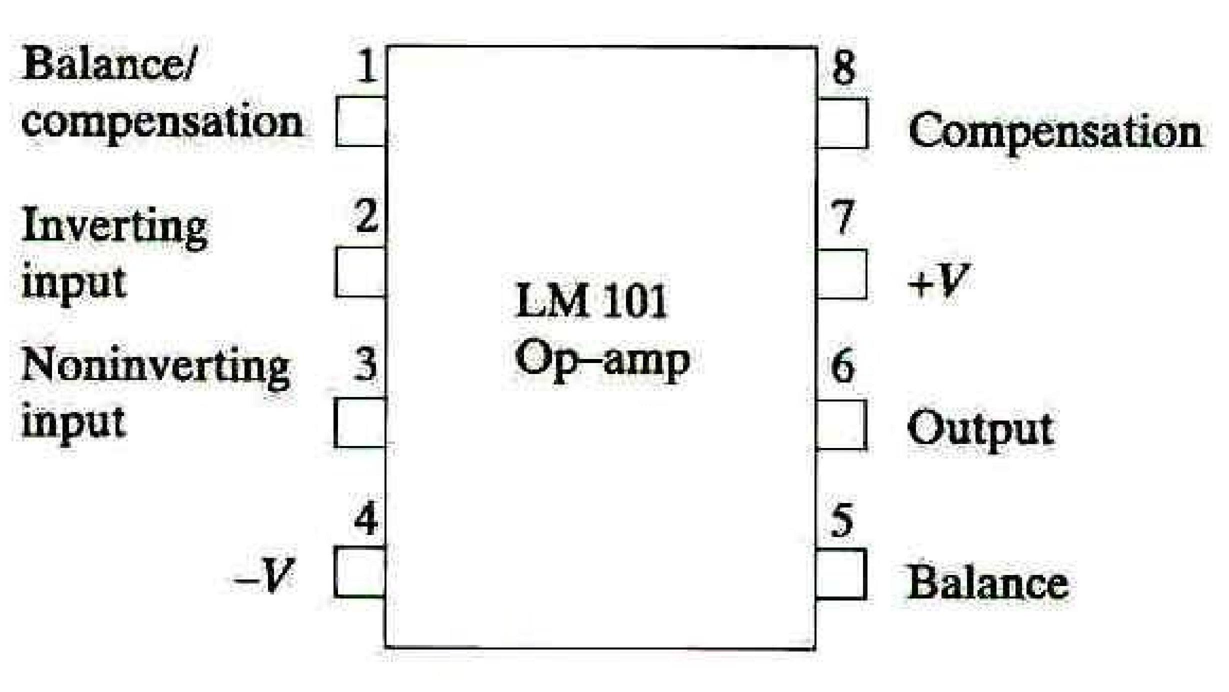
CIRCUITOS COM AMPOPS (Amp. Operacional)

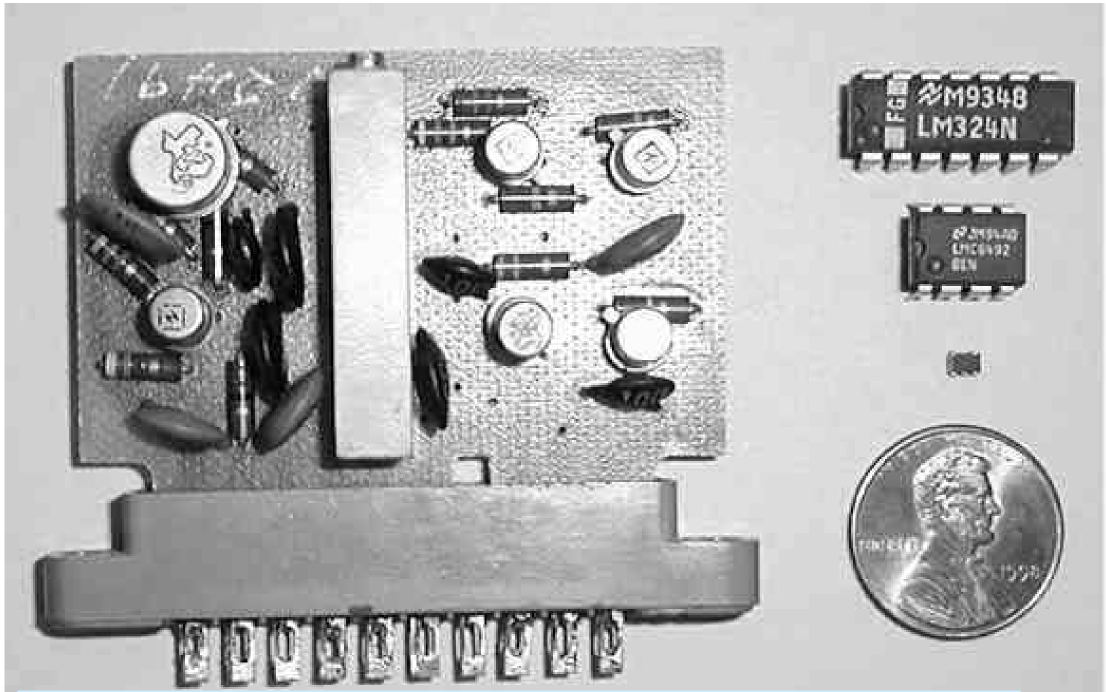
1. AmPops são elementos muito úteis !

2. Já conhecemos todas as ferramentas necessárias para Fazer a análise de circuitos com AmPops

3. O modelo do ampop inclui fontes dependentes

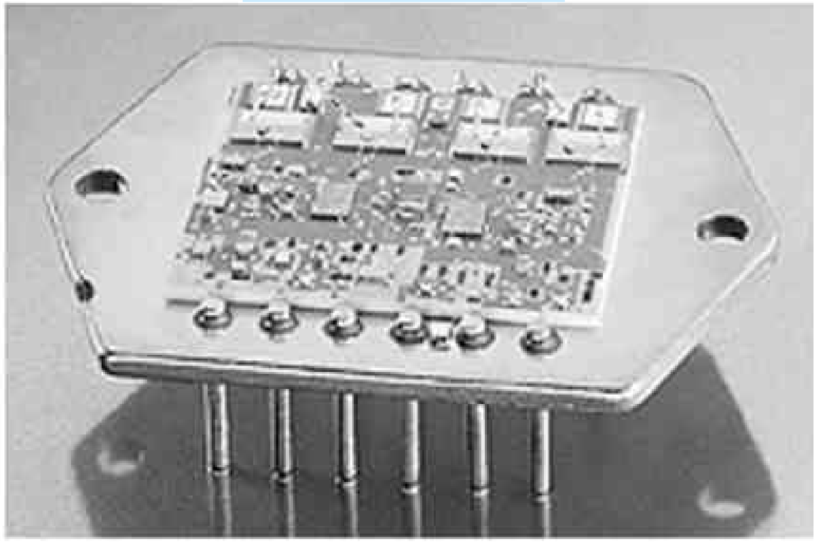


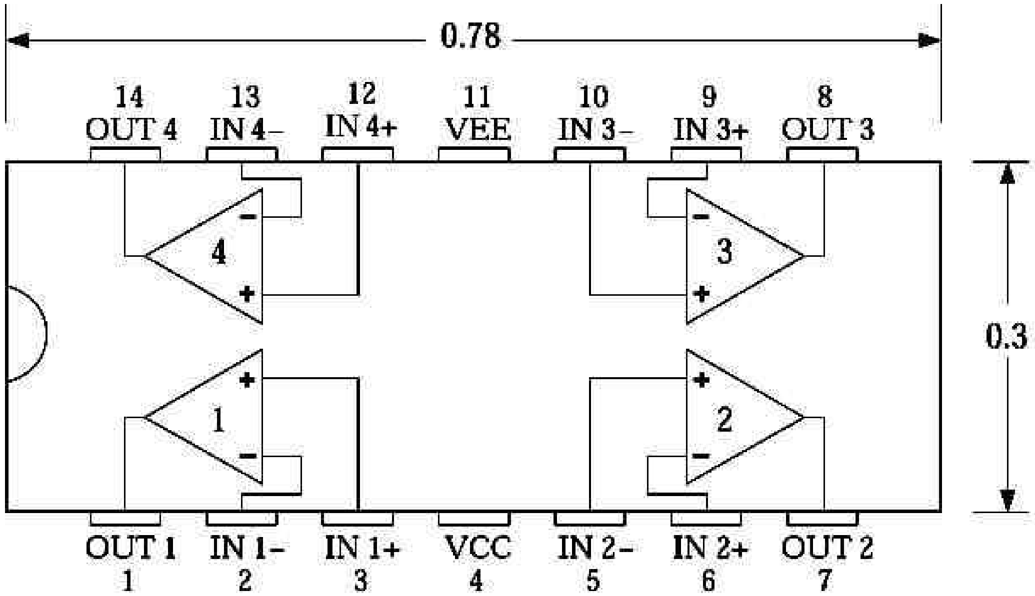
COMMERCIAL PACKAGING DOS AMP-OP



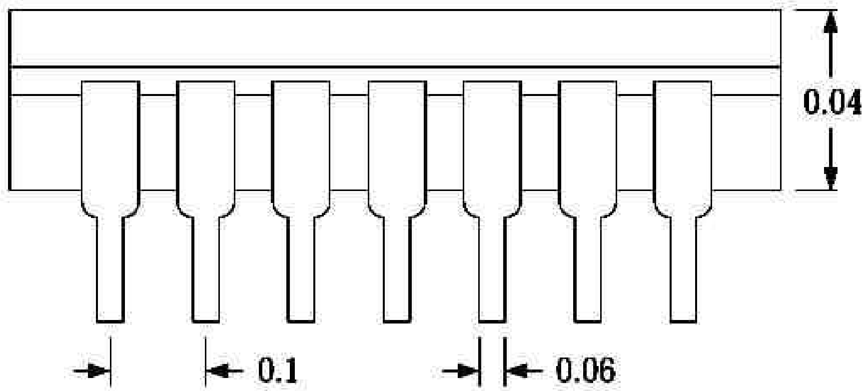
OP-AMP ASSEMBLED ON PRINTED CIRCUIT BOARD

