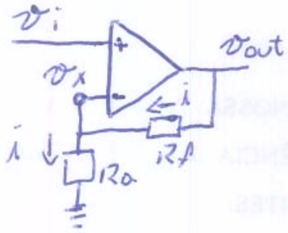
CAP 08 - Exercícios (4, ~~6~~, 9, 10, 11, 17, 18, 19, 20, 21, 24, 25, 28, 29, 31, 37, 38

~~15, 16~~

(4) $(A_o \to \infty) \Rightarrow \tilde{A}_{o_i} = 1 + \dfrac{R_f}{R_a}$ (4)

$\Rightarrow A_o < \infty$



$$\left\{\begin{array}{l} \dfrac{v_x}{R_a} = \dfrac{v_{out}}{R_f + R_a} \Rightarrow v_x = v_{out}\dfrac{R_a}{R_f + R_a} \\ v_{out} = (v_i - v_x) . A_o \end{array}\right.$$

$$\bullet \left\{\begin{array}{l} v_{out} = v_x \dfrac{R_f + R_a}{R_a} \Rightarrow v_{out} = v_x . \left(1 + \dfrac{R_f}{R_a}\right) \Rightarrow \boxed{v_{out} = v_x . A_{oi}} \\ v_{out} = v_i A_o - v_x A_o \Rightarrow v_x = \dfrac{v_i A_o - v_{out}}{A_o} \end{array}\right.$$

$$v_{out} = \frac{v_i A_o - v_{out}}{A_o} A_{oi} \Rightarrow \underbrace{v_{out} + \frac{v_{out}}{A_o}A_{oi}}_{v_{out}\left(1 + \frac{A_{oi}}{A_o}\right)} = v_i A_{oi}$$

$$\frac{v_{out}}{v_i} = \boxed{A_{o_{ni}} = \frac{A_{oi}}{1 + \dfrac{A_{oi}}{A_o}}}$$

$$\bullet \text{erro} = \frac{A_{oi} - A_{o_{ni}}}{A_{oi}} = \left(A_{oi} - \frac{A_{oi}}{1 + \dfrac{A_{oi}}{A_o}}\right) \cdot \frac{1}{A_{oi}} = 1 - \frac{1}{\dfrac{A_o + A_{oi}}{A_o}}$$

$$\text{erro} = 1 - \frac{A_o}{A_o + A_{oi}} = \frac{A_o + A_{oi} - A_o}{A_o + A_{oi}} \Rightarrow \text{erro} = \frac{A_{oi}}{A_o + A_{oi}}$$

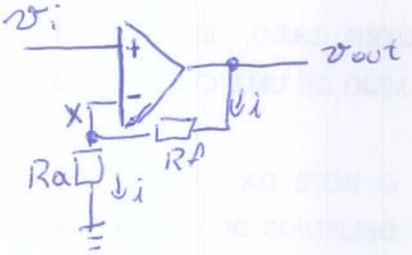
$$\text{erro\%} = \frac{A_{oi}}{A_o + A_{oi}} . 100$$

$$0{,}1 = \frac{4}{A_o + 4} . 100 \Rightarrow 1 . 10^{-3} = \frac{4}{A_o + 4} \Rightarrow A_o + 4 = 4 . 10^3$$

$$\boxed{A_o = 3996}$$

8.9

$$A_o < \infty$$



• $i = \frac{v_x}{R_a} = \frac{v_{out}}{R_f+R_a} \Rightarrow v_x = \frac{R_a v_{out}}{R_f+R_a}$

• $v_{out} = A_o\cdot(v_i - v_x)$

• $v_{out} = A_o\left(v_i - \frac{R_a v_{out}}{R_f+R_a}\right)$

$$v_{out} = A_o v_{in} - \frac{R_a v_{out} A_o}{R_f+R_a} \Rightarrow A_o v_{in} = v_{out}\cdot\left(1+\frac{R_a A_o}{R_f+R_a}\right)$$

$$A_{v_{ni}} = \frac{v_{out}}{v_{in}} = \frac{A_o}{1+\frac{R_a A_o}{R_f+R_a}}\cdot\frac{\left(\frac{R_f+R_a}{R_a}\right)}{\left(\frac{R_f+R_a}{R_a}\right)} \Rightarrow A_{v_{ni}} = \frac{A_o\cdot\overbrace{\left(1+\frac{R_f}{R_a}\right)}^{A_{vi}}}{\underbrace{\left(1+\frac{R_f}{R_a}\right)}_{A_{vi}}+A_o}\cdot\frac{A_o^{-1}}{A_o^{-1}}$$

$$\boxed{A_{vni} = \frac{A_{vi}}{\frac{A_{vi}}{A_o}+1}, \quad A_{vi} = 1+\frac{R_f}{R_a}}$$

