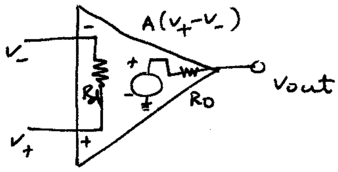
INTERFACING

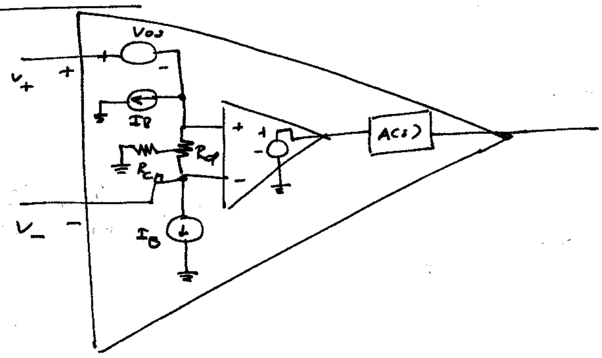
AULA 1 – AMPLIFICADORES OPERACIONAIS

OP. AMP. IDEAL

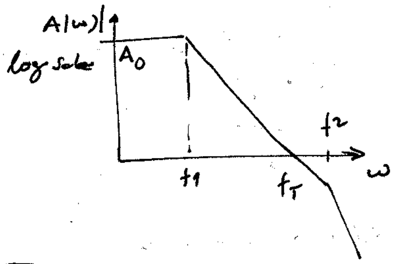


1. ganho em malha aberta $A = \infty$
   $\Rightarrow v_- = v_+$ para funcionamento linear
2. impedância de entrada R_d = infinito
   $\Rightarrow i_- = i_+ = 0$
3. resistência de saída $R_O = 0$
4. largura de banda infinita

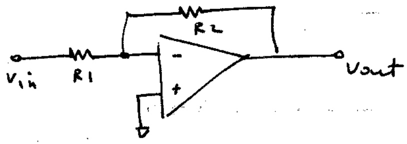
OP. AMP. REAL



- tensão de offset "V_{os}"
- corrente de polarização "I_B"
- corrente de offset "I_{os}"
- resistências de entrada não nulas
- ruído
- largura de banda finita
- slew rate
- settling time
- A_0 finito

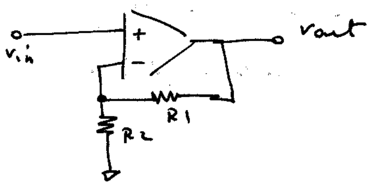


amplificador inversor



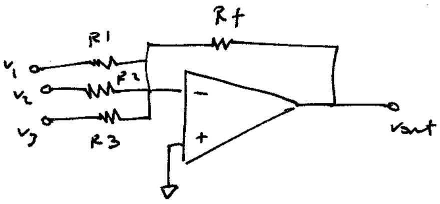
$$v_{out} = -\frac{R2}{R1} v_{in}$$

amplificador não inversor



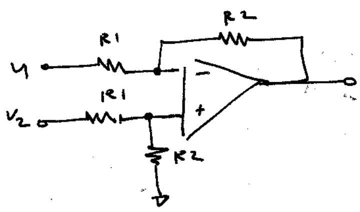
$$v_{out} = \left(1 + \frac{R1}{R2}\right) v_{in}$$

amplificador somador



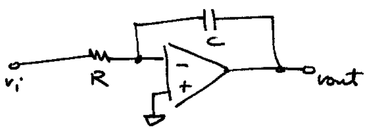
$$v_{out} = -R_f \left(\frac{v_1}{R_1} + \frac{v_2}{R2} + \frac{v_3}{R3} \right)$$