LMC 6294 DIP



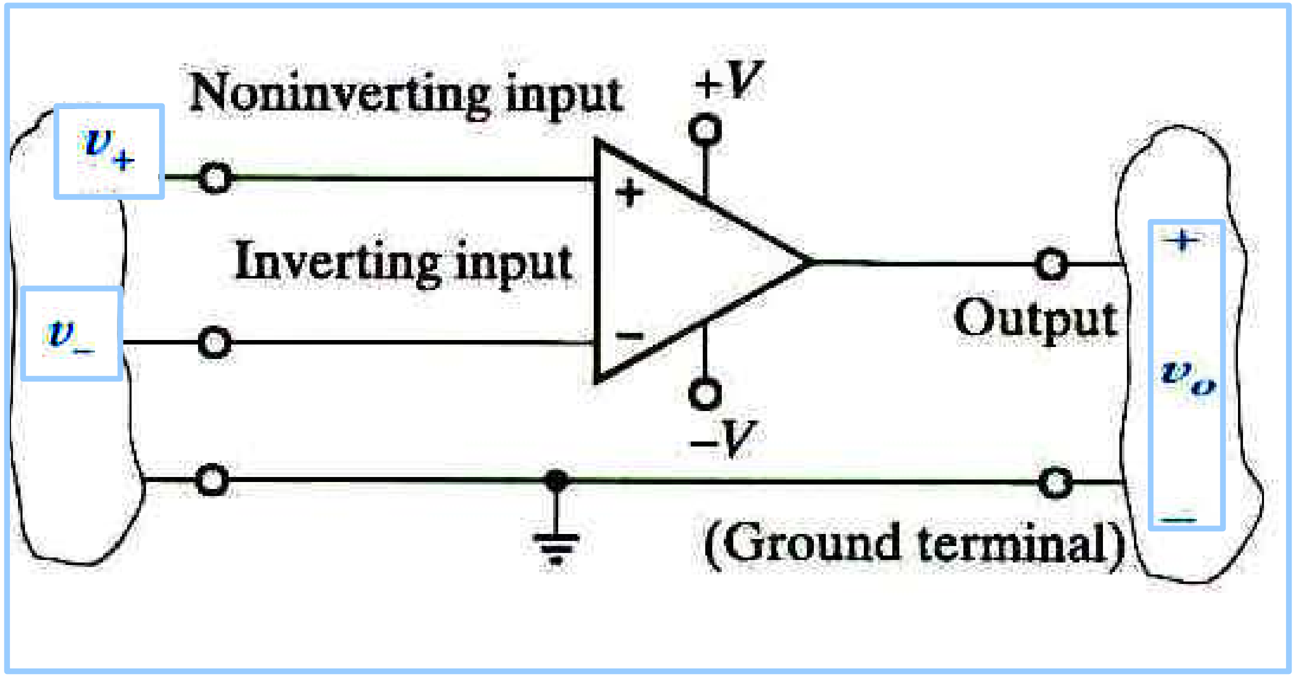


PIN OUT FOR LM324

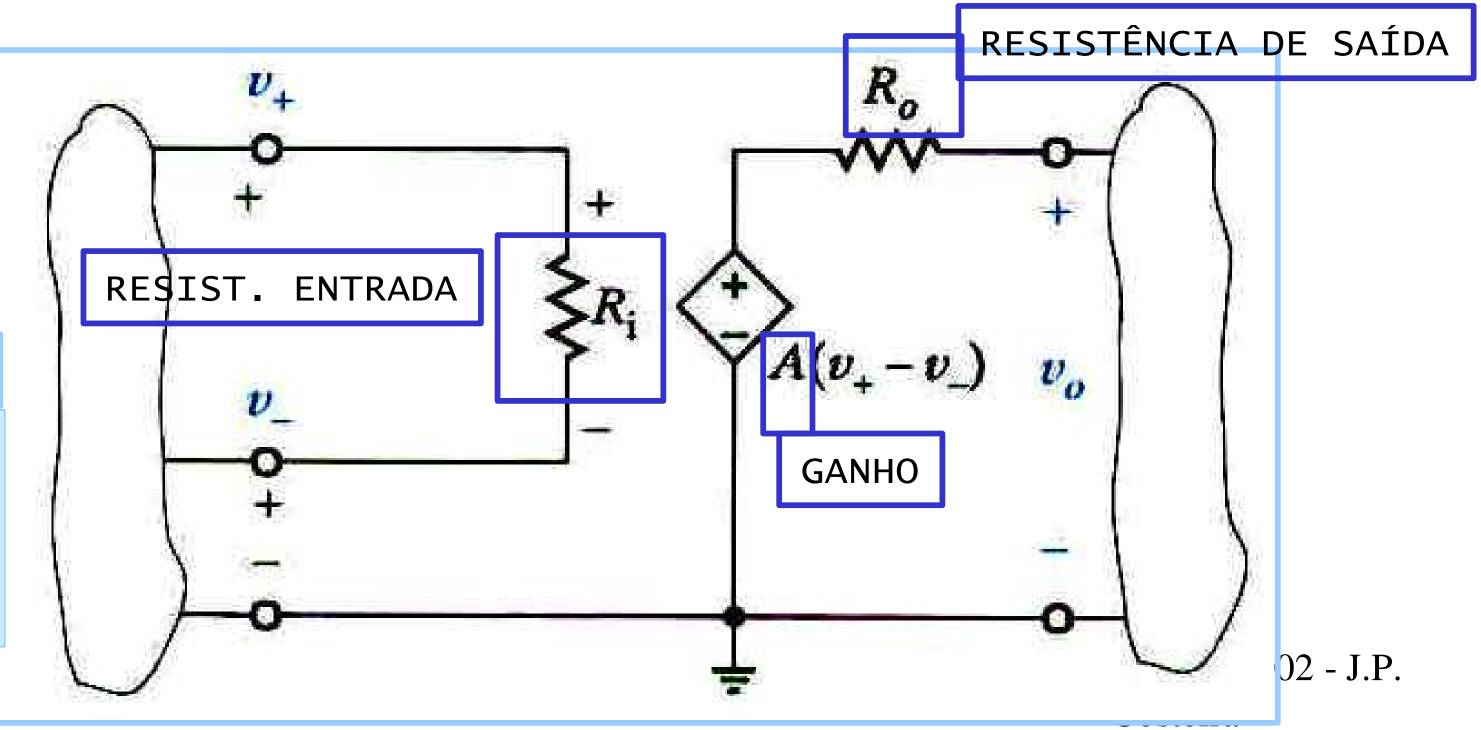


DIMENSIONAL DIAGRAM LM 324

SÍMBOLO DO AMPOP



MODELO LINEAR



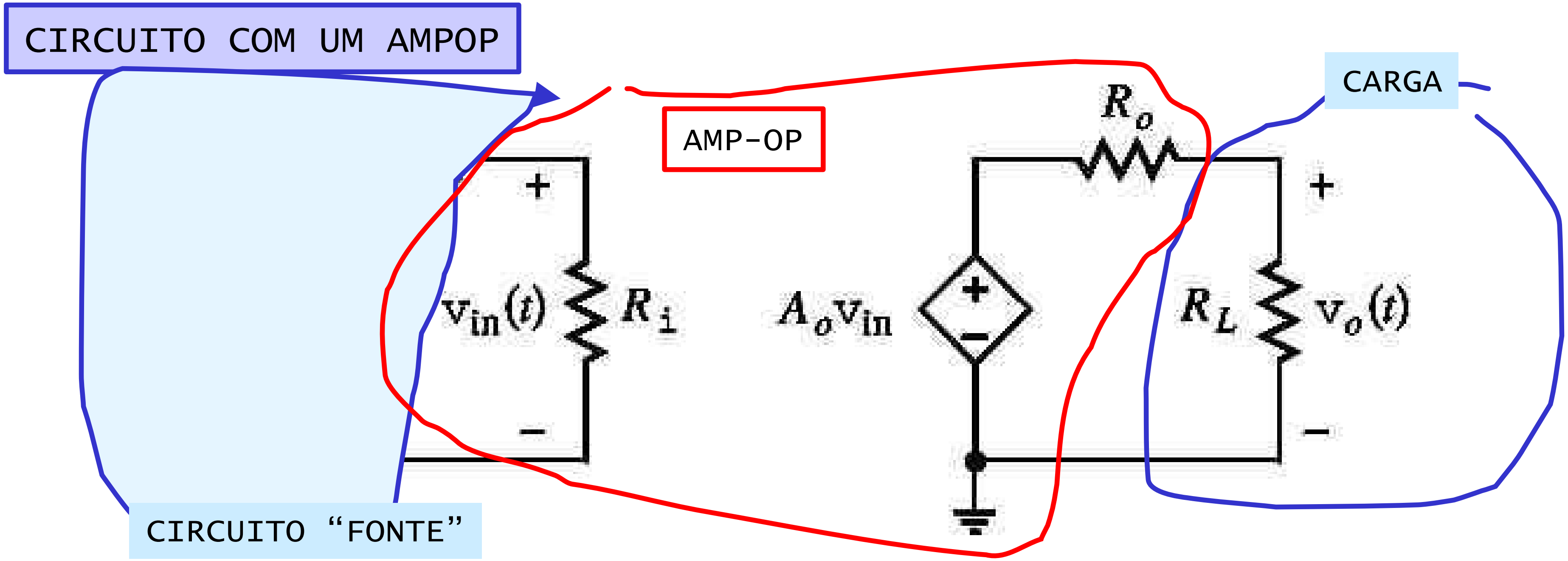
VALORES TÍPICOS

R_i : $10^5\Omega - 10^{12}\Omega$

R_O : $1\Omega - 50\Omega$

$A : 10^5 - 10^7$

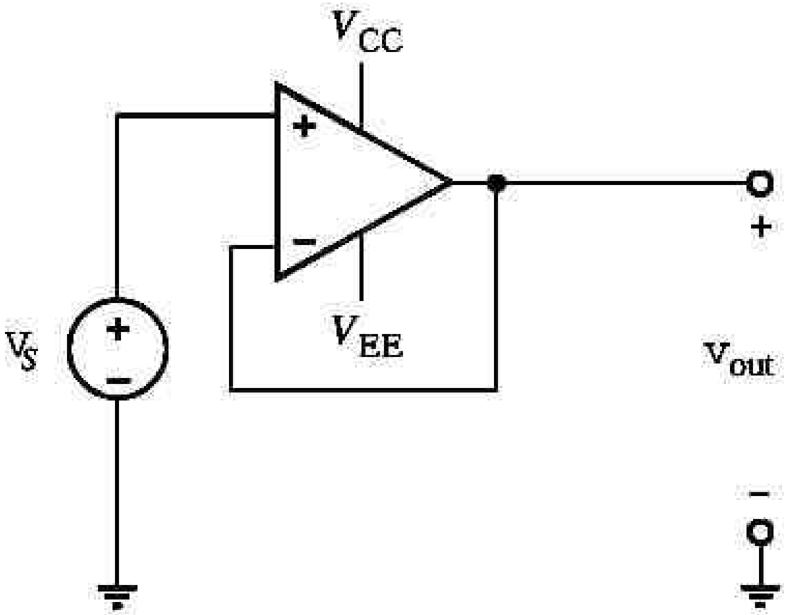
CIRCUITO COM UM AMPOP

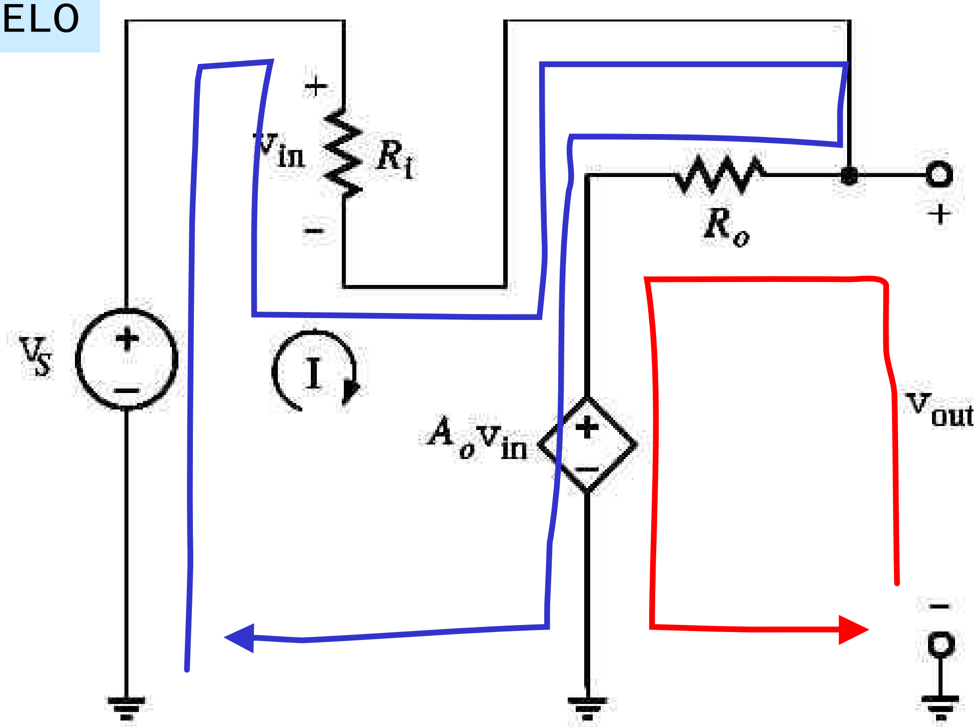


AMPOPS COMERCIAIS E ALGUNS VALORES DAS VARIÁVEIS

MANUFACTURER	PART No	A	Ri[MOhm]	Ro[Ohm]
National	LM324	100,000	1	20
National	LMC6492	50,000	10	150
Maxim	MAX4240	20,000	45	160

SEGUIDOR DE TENSÃO: CIRCUITO E MODELO





$\boxed{\text{KVL}: \; -V_s + R_i I + R_O I + A_O V_{in} = 0}$

$\boxed{\text{KVL}: \; -V_{out} + R_O I + A_O V_{in} = 0}$

VARIÁVEL DE CONTROLO: $V_{in} = R_i I$

PORQUÊ O SEGUIDOR?

