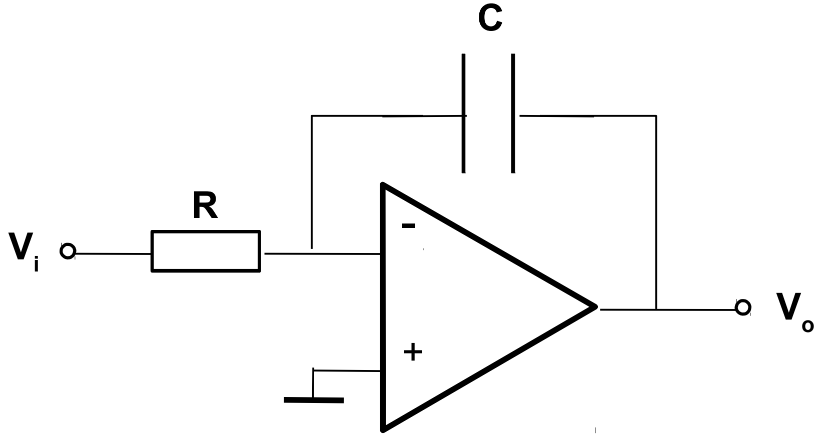
Amplificador diferenciador



$$v_o = -RC\frac{\partial v_i}{\partial t}$$

Aplicaciones del operacional

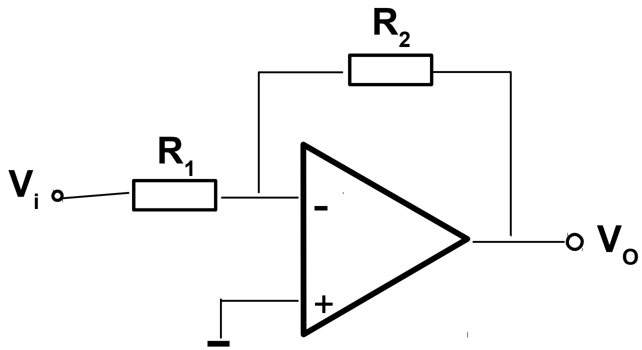
Amplificador integrador



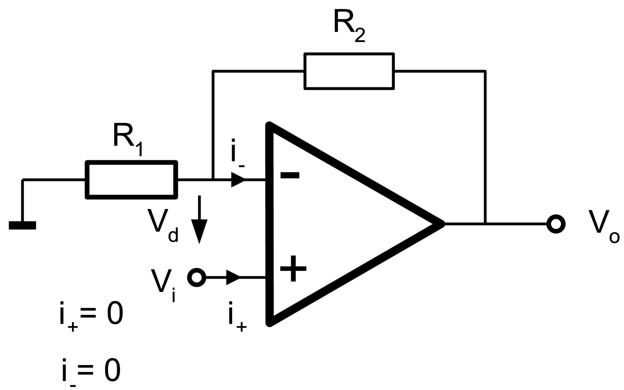
$$v_o = -\frac{1}{RC}\int v_i \partial t$$

Desviaciones del modelo ideal

Ganancia finita



$$v_o = -v_i \frac{R_2}{R_1 + \frac{R_1 + R_2}{A_d}}$$

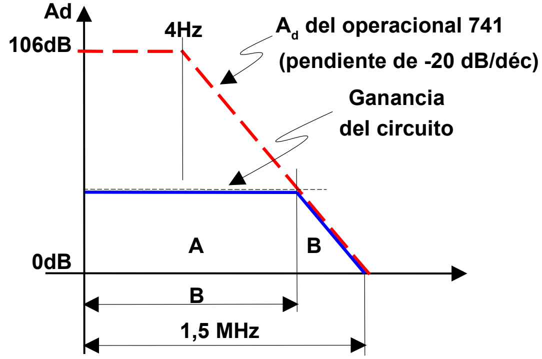


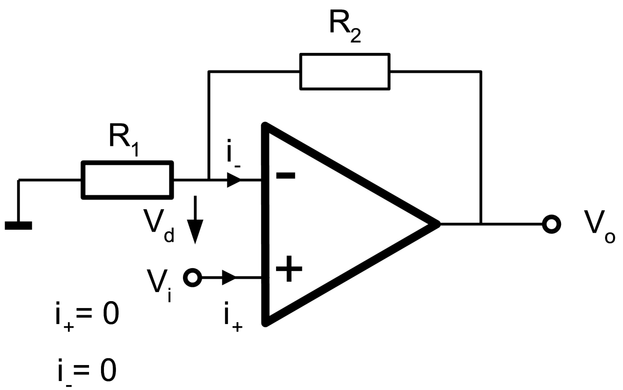
$$v_o = v_i \frac{1}{\frac{R_1}{R_1 + R_2} + \frac{1}{A_d}}$$