amplificador subtractor



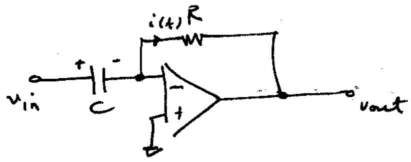
$$v_{out} = \frac{R2}{R1} (v_2 - v_1)$$

amplificador integrador



$$v_{out} = -\frac{1}{RC} \int_0^t v_i(t)\, dt + v_{inicial}$$

amplificador diferenciador



$$v_{out} = -R\, i(t)$$

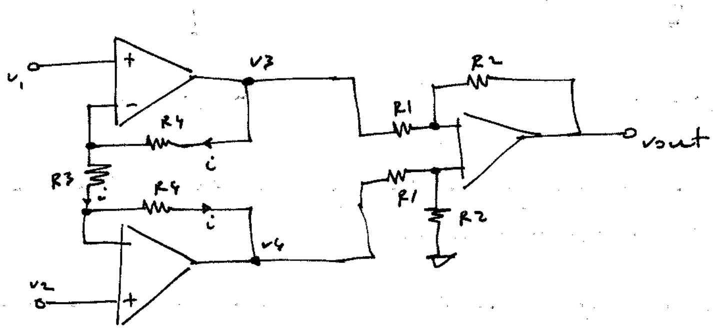
$$Q = cV$$

$$\frac{dQ}{dt} = c\frac{dv}{dt}$$

$$i(t) = c\frac{dv_{in}}{dt}$$

$$v_{out} = -RC\frac{dv_{in}}{dt}$$

amplificador de instrumentação



$$v_{out} = (v_1 - v_2)\cdot\frac{R2}{R1}\cdot\frac{2R4 + R3}{R3}$$

$$CMRR = \frac{A_D}{A_{CM}} = 100 \sim 100.000$$

- elevada impedância entrada
- CMRR elevado

$$(V3 - v_4) = i\,(2R4 + R3)$$

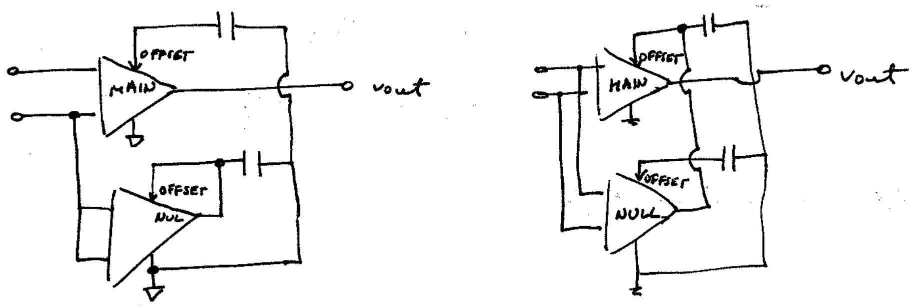
$$i = \frac{v_1 - v_2}{R3}$$

$$\therefore (v_3 - v_4) = \frac{2R4 + R3}{R3}(v_1 - v_2)$$

$$\boxed{CMRR = \frac{A_D}{A_{CM}} \;;\; A_{CM} = \frac{2\Delta R}{R}}$$

amplificador chopper

- reduzido offset
- reduzido drift do offset com a temperatura



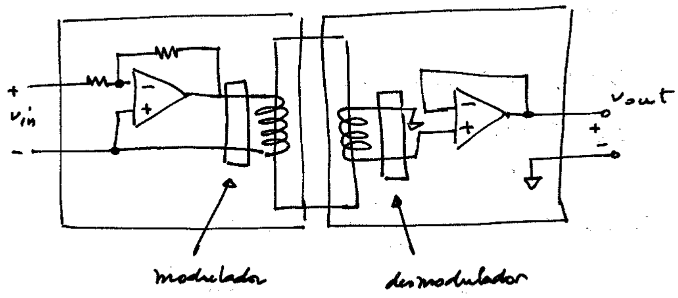
a) fase 1 b) fase 2

- na 1ª fase as entradas do amplificador secundário estão ligadas entre si e o seu offset é anulado

- na 2ª fase o amp secundário monitoriza as 2 entradas principais, que são iguais devido ao circuito de realimentação e ajusta o offset no amplificador principal