PERFORMANCE OF REAL OP-AMPS

Op-Amp	BUFFER GAIN
LM324	0.99999
LMC6492	0.9998
MAX4240	0.99995

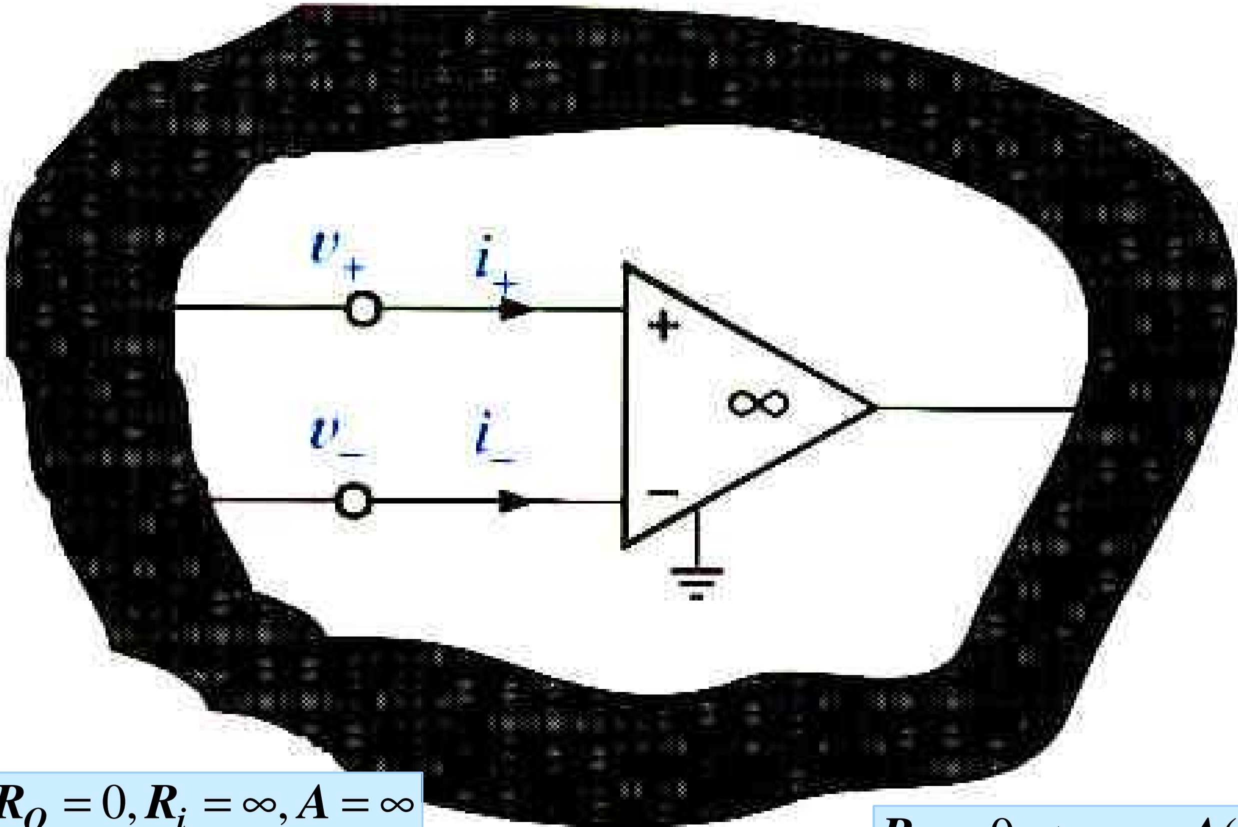
GANHO

RESOLVENDO

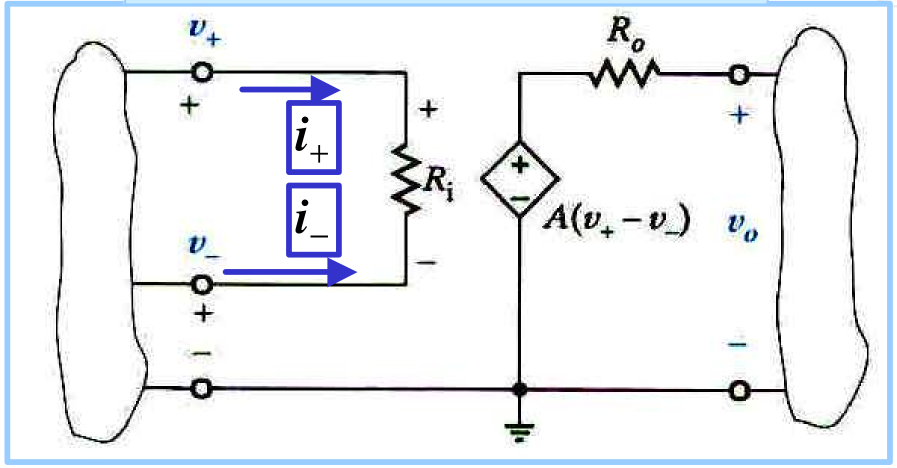
$$\frac{V_{out}}{V_s} = \frac{1}{1 + \dfrac{R_i}{R_o + A_o R_i}}$$

$$A_O \to \infty \Rightarrow \frac{V_{out}}{V_S} \to 1$$

O AMPOP IDEAL



IDEAL $\Rightarrow R_O = 0, R_i = \infty, A = \infty$

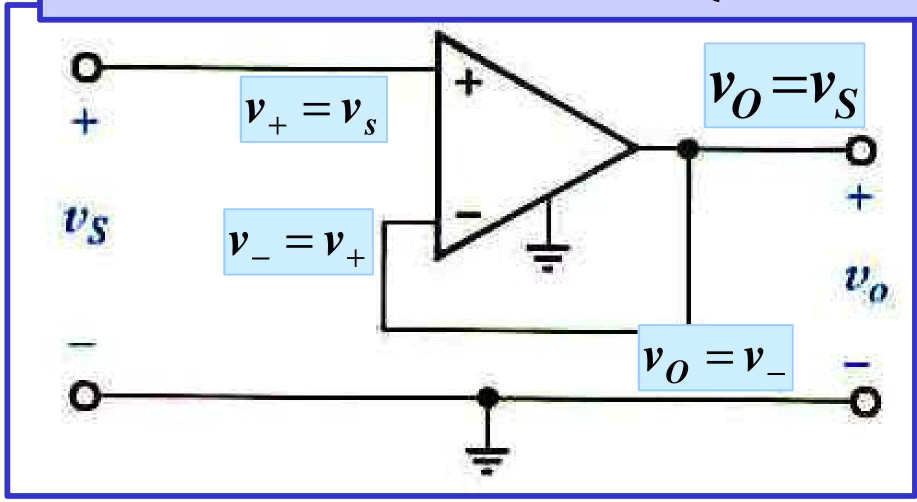


$R_O = 0 \Rightarrow v_O = A(v_+ - v_-)$

$R_i = \infty \Rightarrow \boxed{i_+ = i_- = 0}$

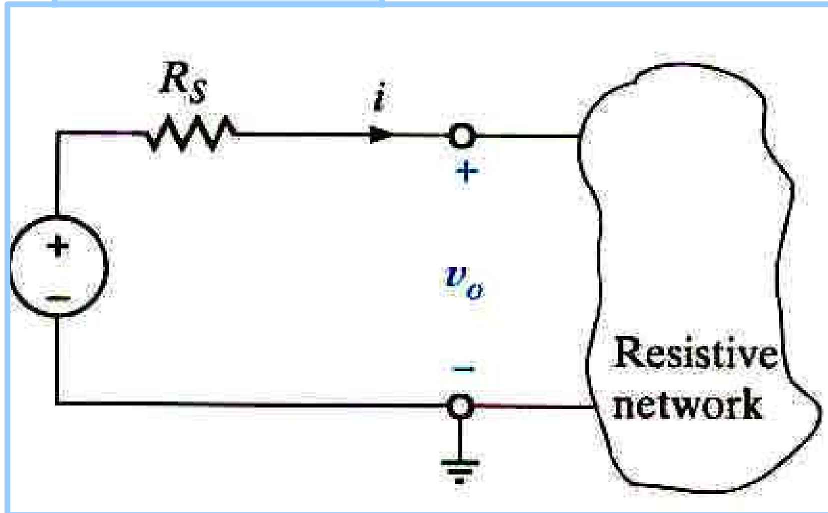
$A = \infty \Rightarrow \boxed{v_+ = v_-}$

SEGUIDOR DE TENSÃO – (UNITY GAIN BUFFER)

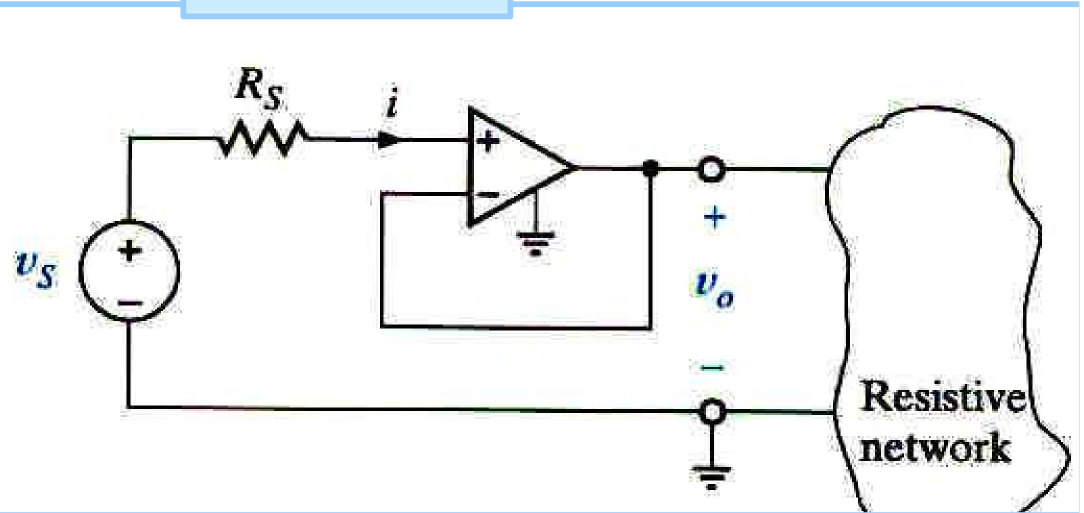


SEGUIDOR DE TENSÃO ISOLA OS DOIS CIRCUITOS.
MUITO ÚTIL PARA FONTES DE MUITO BAIXA POTÊNCIA.

SEM SEGUIDOR



COM SEGUIDOR



$$v_o = v_S - iR_S$$

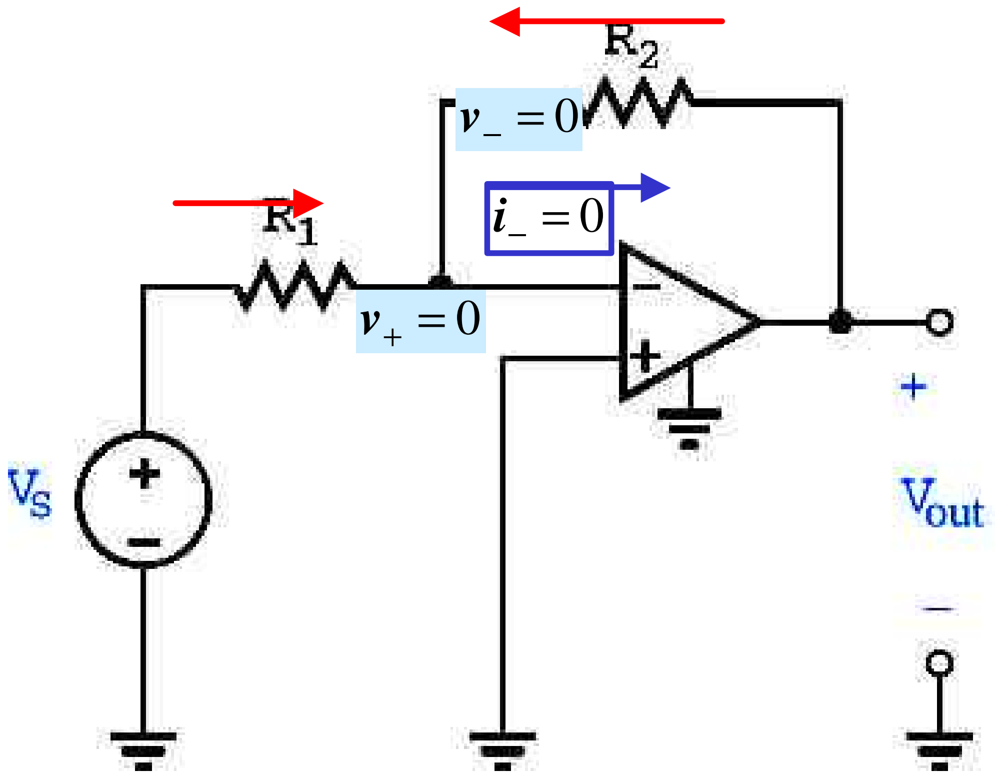
A FONTE FORNECE POTÊNCIA

$$v_O = v_S$$

NÃO HÁ FORNECIMENTO DE POT.

