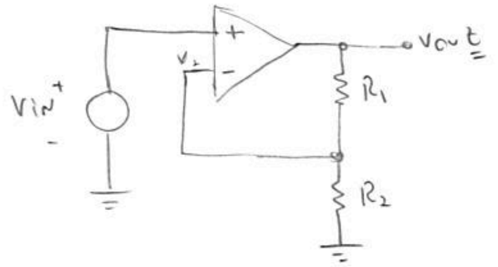
CAP 8

8.3

Não inversor

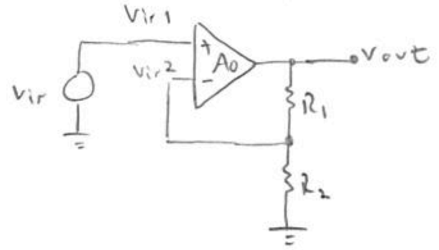


$$\frac{V_{out}}{V_{in}} = 1 + \frac{R_1}{R_2} = 8 \qquad A_o = 2000$$

Erro de ganho: $\left(1 + \frac{R_1}{R_2}\right)\frac{1}{A_o} = 8 \cdot \frac{1}{2000} = 0{,}4\%$

8.8

ΔR de R_2 $\qquad \frac{\Delta R}{R_2} << 1$



$$V_{out} = A_o(v_{in1} - v_{in2})$$

$$V_{out} = A_o\left(V_{in} - \frac{R_2}{R_1+R_2} V_{out}\right)$$

$$V_{out}\left(1 + \frac{R_2 A_o}{R_1+R_2}\right) = A_o V_{in}$$

$$\frac{V_{out}}{V_{in}} = \frac{A_o}{1 + \frac{R_2 A_o}{R_1+R_2}} = \frac{A_o(R_1+R_2)}{A_o R_2 + \underbrace{R_1 + R_2}_{\text{muito menor}}}$$

$$\frac{V_{out}}{V_{in}} = \frac{A_o(R_1+R_2)}{A_o R_2} \quad \text{(nominal)}$$

p/ $R_2' = R_2 + \Delta R_2$

$$\left(\frac{V_{out}}{V_{in}}\right)' = \frac{A_o(R_1 + \Delta R_2 + R_2)}{A_o(\Delta R_2 + R_2)}$$

Erro de ganho

$$\frac{\left(\frac{V_{out}}{V_{in}}\right)' - \left(\frac{V_{out}}{V_{in}}\right)}{\left(\frac{V_{out}}{V_{in}}\right)} \rightarrow \frac{\frac{R_1+R_2+\Delta R_2}{R_2+\Delta R_2} - \frac{R_1+R_2}{R_2}}{\frac{R_1+R_2}{R_2}} =$$

$$= \frac{\frac{R_1}{R_2+\Delta R_2} - \frac{R_1}{R_2}}{1 + \frac{R_1}{R_2}}$$

8.12

Amplificador inversor

$|A_v| = \frac{R_1}{R_2} = 8$ e erro de ganho de 0,2%

$\hookrightarrow \frac{1}{A_o}\left(1 + \frac{R_1}{R_2}\right) = 0{,}002$

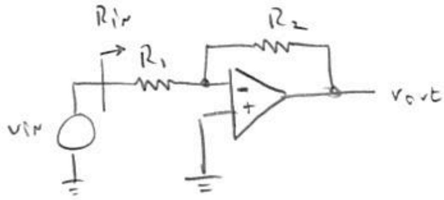
$\frac{1}{A_o}(1+8) = 0{,}002 \rightarrow A_o = \frac{9}{0{,}002} = 4500$

8.15

$R_{in} = 10\,k\Omega$

$\left|\frac{V_{out}}{v_{in}}\right| = 4$

$\left|\frac{V_{out}}{v_{in}}\right| = 4 = \frac{R_2}{R_1}$



$A_o = 1000$

$R_2 = 4R_1$

$R_{out} = 1\,k\Omega$

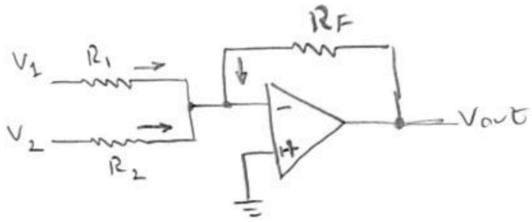
Erro de ganho $\rightarrow \frac{1}{A_o}\left(1 + \frac{R_1}{R_2}\right)$

