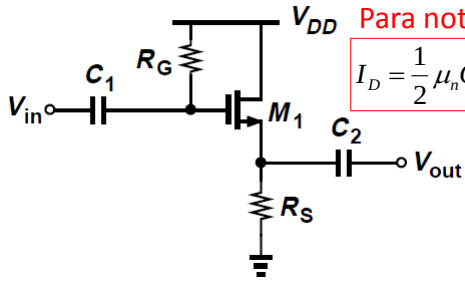
EE 530 Eletrônica Básica I

AMPLIFICADOR OPERACIONAL

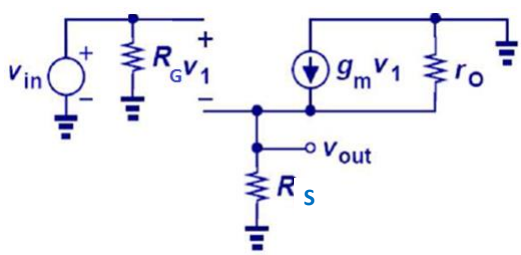
Prof. Pedro Xavier

Seguidor de Fonte com Polarização



Para nota: encontre I_D e A_v

$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{DD} - R_S I_D - V_{TH})^2[1+\lambda(V_{DD} - R_S I_D)]$$



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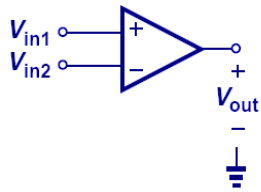
$$\lambda > 0$$

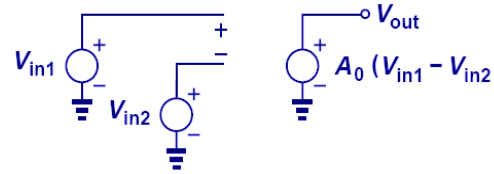
$$A_v = \frac{r_o \,//\, R_S}{\frac{1}{g_m} + r_o \,//\, R_S}$$

$$R_{in} = R_G$$

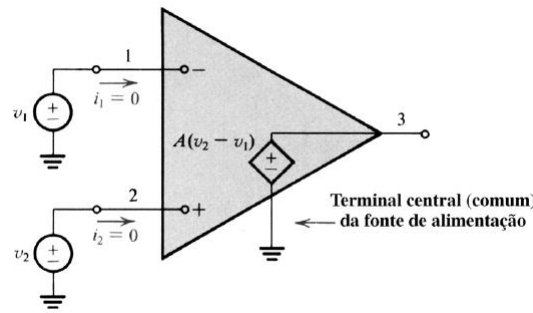
$$R_{out} = R_s \,//\, r_o \,//\, 1/g_m$$