EXEMPLO:USANDO AMPOP IDEAL

CALCULAR O GANHO $G = \frac{V_{out}}{V_s}$

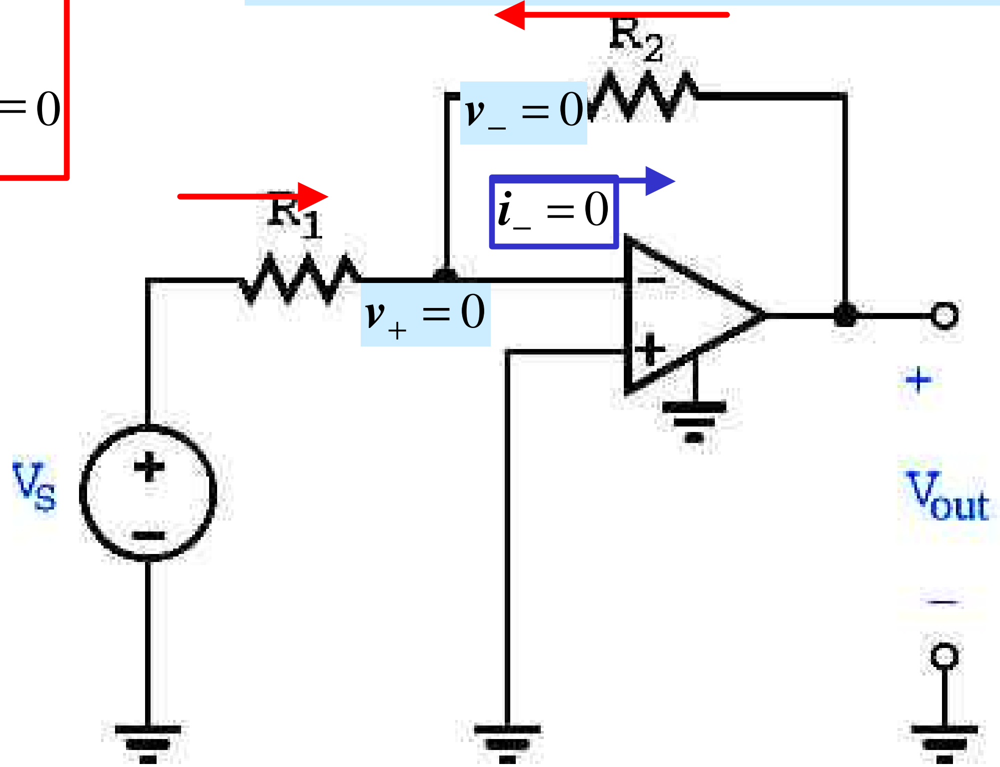


EXEMPLO:USANDO AMPOP IDEAL

CALCULAR O GANHO $G = \frac{V_{out}}{V_s}$

KCL @ v-

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



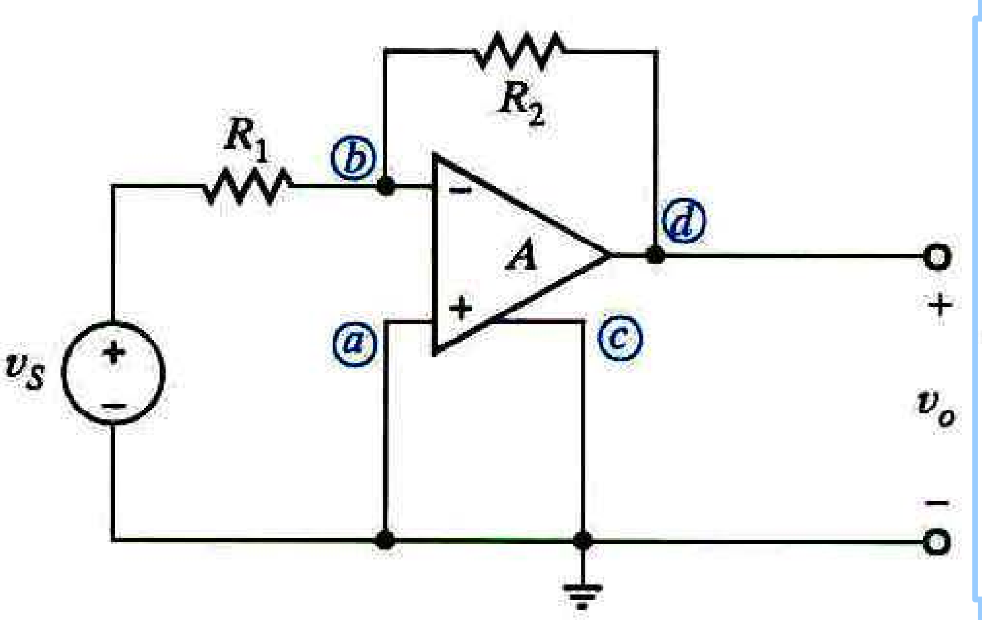
$$A_o = \infty \Rightarrow v_+ = v_- \;\therefore v_- = 0$$

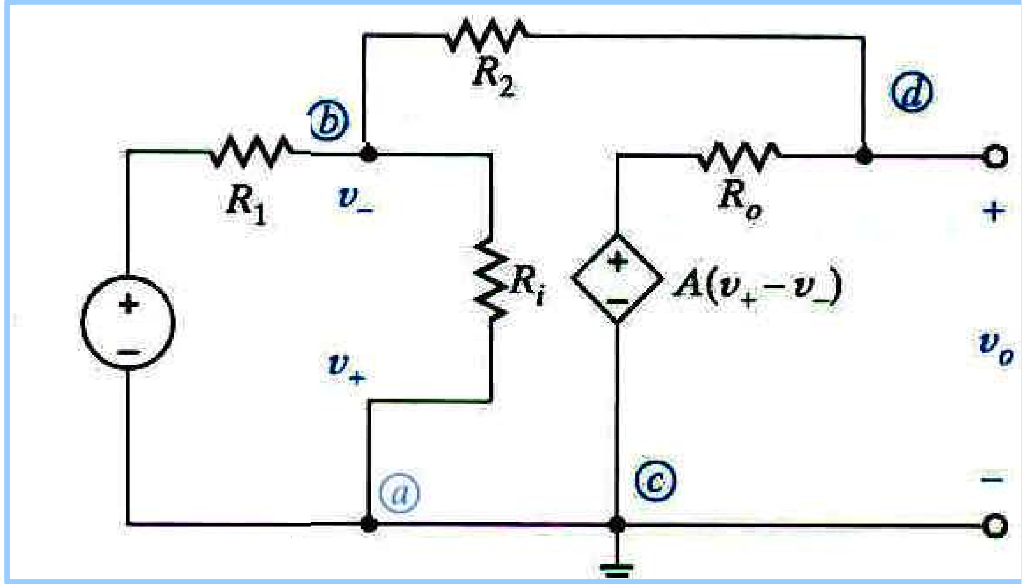
$$R_i = \infty \Rightarrow i_- = i_+ = 0$$

$$G = \frac{V_{out}}{V_s} = -\frac{R_2}{R_1}$$

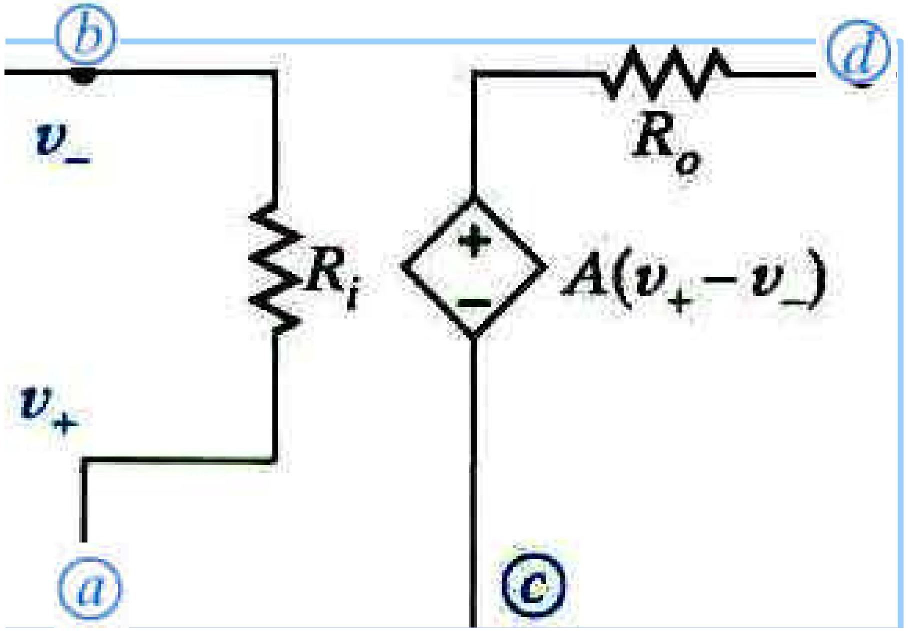
MODELO LINEAR DO AMPOP – “MODELO REAL”

LIGANDO OS OUTROS COMPONENTES.

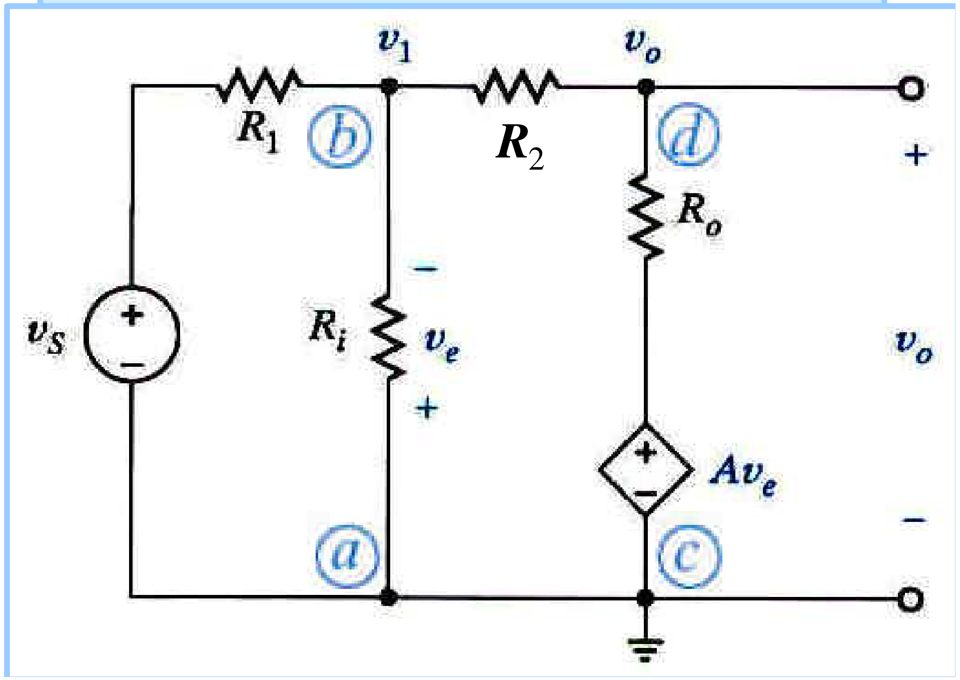




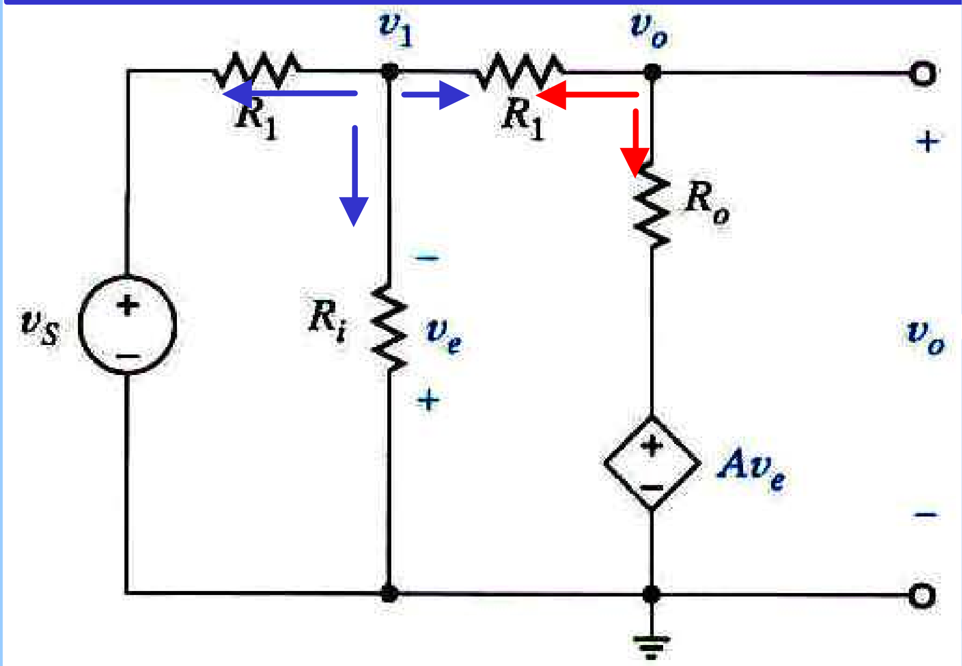
MODELO LINEAR :



FAZENDO “REFRESH” AO DESENHO!!!!!!