Desviaciones del modelo ideal

Ancho de banda finito

$$A_d = \frac{A_0}{1 + j\frac{f}{f_b}}$$

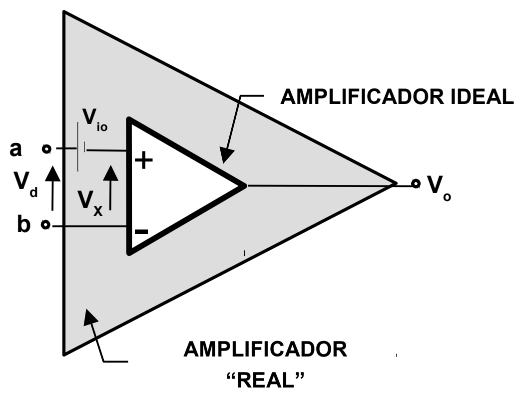


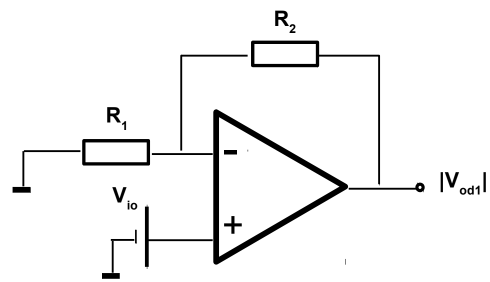


$$v_o = v_i \frac{1}{\frac{R_1}{R_1 + R_2} + \frac{1 + j\frac{f}{f_b}}{A_0}}$$

Desviaciones del modelo ideal

Offset de tensión



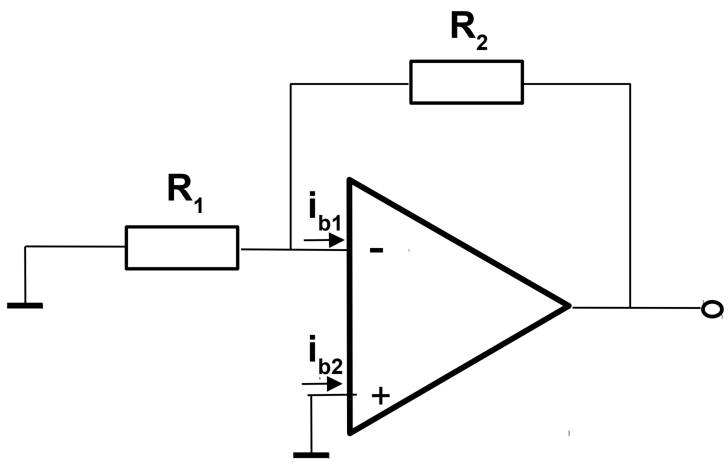


$$|v_o| = |v_{\text{io}}| \frac{R_1 + R_2}{R_1}$$

Para FET se encuentra entre 1mV y 20mV.
Para bipolares se encuentra entre 0'1mV y 2mV.