• $A_{vi}=5 \Rightarrow A_{vni} = \frac{5}{\frac{5}{A_o}+1} \Rightarrow A_{vni} = \frac{5}{\frac{5+A_o}{A_o}} \Rightarrow A_{vni} = \frac{5A_o}{5+A_o}$

$$\boxed{A_{vni} = \frac{5}{5\cdot A_o^{-1}+1}}$$

• $v_x = \frac{v_{out}}{R_f+R_a}\cdot R_a = A_{vni}\cdot\frac{R_a}{R_f-R_a}\cdot v_i$

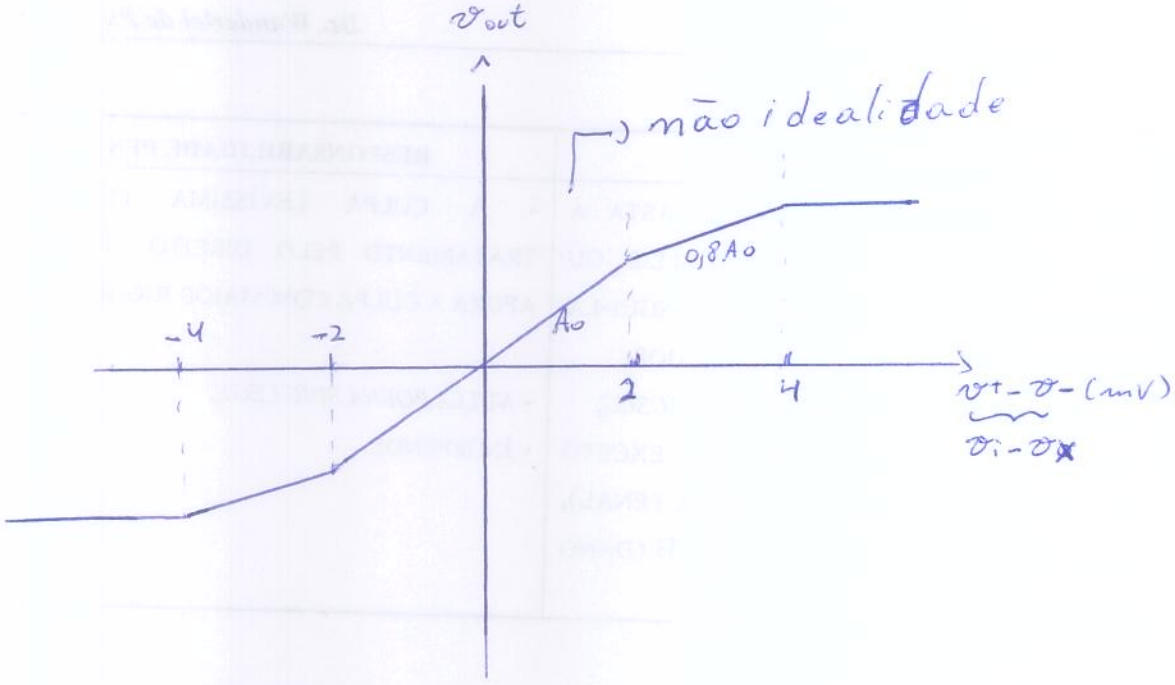
• $(v_i - v_x) = \left(1 - A_{vni}\cdot\frac{R_a}{R_f-R_a}\right)v_i \Rightarrow (v_i-v_x) = \left[1-\left(\frac{R_f+R_a}{R_a}\right)^{-1}A_{vni}\right]\cdot v_i$

$$(v_i-v_x) = \left(1 - A_{vi}^{-1}\cdot A_{vni}\right)v_i \Rightarrow (v_i-v_x) = \left(1-\frac{A_{vni}}{A_{vi}}\right)v_i$$

$$(v_i-v_x) = \left[1 - \frac{\left(\frac{A_{vi}}{\frac{A_{vi}}{A_o}+1}\right)}{A_{vi}}\right]v_i \Rightarrow (v_i-v_x) = \left(1-\frac{1}{\frac{A_{vi}}{A_o}+1}\right)v_i$$