AMPLIFICADOR INVERSOR: ANÁLISE C/ MODELO REAL



MÉTODO DOS NÓS

$$\frac{v_1 - v_S}{R_1} + \frac{v_1}{R_i} + \frac{v_1 - v_o}{R_2} = 0$$

$$\frac{v_o - v_1}{R_2} + \frac{v_o - Av_e}{R_o} = 0$$

VARIÁVEL DE CONTROLO FUNÇÃO DAS TENSÕES NOS NÓS:

$$v_e = -v_1$$

$$A = 10^5,$$

$$R_i = 10^8\Omega, R_O = 10\Omega$$

RECORRENDO À ALGEBRA…

$$\begin{bmatrix} \frac{1}{R_1} + \frac{1}{R_i} + \frac{1}{R_2} & -\left(\frac{1}{R_2}\right) \\ -\left(\frac{1}{R_2} - \frac{A}{R_o}\right) & \frac{1}{R_2} + \frac{1}{R_o} \end{bmatrix} \begin{bmatrix} v_1 \\ v_0 \end{bmatrix} = \begin{bmatrix} \frac{v_S}{R_1} \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} v_1 \\ v_0 \end{bmatrix} = \frac{1}{\Delta} \begin{bmatrix} \frac{1}{R_2} + \frac{1}{R_o} & \frac{1}{R_2} \\ \frac{1}{R_2} - \frac{A}{R_o} & \frac{1}{R_1} + \frac{1}{R_i} + \frac{1}{R_o} \end{bmatrix} \begin{bmatrix} \frac{v_S}{R_1} \\ 0 \end{bmatrix}$$

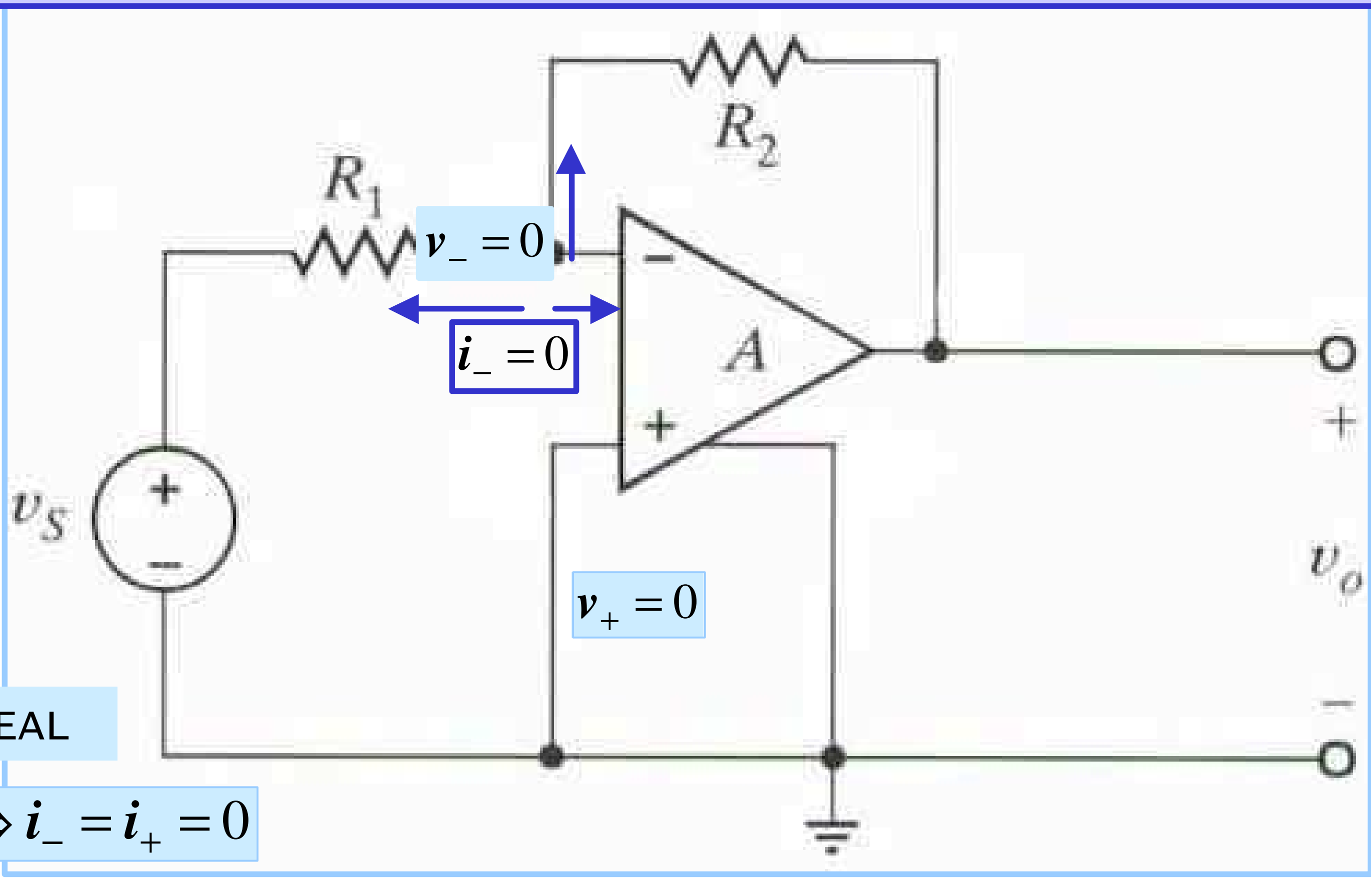
$$\Delta = \left(\frac{1}{R_1} + \frac{1}{R_i} + \frac{1}{R_2}\right)\left(\frac{1}{R_2} + \frac{1}{R_o}\right) - \left(\frac{1}{R_2}\right)\left(\frac{1}{R_2} - \frac{A}{R_o}\right)$$

$$v_o = \frac{\left(\frac{1}{R_2} - \frac{A}{R_o}\right)\left(\frac{v_S}{R_1}\right)}{\left(\frac{1}{R_1} + \frac{1}{R_i} + \frac{1}{R_2}\right)\left(\frac{1}{R_2} + \frac{1}{R_o}\right) - \left(\frac{1}{R_2}\right)\left(\frac{1}{R_2} - \frac{A}{R_o}\right)}$$

$$\frac{v_o}{v_S} = \frac{-(R_2/R_1)}{1 - \left[\left(\frac{1}{R_1} + \frac{1}{R_i} + \frac{1}{R_2}\right)\left(\frac{1}{R_2} + \frac{1}{R_o}\right) \Big/ \left(\frac{1}{R_2}\right)\left(\frac{1}{R_2} - \frac{A}{R_o}\right)\right]}$$

$$R_1 = 1k\Omega, R_2 = 5k\Omega \Rightarrow \frac{v_O}{v_S} = -4.9996994 \qquad A = \infty \Rightarrow \frac{v_O}{v_S} = -5.000$$

EM RESUMO: O AMPLIFICADOR INVERSOR USANDO AMPOP IDEAL VERSUS O LINEAR …



AMPOP IDEAL

$$R_i = \infty \Rightarrow i_- = i_+ = 0$$

$$A = \infty \Rightarrow v_+ = v_-$$

KCL @ TERMINAL INVERSOR

$$\frac{0 - v_S}{R_1} + \frac{0 - v_O}{R_2} = 0$$

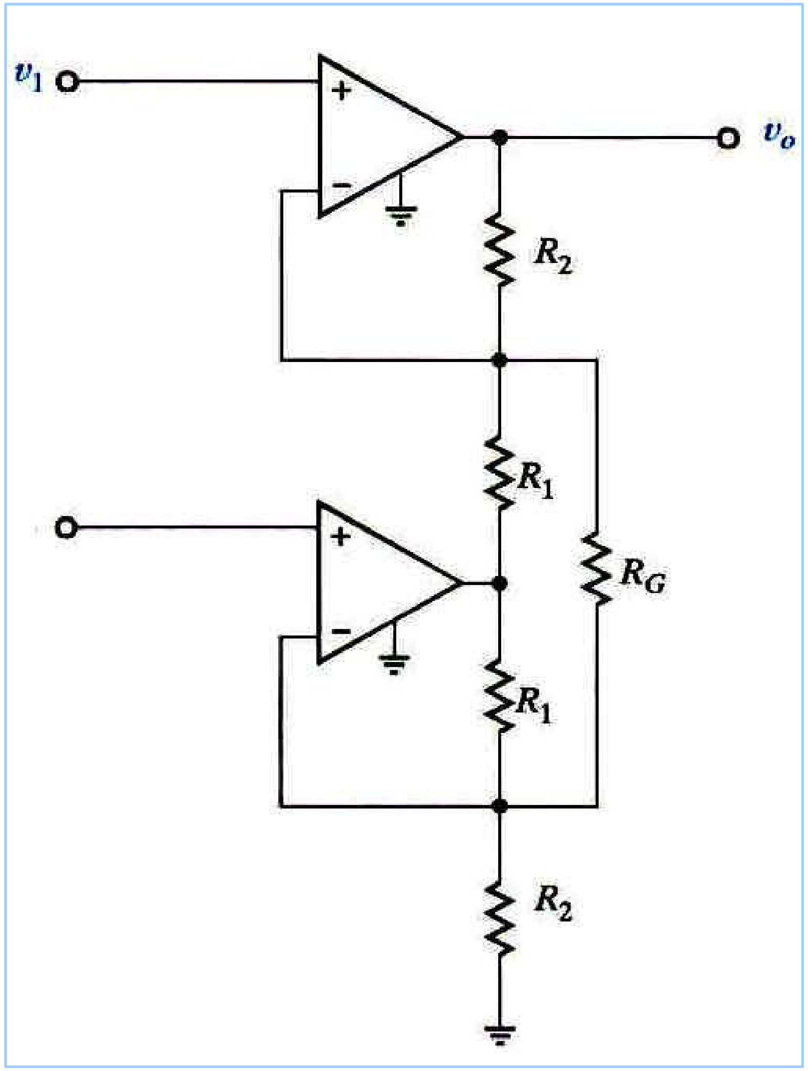
$$\Rightarrow \frac{v_O}{v_s} = -\frac{R_2}{R_1}$$

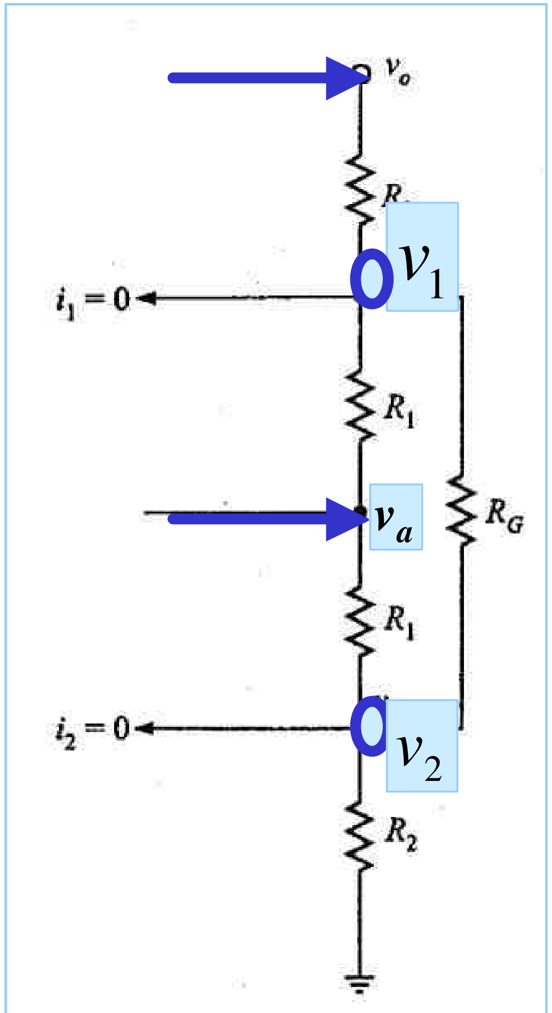
CASO NÃO IDEAL

$$\frac{v_o}{v_S} = \frac{-(R_2/R_1)}{1 - \left[\left(\frac{1}{R_1} + \frac{1}{R_i} + \frac{1}{R_2}\right)\left(\frac{1}{R_2} + \frac{1}{R_o}\right) \Big/ \left(\frac{1}{R_2}\right)\left(\frac{1}{R_2} - \frac{A}{R_o}\right)\right]}$$