Desviaciones del modelo ideal

Corrientes de polarización



$$v_o = R_2 i_{b1}$$

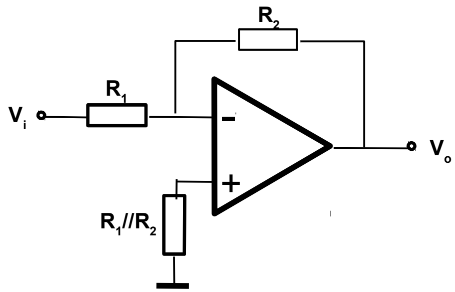
$$I_B = \frac{i_{B1} + i_{B2}}{2}$$ **(hasta décimas de mA en tecnología bipolar)**

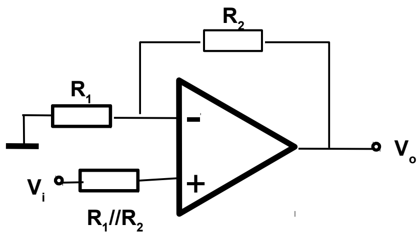
$$I_{i0} = \left| i_{B1} - i_{B2} \right|$$ **(sobre un 25% de I_B)**

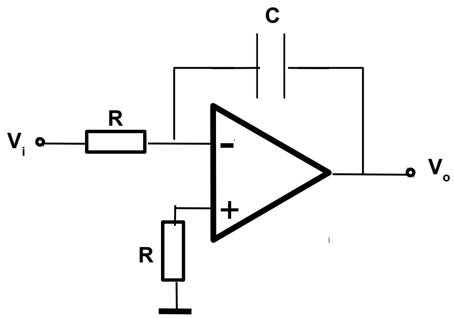
Para FET se encuentra entre 1pA y 10pA.
Para bipolares se encuentra entre 10nA y 100nA.

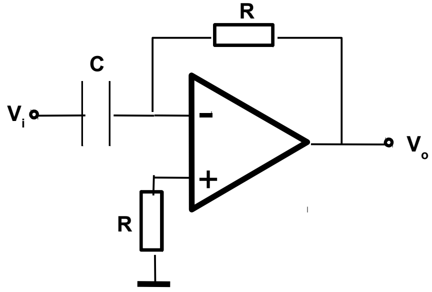
Desviaciones del modelo ideal

Corrientes de polarización







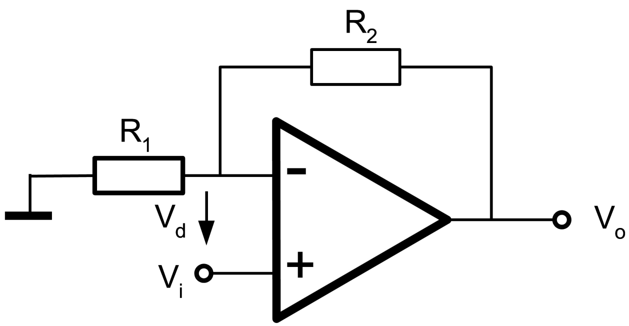


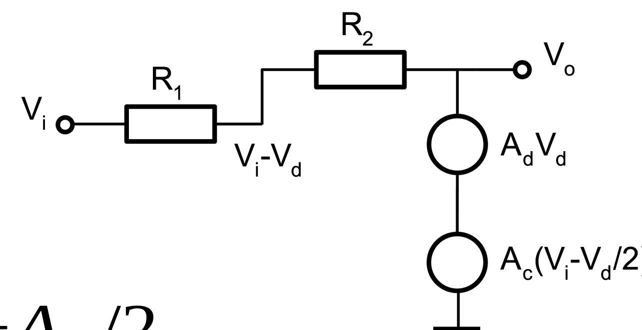
Desviaciones del modelo ideal

Ganancia de modo común

$$v_o = A_d v_d + A_c v_c$$

$$CMRR = \frac{A_d}{A_c}$$ (para el 741 90db)



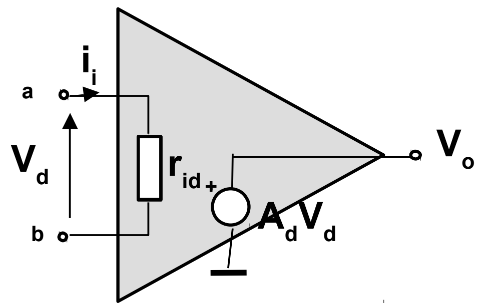


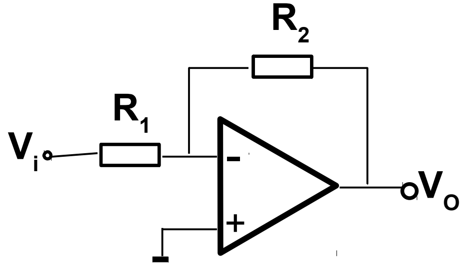
$$v_o = \frac{A_d + A_c/2}{1 + \left(A_d + \frac{A_c}{2}\right)\frac{R_1}{R_1 + R_2}} v_i$$