Amplificador Operacional



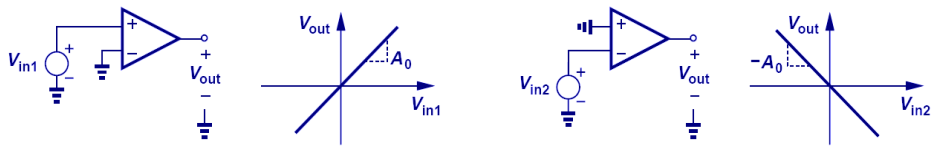


$$V_{out} = A_0\left(V_{in1} - V_{in2}\right)$$



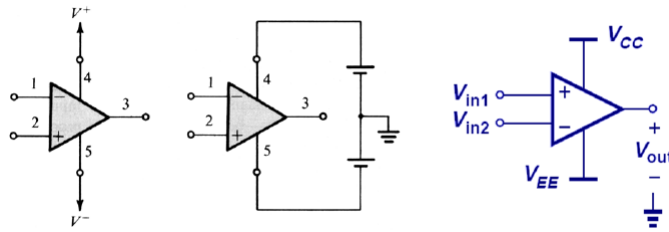
Amplificador Operacional

- Inversor e não inversor

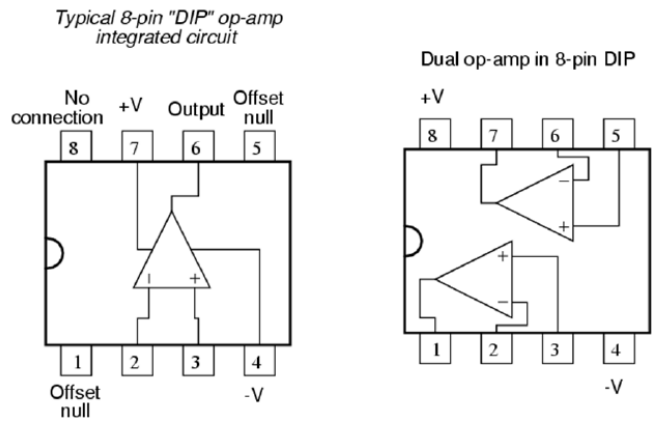


Amplificador Operacional

- Alimentação
  - Em alguns Amp Op, VEE pode ser igual a 0.

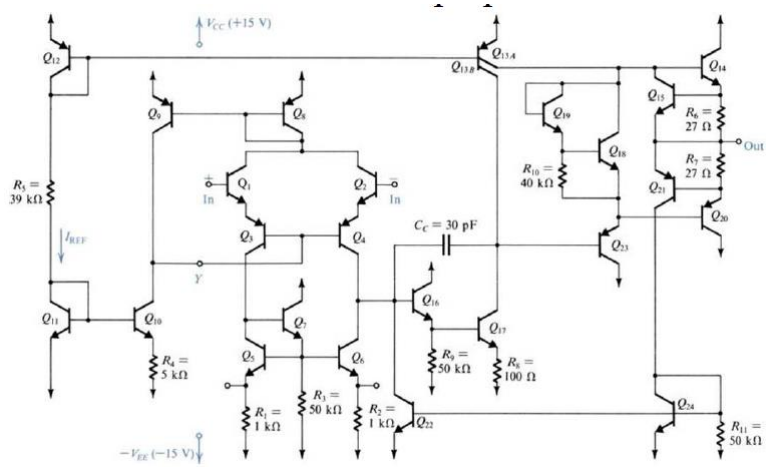


Amplificador Operacional



Amplificador Operacional

- Circuito interno (741)

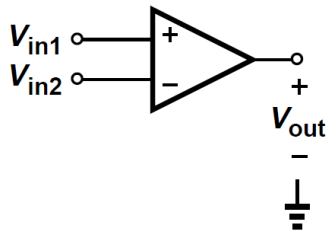


Amplificador Operacional IDEAL

- **Ganho diferencial infinito**
- **Impedância de entrada infinita**
- **Impedância de saída muito baixa**
- **Velocidade infinita**
- Excursão do sinal de saída de V+ até V-
- Offset nulo
- Função de transferência linear
- Módulo e fase inalterados pela frequência
- Razão de Rejeição em Modo Comum (CMRR) infinita

Amplificador Operacional IDEAL

- Curto circuito virtual(V_{in1} ou V_{in2} não está conectado a uma fonte)



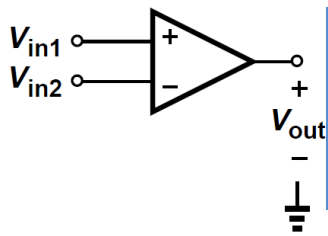
$$V_{out} = A_0\left(V_{in1} - V_{in2}\right)$$

Ganho de malha aberta→∞

Sistema Instável

Amplificador Operacional IDEAL

- Curto circuito virtual(V_{in1} ou V_{in2} não está conectado a uma fonte)