O AMPOP IDEAL É UMA EXCELENTE APROXIMAÇÃO.
EXCEPTO QUANDO INDICADO UTILIZAREMOS SEMPRE O MODELO IDEAL

EXEMPLO USANDO AMPOP IDEAL





CIRCUITO EQUIVALENTE

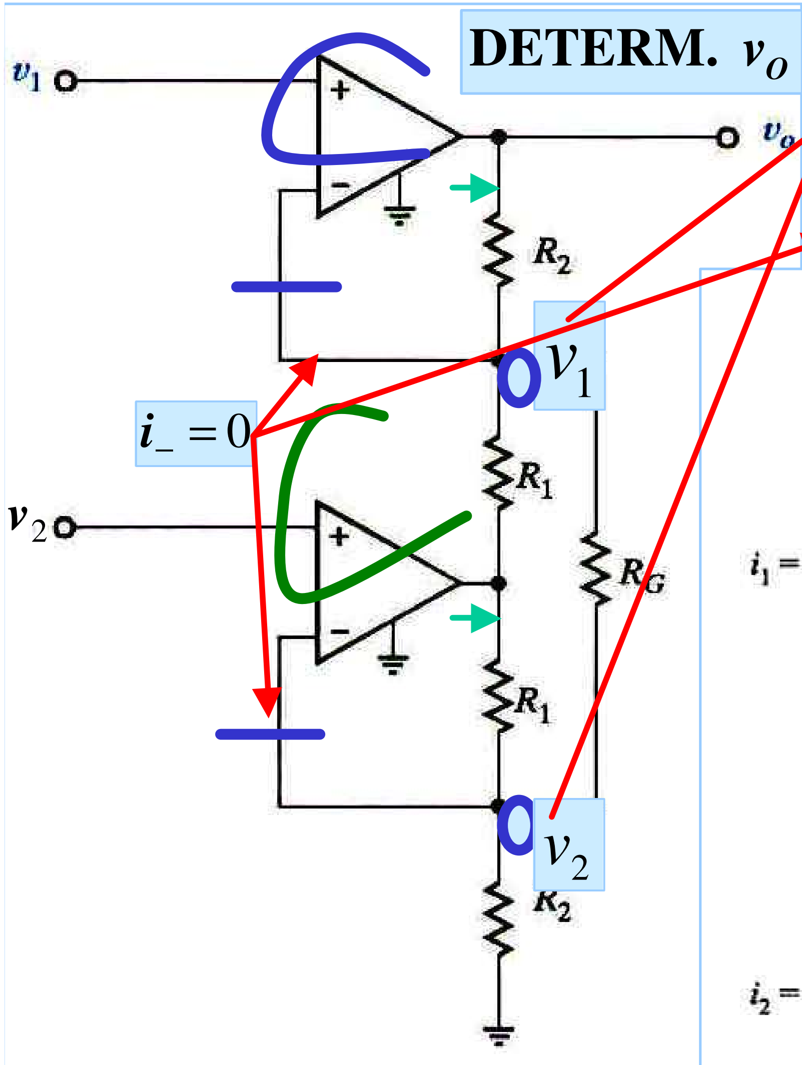
EXAMPLO USANDO AMPOP IDEAL

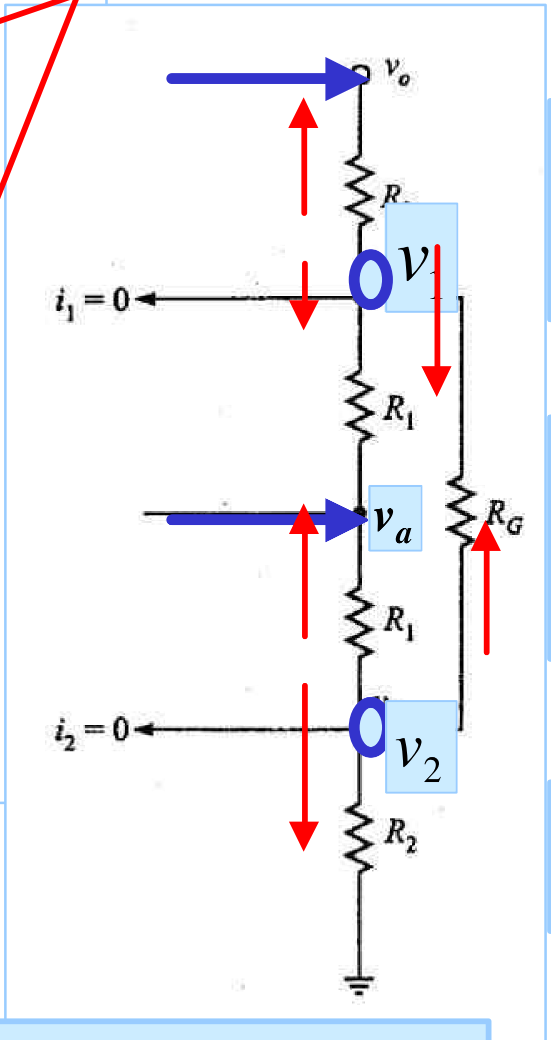
TENSÕES CONHECIDAS? $v_{+1} = v_1, v_{+2} = v_2$

DETERM. v_o

Ganho infinito

Resist. Ent. infinita





CIRCUITO EQUIVALENTE

HÁ CORRENTE A "SAIR" DOS AMPOPS

KCL@v1

$$\frac{v_1 - v_o}{R_2} + \frac{v_1 - v_a}{R_1} + \frac{v_1 - v_2}{R_G} = 0$$

KCL@v2

$$\frac{v_2 - v_a}{R_1} + \frac{v_2 - v_1}{R_G} + \frac{v_2}{R_2} = 0$$

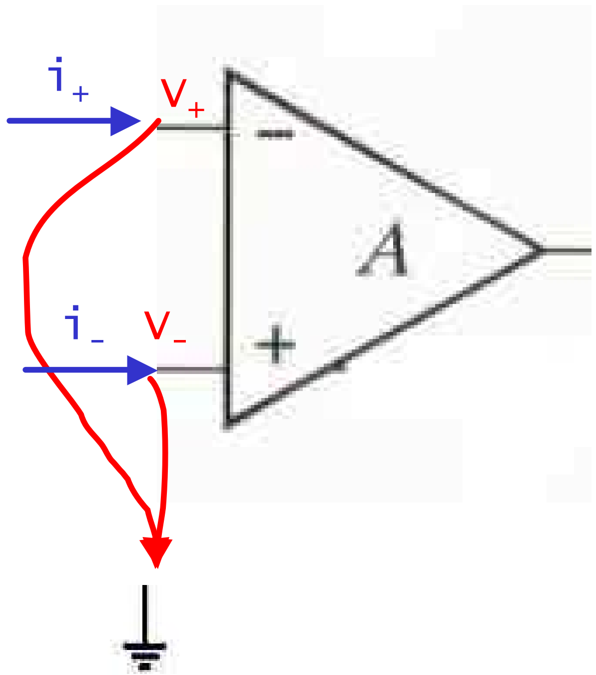
RESOLVENDO P/ vo

$$v_o = (v_1 - v_2)\left(1 + \frac{R_2}{R_1} + \frac{2R_2}{R_G}\right)$$

RESUMO (MUITO IMPORTANTE): AMPOP IDEAL

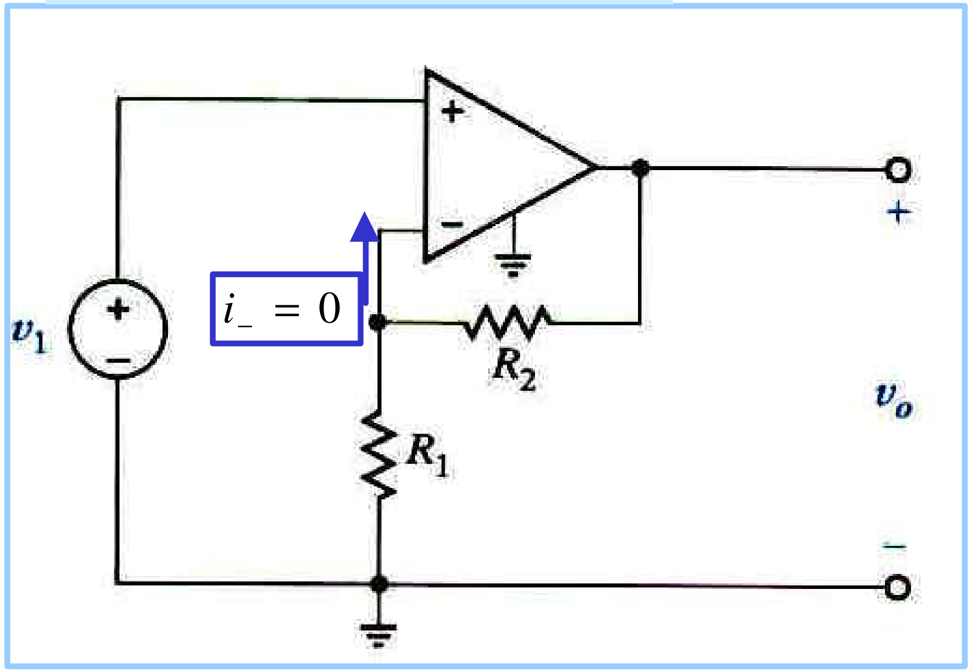
1 – GANHO INFINITO => $V_+ - V_- = 0$

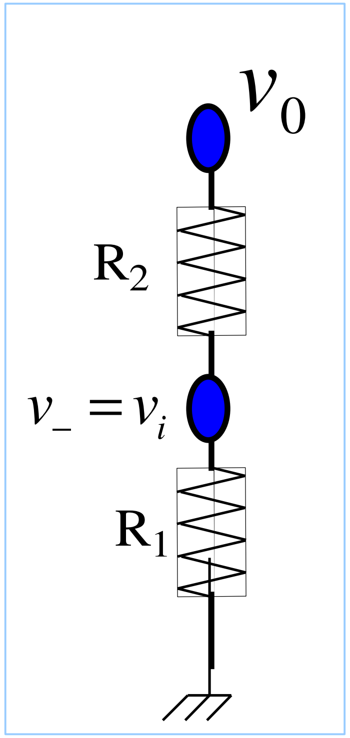
2 – RESISTÊNCIA DE ENTRADA INFINITA => $i_- = 0$ e $i_+ = 0$



MAIS EXEMPLOS

AMPLIFICADOR NÃO INVERSOR





TENSÕES CONHECIDAS $v_+ = v_1$

$$v_+ = v_1 \Rightarrow v_- = v_1$$

GANHO INFINITO

RESIST. ENTRADA INF.

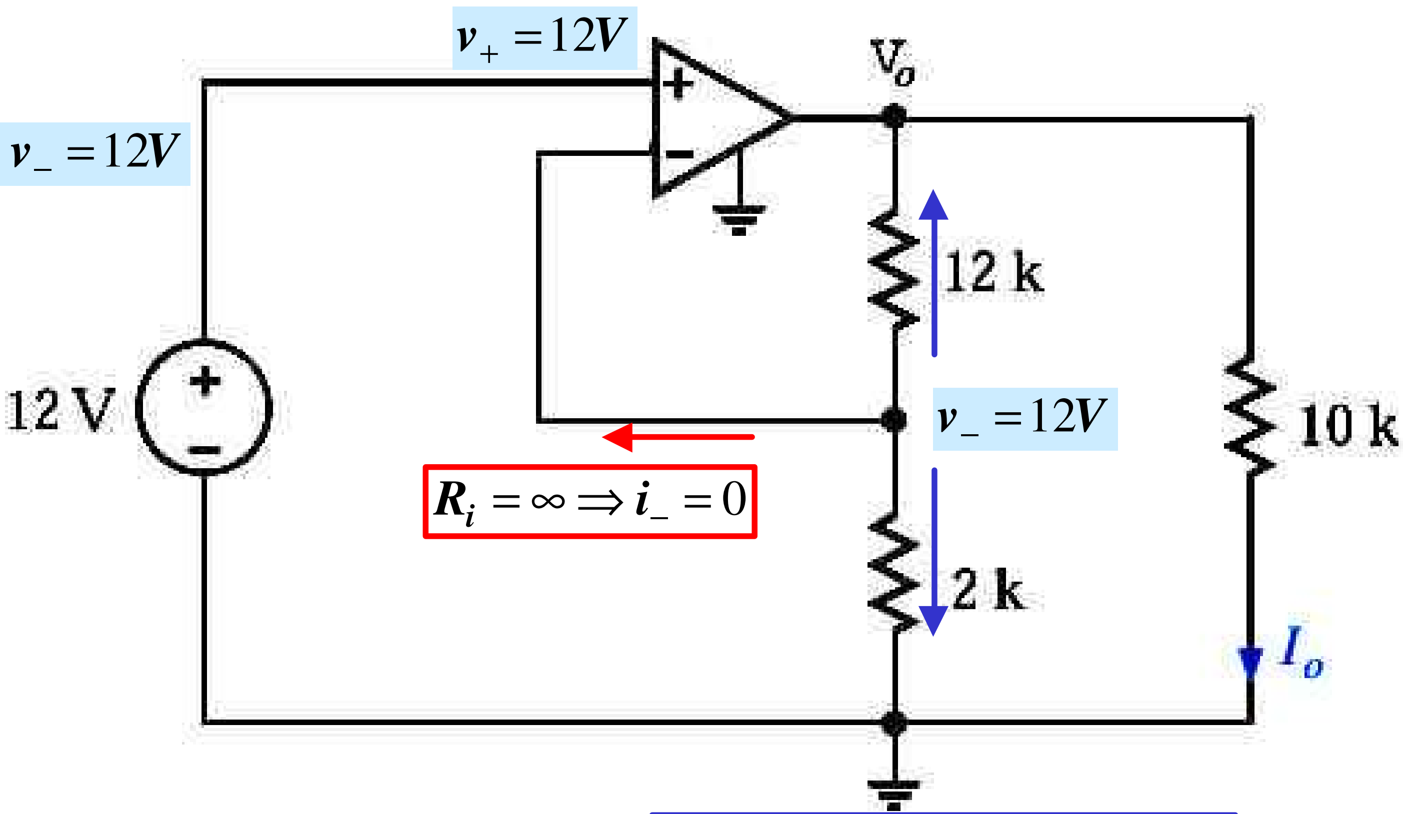
"DIVISOR DE TENSÃO INVERSO"