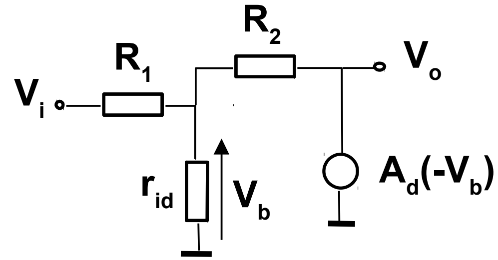
?

Desviaciones del modelo ideal

Resistencia entre entradas



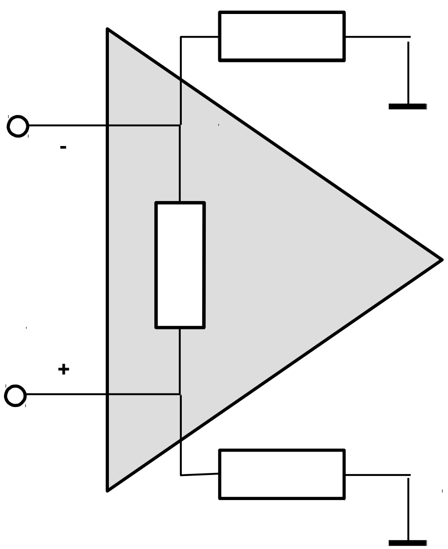




$$v_o = -v_i \frac{A_d}{\frac{R_1}{R_2}\left(1 + A_d\right) + 1 + \frac{R_1}{R_{\text{id}}}}$$