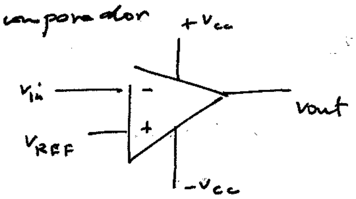
amplificador isolador

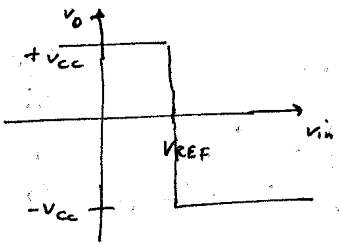
- qdo a aplicação exige isolamento entre o sensor e o circuito de aquisição de dados



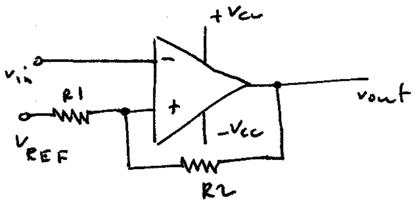
Aplicações não lineares (realimentação positiva)

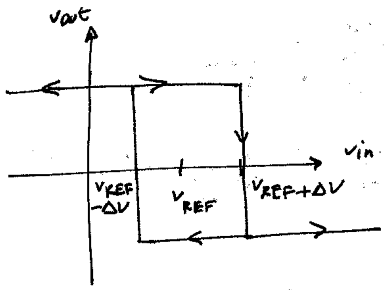
- comparador





- comparador com histerése





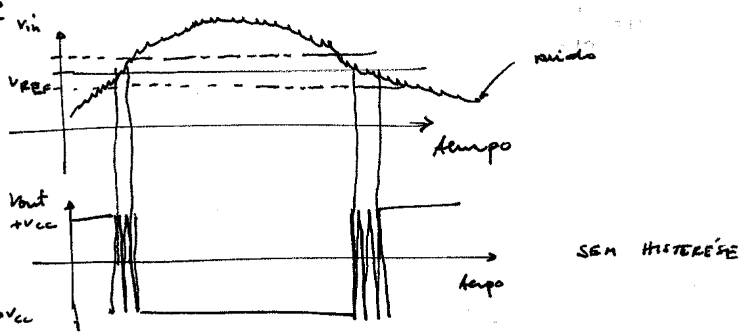
caso 1 ⇒ $V_{out} = +V_{cc}$

$$v_+ = V_{REF} + R1 \frac{+V_{cc} - V_{REF}}{R1 + R2}$$

caso 2 → $V_{out} = -V_{cc}$

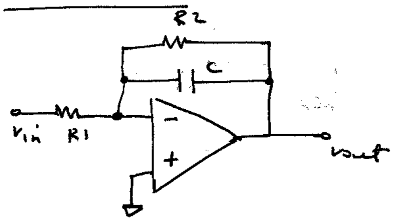
$$v_+ = V_{REF} + R1 \frac{-V_{cc} - V_{REF}}{R1 + R2}$$

exemplo



filtros activos

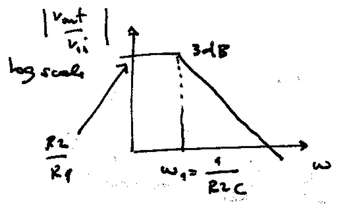
passa-baixo



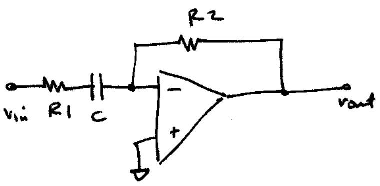
$$\frac{v_{out}}{v_{in}} = -\frac{Z_{eq}}{R_1}$$

$$\frac{1}{Z_{eq}} = \frac{1}{R_2} + j\omega C = \frac{1 + j\omega R_2 C}{R_2}$$

$$\frac{v_{out}}{v_{in}} = -\frac{R_2}{R_1}\frac{1}{1 + j\,\omega/\omega_1} \qquad \omega_1 = \frac{1}{R_2 C}$$



passa-alto



$$\frac{v_{out}}{v_{in}} = -\frac{R_2}{Z_{1\,equiv}}$$

$$Z_{eq} = R_1 + \frac{1}{j\omega C} = \frac{1 + j\omega R_1 C}{j\omega C}$$

$$\frac{v_{out}}{v_{in}} = \frac{-j\omega R_2 C}{1 + j\omega R_1 C}$$