$$v_i = \frac{R_1}{R_1 + R_2} v_0 \Rightarrow v_0 = \frac{R_1 + R_2}{R_1} v_i$$

AINDA MAIS…

CALULE I_O. ASSUMINDO AMPOP IDEAL

$A_O = \infty \Rightarrow v_- = 12V$

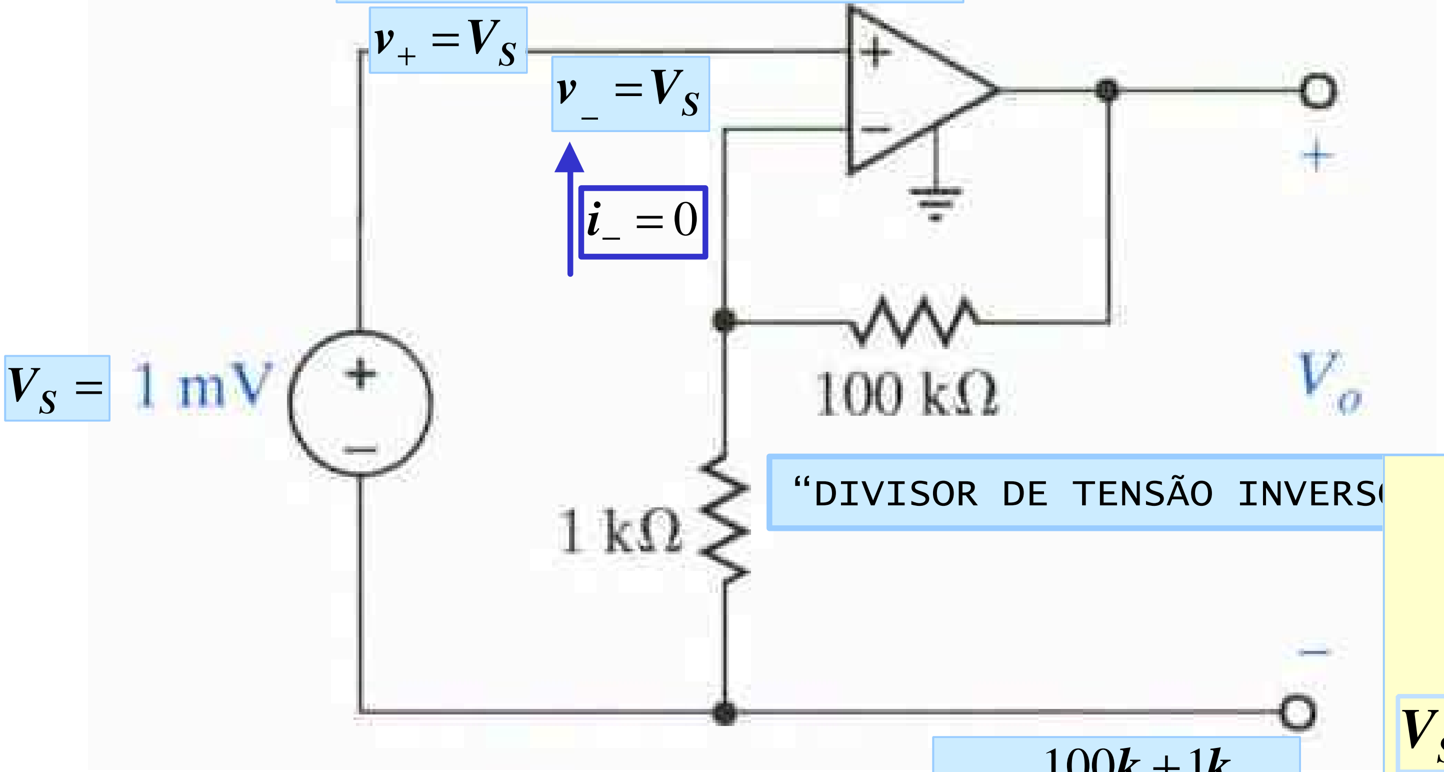


$$\text{KCL@ } v_- : \quad \frac{12 - V_o}{12k} + \frac{12}{2k} = 0 \Rightarrow V_o = 84V$$

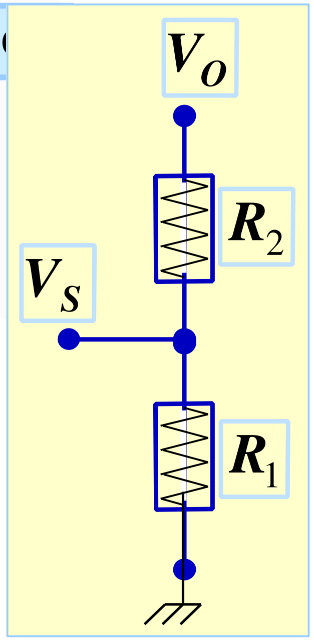
$$\therefore I_O = \frac{V_o}{10k} = 8.4mA$$

AMPLIFICADOR NÃO INVERSOR

CALCULAR GANHO E V_O



"DIVISOR DE TENSÃO INVERS

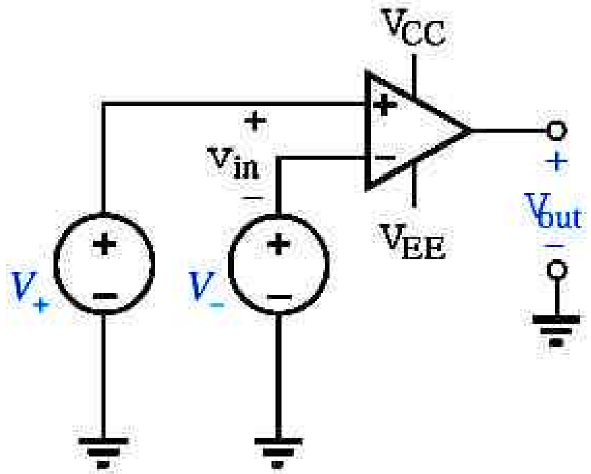


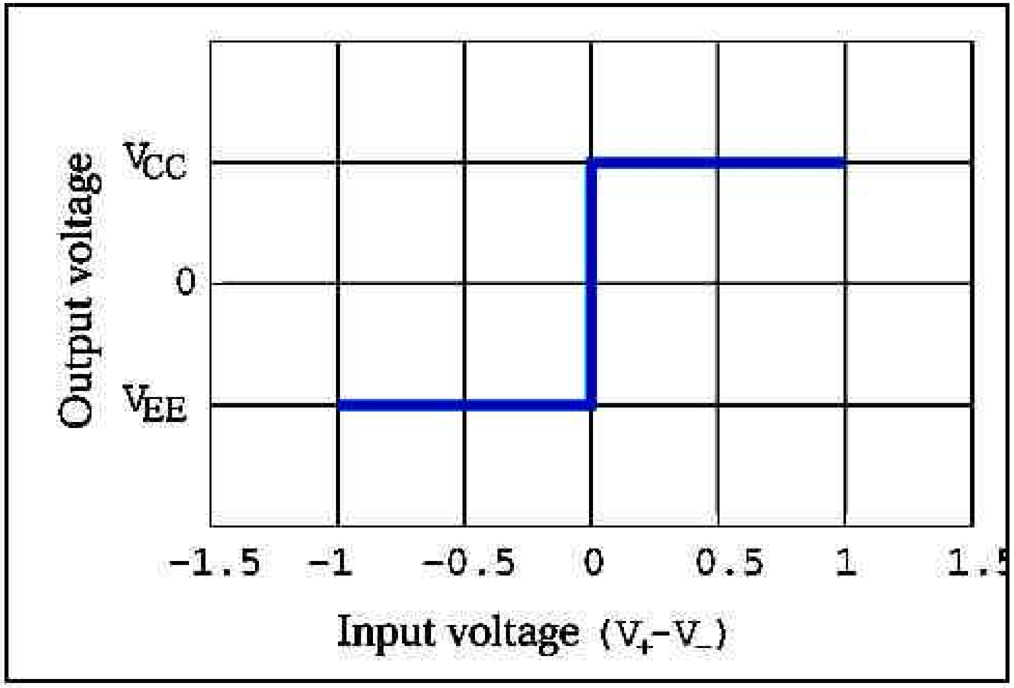
$$V_O = \frac{100k + 1k}{1k} V_S$$

$$G = \frac{V_O}{V_S} = 101$$

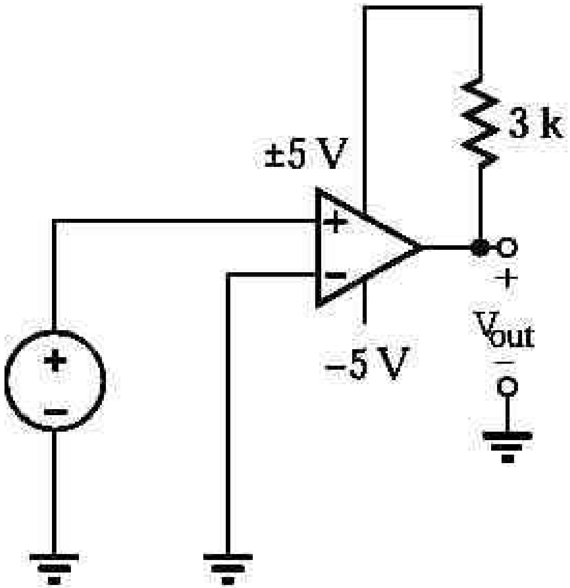
$$V_S = 1mV \Rightarrow V_O = 0.101V$$

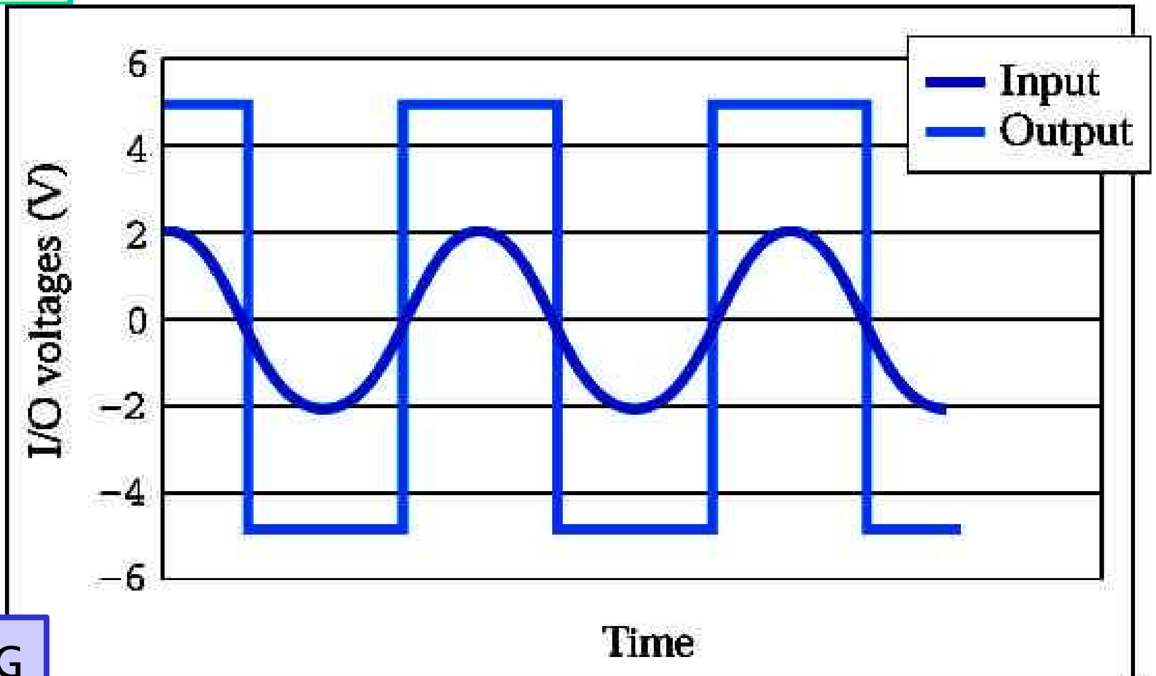
CIRCUITOS COMPARADORES





ALGUNS AMPOPS REAIS NECESSITAM UM “pull up resistor.”