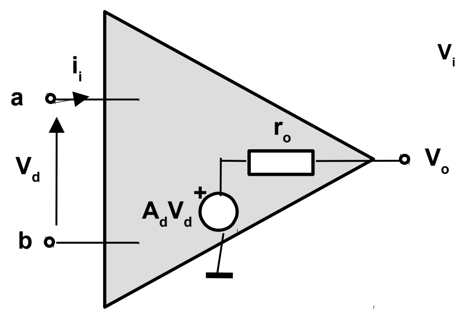
Desviaciones del modelo ideal

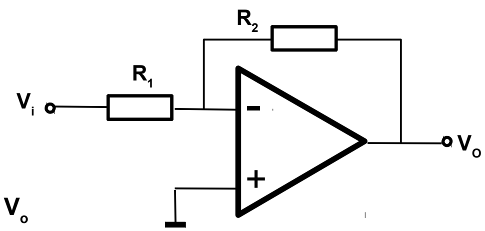
Resistencia en modo común

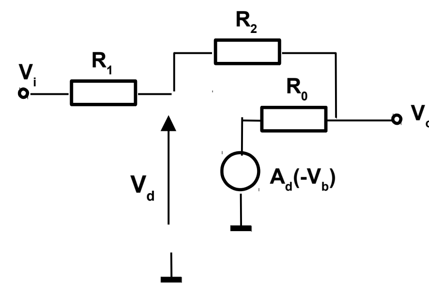


Desviaciones del modelo ideal

Impedancia de salida no nula





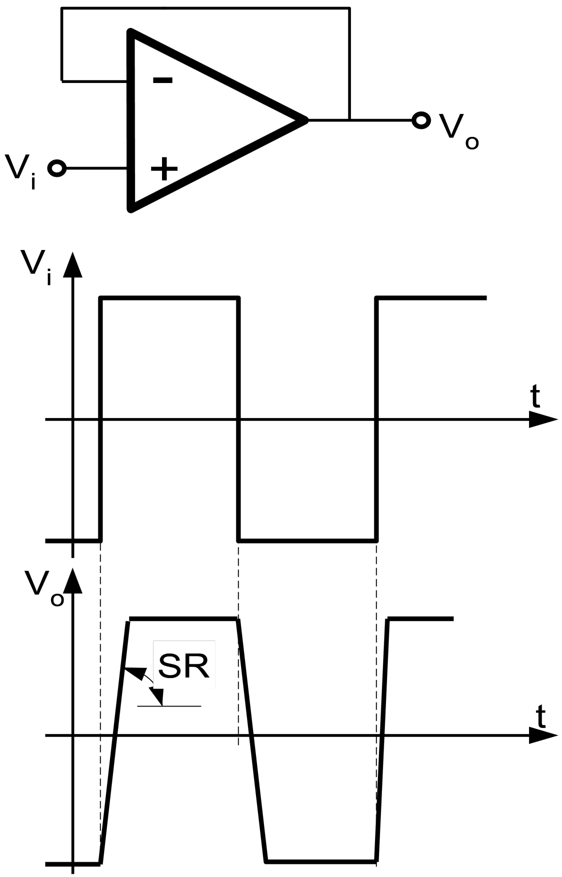


$$A_d' = \frac{V_0}{V_d} \simeq \frac{A_d}{1 + \frac{R_0}{R_2}}$$

Para un operacional de propósito general se encuentra entre 40 y 100 ohmios.

Desviaciones del modelo ideal

slew-rate limitado

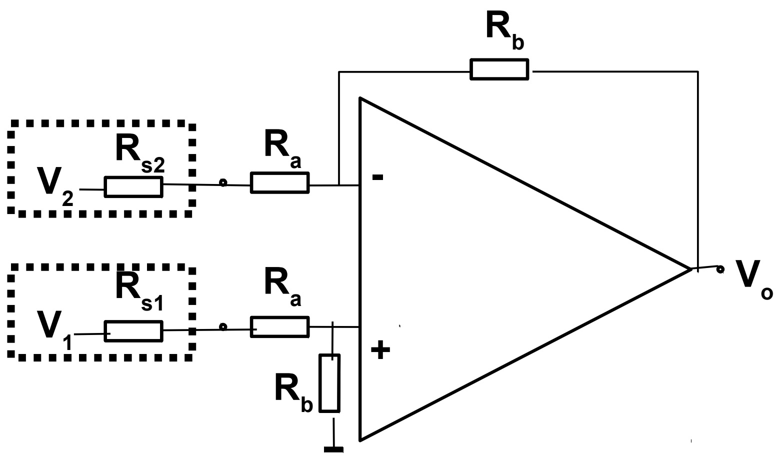


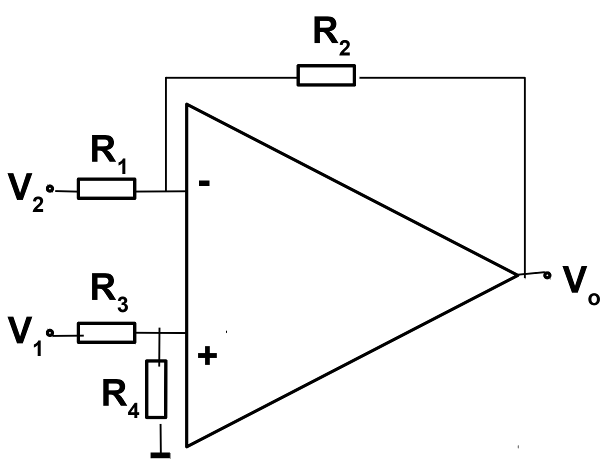
$$\frac{dv_o}{dt} = 2\pi f\,V\cos(2\pi f t) \Rightarrow \left(\frac{dv_o}{dt}\right)_{\text{máx}} = 2\pi f V$$