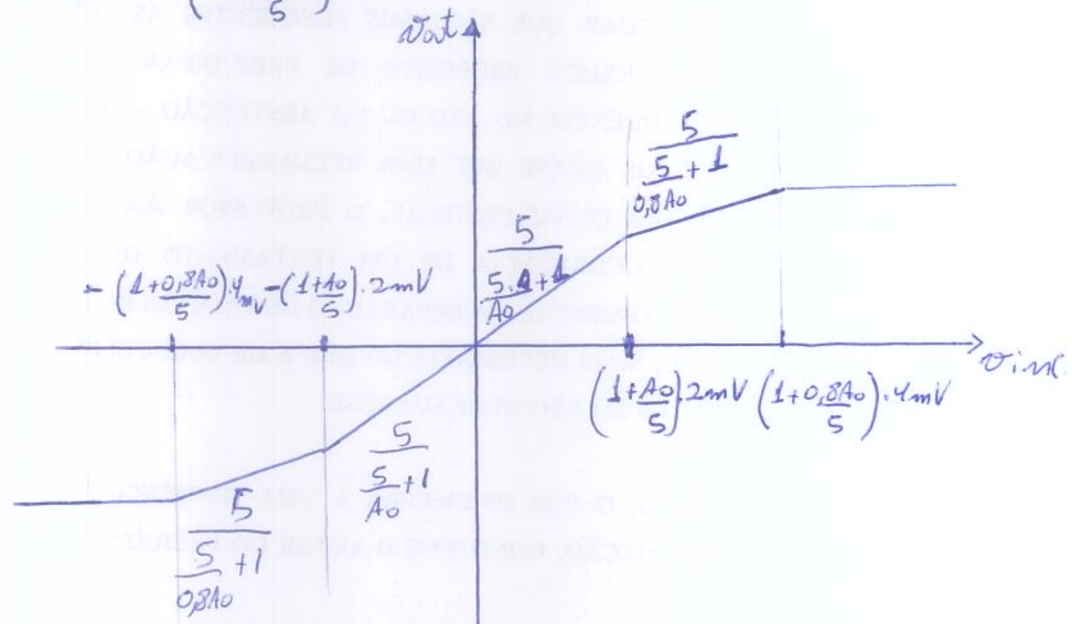
$$(v_i-v_x) = \left(1 - \frac{1}{\frac{A_{vi}+A_o}{A_o}}\right)v_i \Rightarrow (v_i-v_x) = \left(1-\frac{A_o}{A_{vi}+A_o}\right)v_i$$

$$(v_i-v_x) = \left(\frac{A_{vi}+A_o-A_o}{A_{vi}+A_o}\right)v_i \Rightarrow \boxed{\frac{(v_i-v_x)}{v_i} = \frac{A_{vi}}{A_{vi}+A_o}} \Rightarrow v_i = \left(1+\frac{A_o}{A_{vi}}\right)\cdot(v_i-v_x)$$



$\bullet\ (v_i - v_x) = 2\,mV \Rightarrow v_i = \left(1 + \dfrac{A_o}{5}\right) \cdot 2\,mV$

$\bullet\ (v_i - v_x) = 4\,mV \Rightarrow v_i = \left(1 + \dfrac{0{,}8A_o}{5}\right) \cdot 4\,mV$

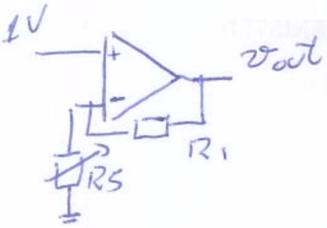


~~obs: A inclinação (A_{oni}) da reta ($v_{out} \times v_{in}$) praticamente não muda é mais sua~~

obs: A mudança da inclinação da reta ($v_{out} \times v_{in}$) é ~~muito~~ pequena com a mudança de A_o. A malha fechada lineariza a relação ganho x entrada.