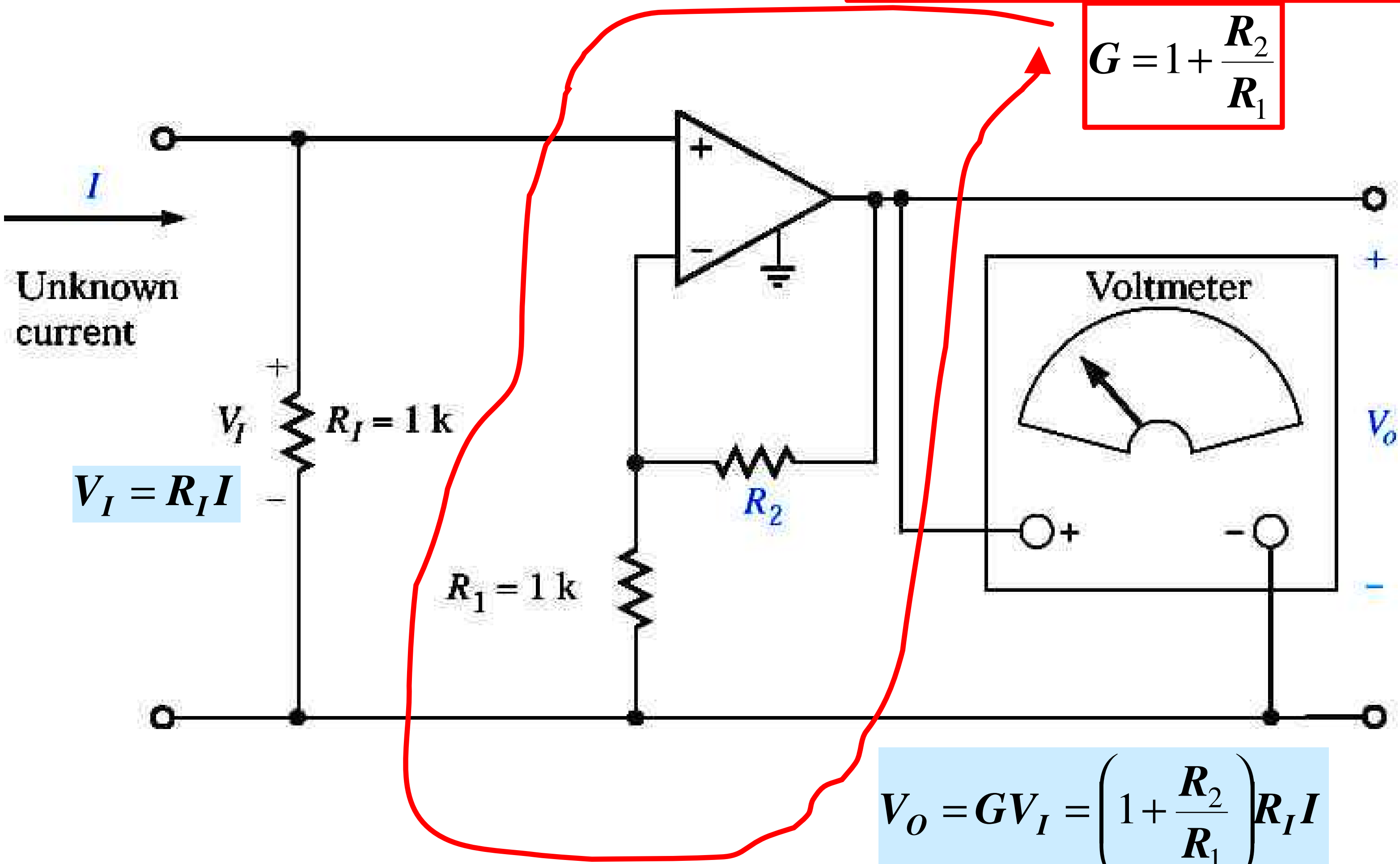


DETECTOR DE ZERO-CROSSING

APLICAÇÃO: AMPERÍMETRO

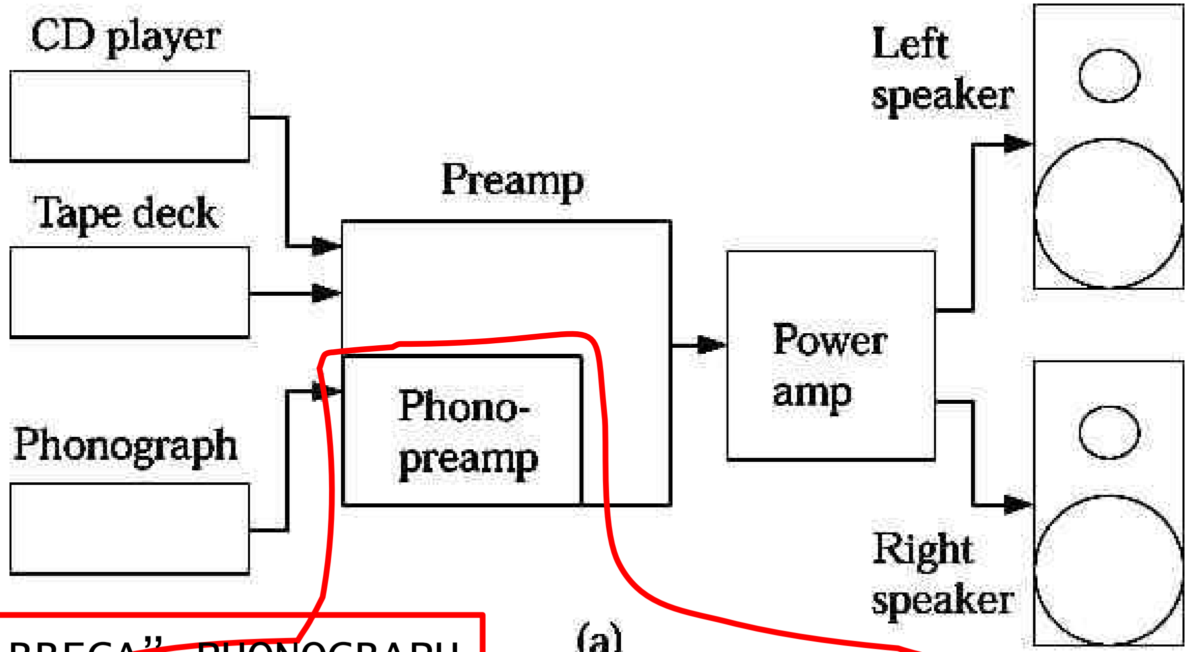
APLIFICADOR NÃO INVERSOR

$$G = 1 + \frac{R_2}{R_1}$$



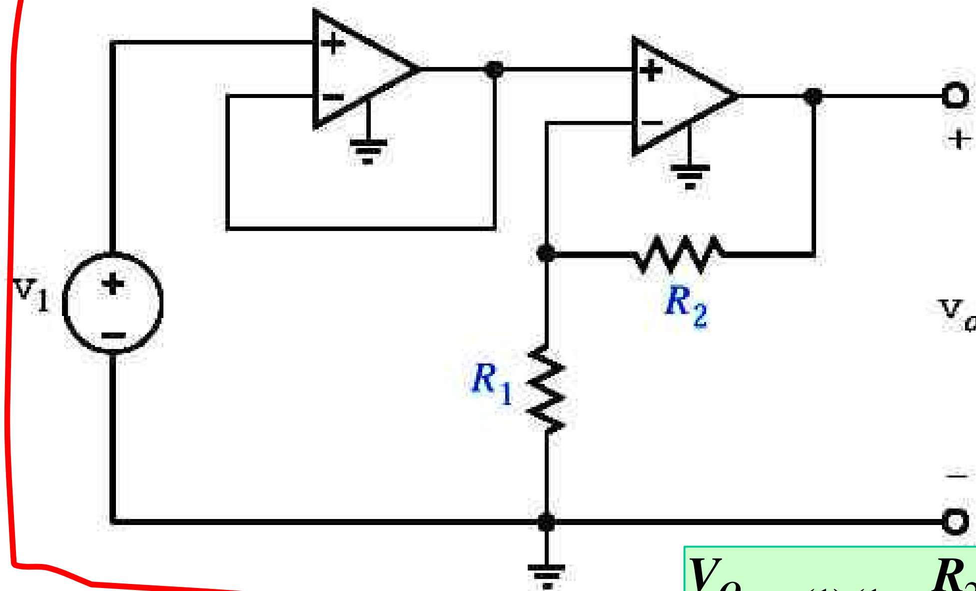
$$V_I = R_I I$$

$$V_O = G V_I = \left(1 + \frac{R_2}{R_1}\right) R_I I$$



NÃO "CARREGA" PHONOGRAPH

(a)



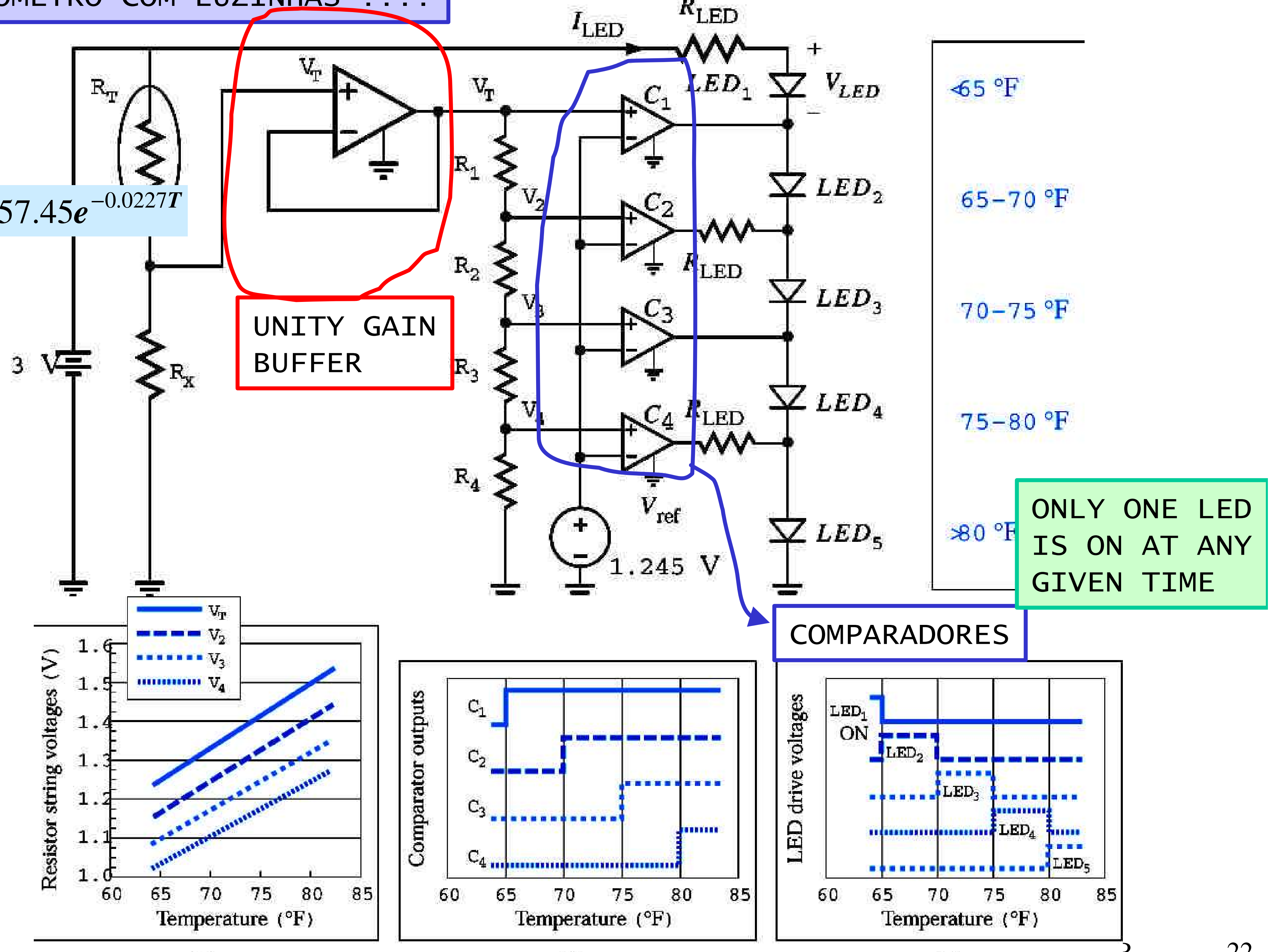
(b)

$$\frac{V_o}{V_1} = (1)(1+\frac{R_2}{R_1})$$

DETERMINE R_2, R_1 DE MODO A APMLIFICAR POR UM FACTOR DE 1000

TERMÓMETRO COM LUZINHAS !!!!

$$R_T = 57.45e^{-0.0227T}$$



(a) (b) (c)

RESUMO (MUITO IMPORTANTE): AMPOP IDEAL

1 – GANHO INFINITO => $V_+ - V_- = 0$
2 – RESISTÊNCIA DE ENTRADA INFINITA => $i_- = 0$ e $i_+ = 0$
3 – RESOLVER O RESTO DO CIRCTUITO USANDO KVL, KCL ETC