$$2\pi f V < SR \Rightarrow f_{\text{máx}} = \frac{SR}{2\pi V}$$

Amplificador de instrumentación

Simple restador





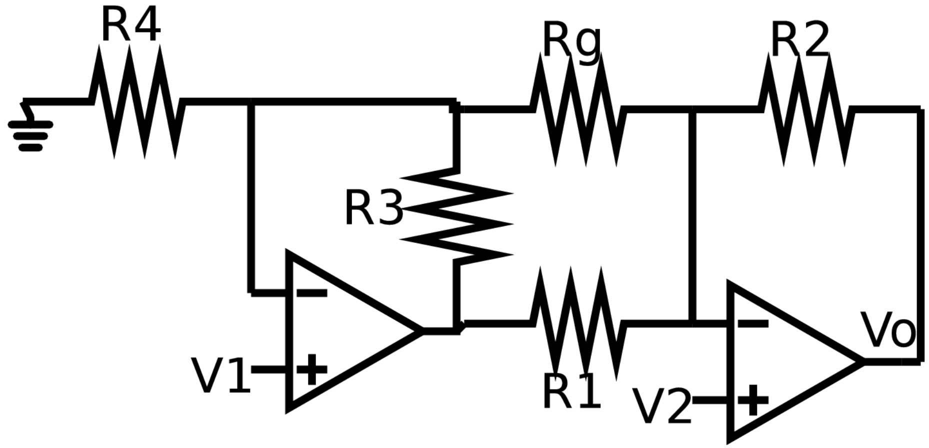
$$V_1 = V_2 = V_{ic} \Rightarrow$$

$$V_{oc} = V_{ic}\left(\frac{R_4}{R_3 + R_4}\frac{R_1 + R_2}{R_1} - \frac{R_2}{R_1}\right)$$

(CMRR finito)

Amplificador de instrumentación

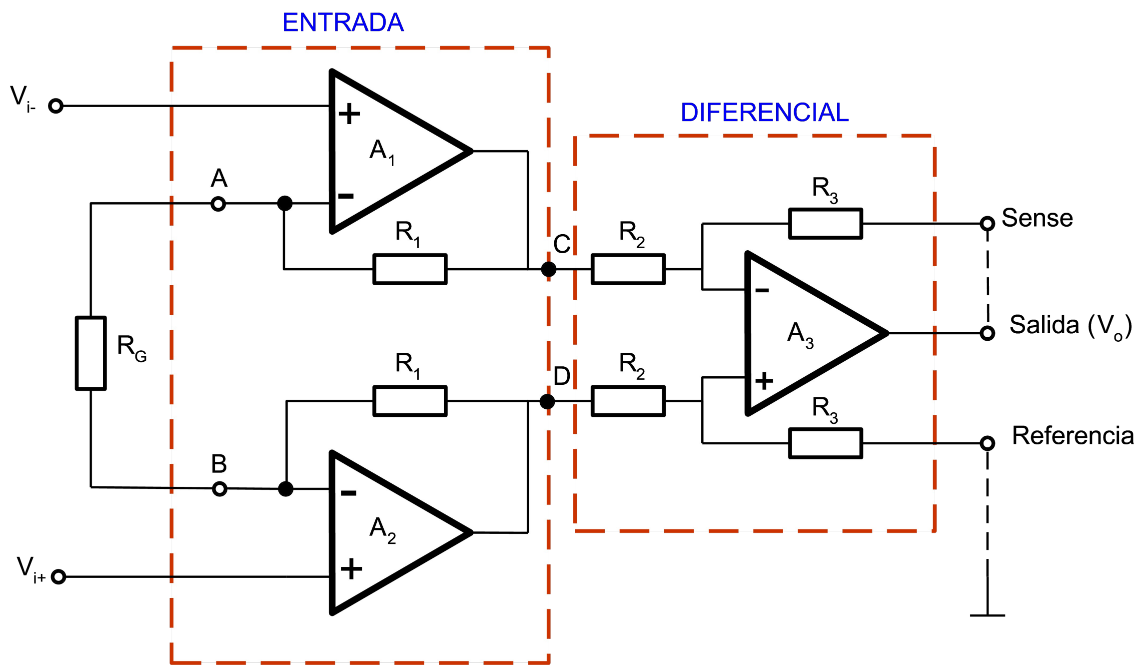
Amplificador de dos operacionales



$$R_2 R_3 = R_1 R_4 \Rightarrow \frac{V_o}{V_2 - V_1} = 1 + \frac{R_2}{R_1} + \frac{R_2}{R_g}\left(1 + \frac{R_3}{R_1}\right)$$

Amplificador de instrumentación

Amplificador de tres operacionales



$$v_o = \frac{R_3}{R_2} \cdot \left(1 + \frac{2R_1}{R_G}\right)\left(v_{i+} - v_{i-}\right)$$

$$A_d = 1 + \frac{2R_1}{R_G}$$