8.10

$R_S = R_o + \alpha W$



$$v_{out} = v_{in} \cdot \left(1 + \frac{R_1}{R_S}\right)$$

$$v_{out} = 1 \cdot \left(1 + \frac{R_1}{R_o + \alpha W}\right)$$

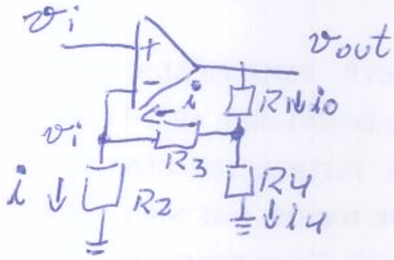
$$\cancel{v_{out} = \frac{R_o + \alpha W + R_1}{R_o + \alpha W} \Rightarrow v_{out} R_o + v_{out} \alpha W = R_o + \alpha W + R_1}$$

$$\frac{d v_{out}}{dW} = R_1 \cdot \alpha \cdot (-1) \cdot \left(\frac{1}{R_o + \alpha W}\right)^2$$

$$\frac{d v_{out}}{dW} = \frac{-\alpha R_1}{(R_o + \alpha W)^2}$$

8.11 $A_o = \infty$

$$\boxed{\cdot\ i = \frac{v_i}{R_2}}$$



$$\cdot\ i_o = \frac{v_{out} - v_{R4}}{R_1} = \frac{v_{out} - (v_i + v_{R3})}{R_1}$$

$$\cdot\ i_o = \frac{v_{out} - v_i - R_3 \cdot i}{R_1}$$

$$\cdot\ i_o = \frac{v_{out} - v_i - \frac{R_3}{R_2} \cdot v_i}{R_1} \Rightarrow \boxed{i_o = \frac{v_{out} - v_i\left(1 + \frac{R_3}{R_2}\right)}{R_1}}$$

$$\cancel{\cdot\ v_{out} = R_1 i_o \quad i_o = i + i_4 \Rightarrow i_o = \frac{v_i}{R_2} + R_4 i_4 \Rightarrow i_o = \frac{v_i}{R_2} + R_4 \cdot (i_o - i)}$$

$$\cancel{i_o = \frac{v_i}{R_2} + R_4 i_o - R_4 i \Rightarrow i_o(R_4 - 1) = R_4 i - \frac{v_i}{R_2}}$$

$$\cancel{i_o(R_4 - 1) = R_4 \frac{v_i}{R_2} - \frac{v_i}{R_2}}$$

$$\cdot\ v_{R4} = i \cdot (R_3 + R_2) \Rightarrow v_{R4} = v_i\left(\frac{R_3 + R_2}{R_2}\right) \Rightarrow R_4 i_4 = v_i\left(\frac{R_3 + R_2}{R_2}\right)$$

$$R_4 \cdot (i_o - i) = v_i\left(\frac{R_3 + R_2}{R_2}\right)$$

$$R_4 \cdot \left[\frac{v_{out} - v_i\left(1 + \frac{R_3}{R_2}\right)}{R_1} - \frac{v_i}{R_2}\right] = v_i\left(\frac{R_3 + R_2}{R_2}\right)$$

4

$$\frac{R_4}{R_?}\cdot\left[\frac{R_2 v_{out}-R_2 v_i\left(\frac{R_3+R_2}{R_2}\right)-v_i R_1}{R_1 R_2}\right]=v_i\left(\frac{R_3+R_2}{R_2}\right)$$

$$\frac{R_4}{R_1R_2}\left[R_2 v_{out}-R_2 v_i\left(\frac{R_3+R_2}{R_2}\right)-v_i R_1\right]=v_i\left(\frac{R_3+R_2}{R_2}\right)$$

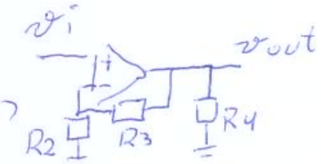
$$\frac{R_4}{R_1\cancel{R_2}}\cdot\cancel{R_2}v_{out}-\frac{R_4}{R_1\cancel{R_2}}\cdot\cancel{R_2}v_i\left(\frac{R_3+R_2}{R_2}\right)-\frac{R_4}{\cancel{R_1}R_2}\cdot v_i\cancel{R_1}=v_i\left(\frac{R_3+R_2}{R_2}\right)$$

$$\frac{R_4}{R_1}v_{out}=v_i\left(\frac{R_3+R_2}{R_2}\right)+\frac{R_4}{R_1}v_i\left(\frac{R_3+R_2}{R_2}\right)+\frac{R_4}{R_2}v_i$$

$$\frac{R_4}{R_1}v_{out}=v_i\left[\frac{R_3+R_2}{R_2}\cdot\left(1+\frac{R_4}{R_1}\right)+\frac{R_4}{R_2}\right]$$

$$\frac{v_{out}}{v_i}=\frac{R_1}{R_4}\frac{R_3+R_2}{R_2}\cdot\left(1+\frac{R_4}{R_1}\right)+\frac{R_1}{\cancel{R_4}}\cdot\frac{\cancel{R_4}}{R_2}$$

$$\boxed{\frac{v_{out}}{v_i}=\frac{R_3+R_2}{R_2}\cdot\left(\frac{R_1}{R_4}+1\right)+\frac{R_1}{R_2}}$$