$R_{in} = R_1 = 10\,k\Omega$

$\frac{1}{1000}\left(1 + \frac{40k}{10k}\right) = 0{,}5\%$

$R_2 = 40\,k\Omega$

8.30 Somador de tensão



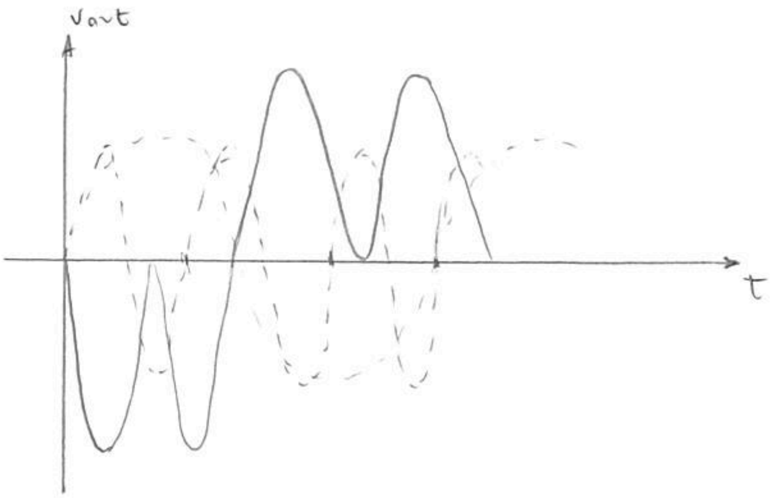
$$\frac{V_1}{R_1} + \frac{V_2}{R_2} = -\frac{V_{out}}{R_F}$$

$$V_{out} = -R_F\left(\frac{V_1}{R_1} + \frac{V_2}{R_2}\right)$$

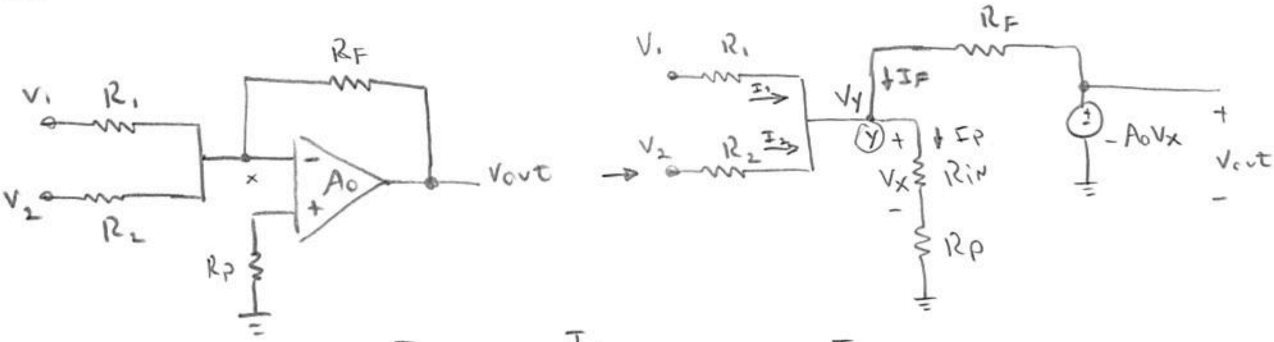
Nesse caso, $R_1 = R_2$, e $V_1 = V_0 \operatorname{sen} \omega t$, $V_2 = V_0 \operatorname{sen} 3\omega t$

$$V_{out} = -\frac{R_F}{R_1} \cdot V_0 \left(\operatorname{sen} \omega t + \operatorname{sen} 3\omega t\right)$$