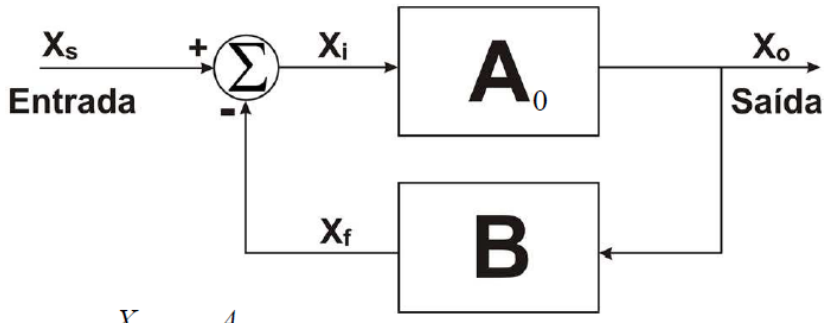


$$V_{out} = A_0\left(V_{in1} - V_{in2}\right)$$

$$V_{in1} - V_{in2} = \frac{V_{out}}{A_0} \xrightarrow{A_0 \to \infty} V_{in1} = V_{in2}$$

Realimentação Negativa (malha fechada)

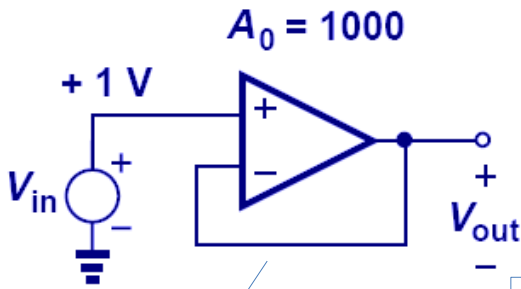
- A realimentação negativa permite o controle do ganho e pode deixar o sistema estável.



$$\frac{X_0}{X_S} = \frac{A_0}{1 + A_0 B}$$

Amplificador com Ganho Unitário

- Seguidor de tensão (Buffer)



$$V_{out} = A_0 (V_{in} - V_{out})$$

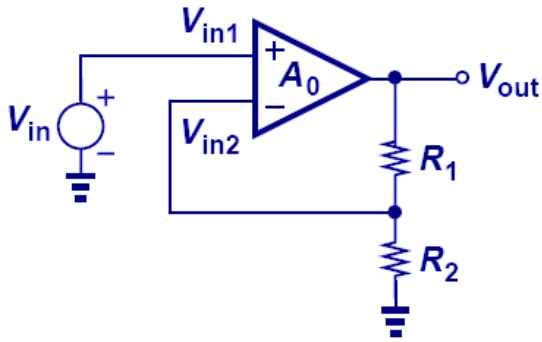
$$\frac{V_{out}}{V_{in}} = \frac{A_0}{1 + A_0}$$

Realimentação negativa

Ganho de malha fechada
Sistema Estável

Amplificador Não Inversor ($A_0 \rightarrow \infty$)

- Calcule o ganho.

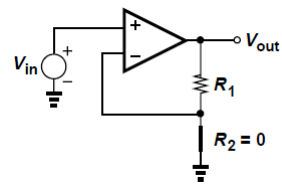


$$\frac{V_{out}}{V_{in}} = 1 + \frac{R_1}{R_2}$$

$$R_{in} = \infty$$

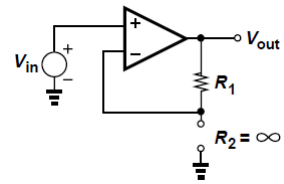
Amplificador Não Inversor ($A_0 \rightarrow \infty$)

- $R_2=0 \rightarrow A_V=A_0=\infty$



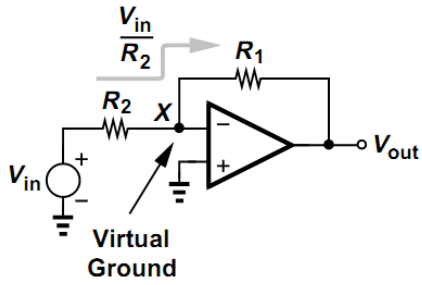
$$\frac{V_{out}}{V_{in}} = 1 + \frac{R_1}{R_2}$$

- $R_2= \infty \rightarrow A_V=1$



Amplificador Inversor ($A_0 \rightarrow \infty$)