$\rightarrow$ Tensão de pico $\rightarrow -\dfrac{R_F}{R_2} \cdot V_0 \times 2$



8.34



No nó Y:

$$\overbrace{\frac{V_1 - V_y}{R_1}}^{I_1} + \overbrace{\frac{V_2 - V_y}{R_2}}^{I_2} + \overbrace{\frac{-A_0V_x - V_y}{R_F}}^{I_F} = \overbrace{\frac{V_y}{R_{in}+R_p}}^{I_p}$$

onde $V_x = V_y \cdot \dfrac{R_{in}}{R_{in}+R_p} \rightarrow V_y = V_x \dfrac{R_{in}+R_p}{R_{in}}$

$$\frac{V_1}{R_1} + \frac{V_2}{R_2} = V_y\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_F} + \frac{1}{R_{in}+R_p}\right) + \frac{A_0V_x}{R_F}$$

$$= \left[\frac{R_{in}+R_p}{R_p}\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_F} + \frac{1}{R_{in}+R_p}\right) + \frac{A_0}{R_F}\right] \times V_x$$

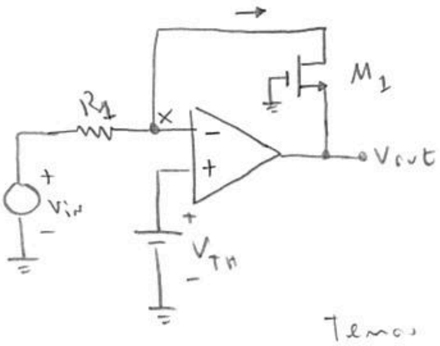
sabendo que $V_x = \dfrac{-V_{out}}{A_0}$

$$\left(\frac{V_1}{R_1} + \frac{V_2}{R_2}\right) = -\frac{V_{out}}{A_0} \times \left[\frac{R_{in}+R_p}{R_p}\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_F} + \frac{1}{R_{in}+R_p}\right) + \frac{A_0}{R_F}\right]$$

Portanto,

$$V_{out} = \frac{-A_0\left(\dfrac{V_1}{R_1} + \dfrac{V_2}{R_2}\right)}{\left(\dfrac{R_{in}+R_p}{R_p}\right) \times \left(\dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_F} + \dfrac{1}{R_{in}+R_p}\right) + \dfrac{A_0}{R_F}}$$

8.45 Amplificador raiz quadrada



V_{out} em termos de V_{in}

$A_0 = \infty$

$$I_{R_1} = \frac{V_{in} - V_{TH}}{R_1} = \frac{1}{2} \frac{W}{L} C_{ox} \mu_n (V_{GS} - V_{TH})^2$$

Temos $V_{GS} = -V_{out}$

Portanto, $\frac{1}{2} \frac{W}{L} \mu_n C_{ox} (-V_{out} - V_{TH})^2 = \frac{V_{in} - V_{TH}}{R_1}$

$$(-V_{out} - V_{TH})^2 = \frac{2(V_{in} - V_{TH})}{\frac{W}{L} \mu_n C_{ox} R_1} \rightarrow -V_{out} - V_{TH} = \sqrt{\frac{2(V_{in} - V_{TH})}{\frac{W}{L} \mu_n C_{ox} R_1}}$$

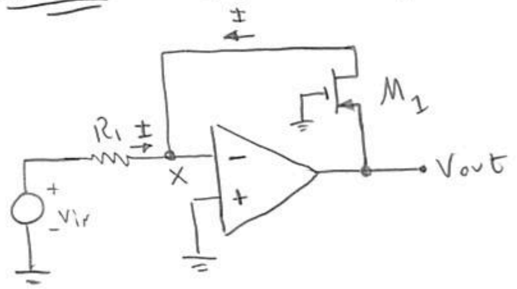
$$\therefore V_{out} = -\sqrt{\frac{2(V_{in} - V_{TH})}{\frac{W}{L} \mu_n C_{ox} R_1}} - V_{TH}$$

Ganho de pequeno sinal $\rightarrow$ $\frac{d V_{out}}{d V_{in}} = -\frac{d}{d V_{in}} \left(\sqrt{\frac{2(V_{in} - V_{TH})}{\frac{W}{L} \mu_n C_{ox} R_1}} \right)$

$$= \frac{1}{\frac{W}{L} \mu_n C_{ox} R_1} \sqrt{\frac{\frac{W}{L} \mu_n C_{ox} R_1}{2(V_{in} - V_{TH})}}$$

$$= \sqrt{\frac{1}{2 \frac{W}{L} \mu_n C_{ox} R_1 (V_{in} - V_{TH})}}$$

8.46 V_{out} em função de V_{in}



temos que $\frac{V_x - V_{in}}{R_1} = I$

Assumindo $A_0 = \infty$, $V_x = 0$ (terra virtual)

$$-\frac{V_{in}}{R_1} = \frac{1}{2}\frac{W}{L}\mu_n C_{ox}(V_{GS} - |V_{TH}|)^2$$

onde $V_{GS} = -V_{out}$

$$-\frac{V_{in}}{R_1} = \frac{1}{2}\frac{W}{L}\mu_n C_{ox}(-V_{out} - |V_{TH}|)^2$$

$$-\frac{2V_{in}}{\frac{W}{L}\mu_n C_{ox} R_1} = (V_{out} + |V_{TH}|)^2$$

$$V_{out} = \sqrt{-\frac{2V_{in}}{\frac{W}{L}\mu_n C_{ox} R_1}} - |V_{TH}|$$

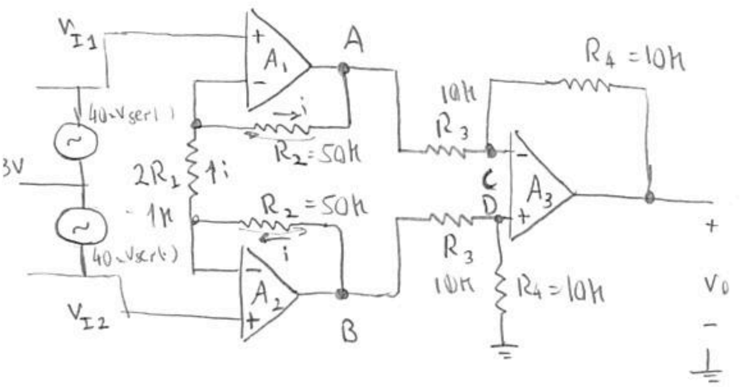
Sedra - Versão Ingles - Amplificador de Instrumentação

2.72 Considere o amplificador de instrumentação abaixo.

A tensão de entrada de modo comum é +3V dc, e o sinal diferencial de entrada senoidal, com pico a pico de 80mV

$2R_1 = 1K\Omega$ $R_2 = 50K\Omega$ $R_3 = R_4 = 10K\Omega$

Encontre a tensão em cada nó do circuito.



$V_{I1} = 3 + 40m. \text{sen}(wt)$

$V_{I2} = 3 - 40m\ \text{sen}(wt)$

$V_{id} = (V_{I2} - V_{I1}) = -80m\ \text{sen}(wt)$

$i = \frac{V_{id}}{2R_1} = -0{,}08\ \text{sen}(wt)\ mA$ Sinal de i é o contrário do adotado pela convenção

$V_A = 3 + 40m\ \text{sen}(wt) - R_2 \times i = 3 + 40m\ \text{sen}(wt) + 50\cancel{K} . 0{,}08\ \text{sen}(wt) \times \cancel{10^{-3}}$

$V_A = 3 + 40m\ \text{sen}(wt) + 4\ \text{sen}(wt) = 3 + 4{,}04\ \text{sen}(wt)\ V$

$V_B = 3 - 40m\ \text{sen}(wt) + R_2 \times i = 3 - 40m\ \text{sen}(wt) - 50\cancel{K} . 0{,}08\ \text{sen}(wt) \times \cancel{10^{-3}}$

$V_B = 3 - 40m\ \text{sen}(wt) - 4\ \text{sen}(wt) = 3 - 4{,}04\ \text{sen}(wt)\ V$

$V_C = V_D$ (simetria)

$V_C = V_D = V_B . \frac{10K}{10K + 10K} = \frac{V_B}{2} = 1{,}5 - 2{,}02\ \text{sen}(wt)\ V$

$V_0 = V_B - V_A = -8{,}08\ \text{sen}(wt)\ V$

ou $V_0 = \frac{R_4}{R_3}\left(\frac{R_2}{R_1} + 1\right) . V_{id} = \left(\frac{50K}{500} + 1\right) . (-0{,}08)\ m.\ \text{sen}(wt)$