- Terra virtual

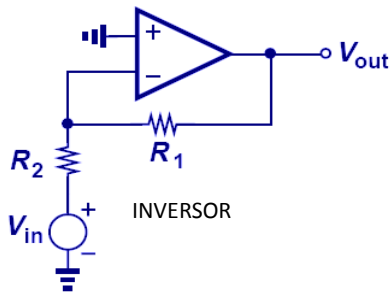


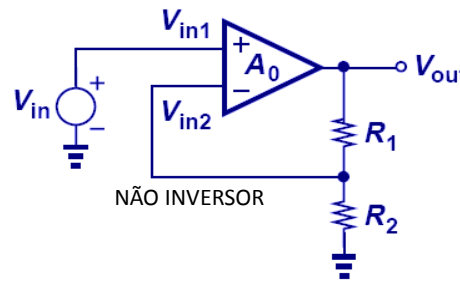
$$\frac{0 - V_{out}}{R_1} = \frac{V_{in}}{R_2}$$

$$\frac{V_{out}}{V_{in}} = \frac{-R_1}{R_2}$$

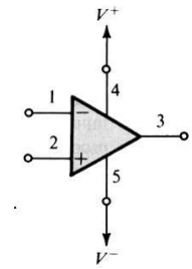
$$R_{in} = R_2$$

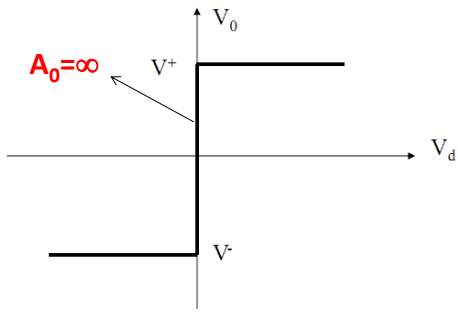
Outra forma de representar

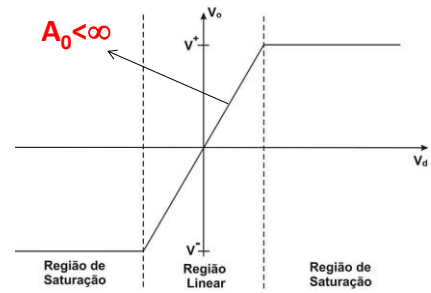




Ganho Infinito e Finito

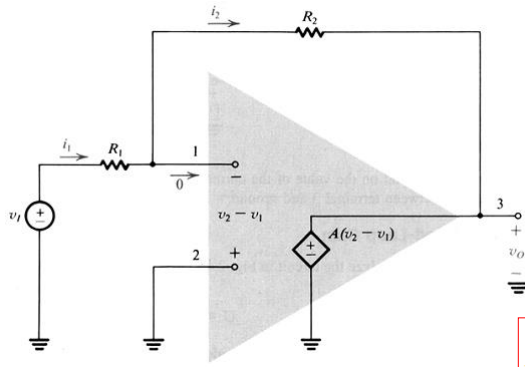






Amplificador Inversor ($A_0<\infty$)

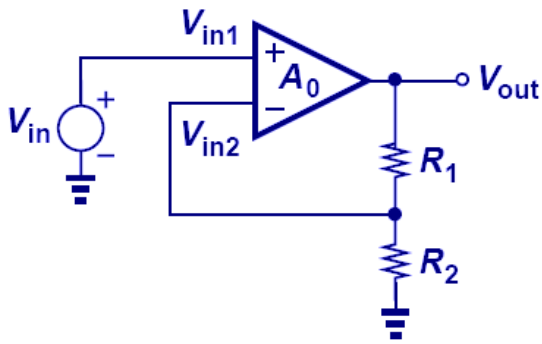
- Calcular o ganho.



$$A_v = \frac{v_O}{v_I} = \frac{-R_2/R_1}{1+(1+R_2/R_1)/A}$$

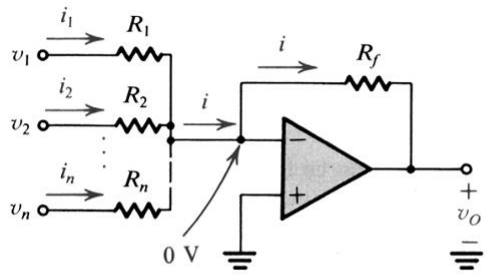
Amplificador Não Inversor ($A_0<\infty$)

- Calcular o ganho.



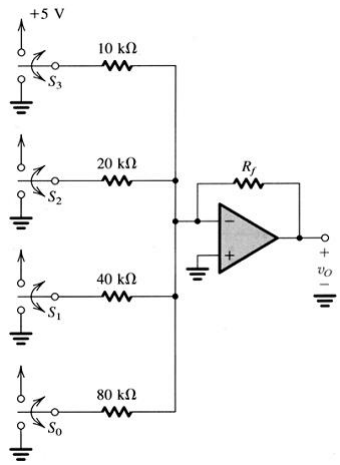
$$\frac{V_{out}}{V_{in}} = \frac{A_0}{1 + \frac{R_2}{R_1 + R_2} A_0}$$

Somador Inversor



$$v_O = -\left(\frac{R_f}{R_1} v_1 + \frac{R_f}{R_2} v_2 + \cdots + \frac{R_f}{R_n} v_n \right)$$

Determine v_o



$$-vo = \frac{R_f}{80}v_0 + \frac{R_f}{40}v_1 + \frac{R_f}{20}v_2 + \frac{R_f}{10}v_3$$

$$vo = -R_f\left(\frac{1}{80}v_0 + \frac{1}{40}v_1 + \frac{1}{20}v_2 + \frac{1}{10}v_3\right)$$

$$vo = R_f\left(\frac{v_0 + 2v_1 + 4v_2 + 8v_3}{80}\right)$$

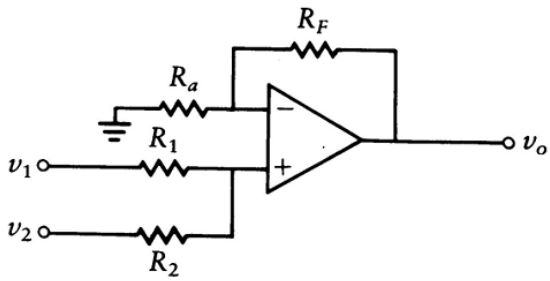
$$vo = R_f\left(\frac{2^0v_0 + 2^1v_1 + 2^2v_2 + 2^3v_3}{5 * 2^4}\right)$$

$$vo = R_f 5\left(\frac{2^0a_0 + 2^1a_1 + 2^2a_2 + 2^3a_3}{5 * 2^4}\right)$$

$$v_O = -\frac{R_f}{16}\left[2^0a_0 + 2^1a_1 + 2^2a_2 + 2^3a_3\right]$$

Conversor D/A

Somador não inversor



PARA CASA:
Prove que:

$$v_o = (R_1 \| R_2)\left(\frac{v_1}{R_1} + \frac{v_2}{R_2}\right)\left(1 + \frac{R_F}{R_a}\right)$$

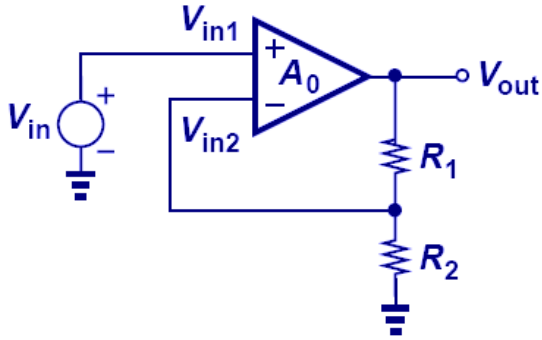
$$R_{I1} = R_1 + R_2$$

$$R_{I2} = R_2 + R_1$$

Amplificador Não Inversor ($A_0<\infty$)

- Calcular o ganho.

PARA NOTA



$$\frac{V_{out}}{V_{in}} = \frac{A_0}{1 + \frac{R_2}{R_1 + R_2} A_0}$$

Fontes de figuras da aula

- Aula do prof. Fabiano Fruett
- Fundamentos de Microeletrônica (Razavi)
- Microeletrônica (Sedra)
- Electronic Design - Circuits and Systems (Savant)

Sugestão de estudo

- Razavi, cap. 8
- Sedra/Smith, cap. 2
- Sedra/Smith, cap. 8
- Savant, cap. 8