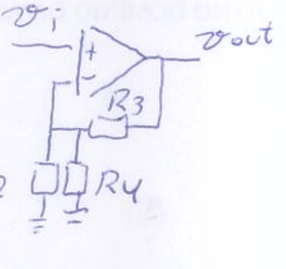


- $R_1 \to 0 \Rightarrow \frac{v_{out}}{v_{in}}=\frac{R_3+R_2}{R_2} \Rightarrow \boxed{\frac{v_{out}}{v_{in}}=1+\frac{R_3}{R_2}}$ => OK, ganho do amp. ñ inv. ($R_f=R_3$, $R_a=R_2$)

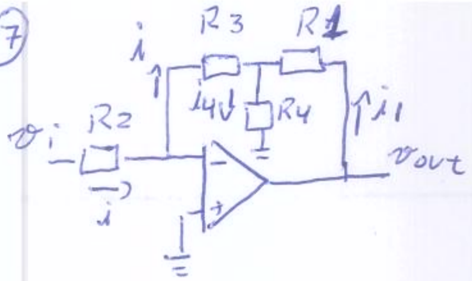
- $R_3 \to 0 \Rightarrow \frac{v_{out}}{v_{in}}=\frac{R_1}{R_4}+1+\frac{R_1}{R_2} \Rightarrow \frac{v_{out}}{v_{in}}=\frac{R_1R_2+R_1R_4}{R_2R_4}+1 \Rightarrow \frac{v_{out}}{v_{in}}=\frac{R_1.(R_2+R_4)}{R_2R_4}+1$

$$\Rightarrow \boxed{\frac{v_{out}}{v_{in}}=\frac{R_1}{R_2 /\!/ R_4}+1}$$

OK, ganho do Amp. ñ inversor ($R_f=R_1$, $R_a=R_2/\!/R_4$)



(17)



$$i = \frac{v_i}{R_2}$$

$$i_1 = \frac{v_{out} - \overset{\sim -v_{R3}}{v_{R4}}}{R_1} \Rightarrow i_1 = \frac{v_{out} + v_{R3}}{R_1}$$

$$i_1 = (v_{out} + R_3 \cdot i) \cdot \frac{1}{R_1} \Rightarrow i_1 = \left(v_{out} + \frac{R_3}{R_2} \cdot v_i\right) \cdot \frac{1}{R_1}$$

- $i_4 = i + i_1 \Rightarrow \frac{\overset{\sim -v_{R3}}{v_{R4}}}{R_4} = \frac{v_i}{R_2} + \left(v_{out} + \frac{R_3}{R_2} v_i\right) \cdot \frac{1}{R_1}$

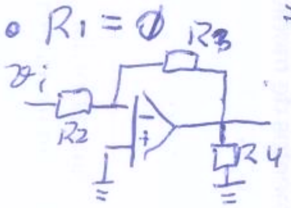
$$\frac{1}{R_4} \cdot (-R_3 i) = \frac{v_i}{R_2} + \frac{v_{out}}{R_1} + \frac{R_3}{R_1 R_2} \cdot v_i$$

$$\frac{1}{R_4} \cdot \left(-R_3 \cdot \frac{v_i}{R_2}\right) = \frac{v_i}{R_2} + \frac{v_{out}}{R_1} + \frac{R_3}{R_1 R_2} v_i$$

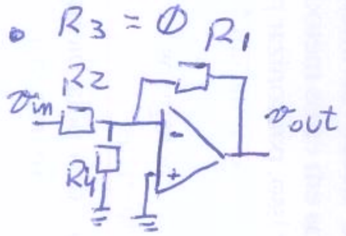
$$\frac{v_{out}}{R_1} = -\left(\frac{R_3}{R_2 R_4} + \frac{1}{R_2} + \frac{R_3}{R_1 R_2}\right) v_i$$

$$\boxed{\frac{v_{out}}{v_i} = -\left(\frac{R_1 R_3}{R_2 R_4} + \frac{R_1}{R_2} + \frac{R_3}{R_2}\right)}$$

- $R_1 = 0$ $\Rightarrow \frac{v_{out}}{v_i} = -\frac{R_3}{R_2} \Rightarrow OK$

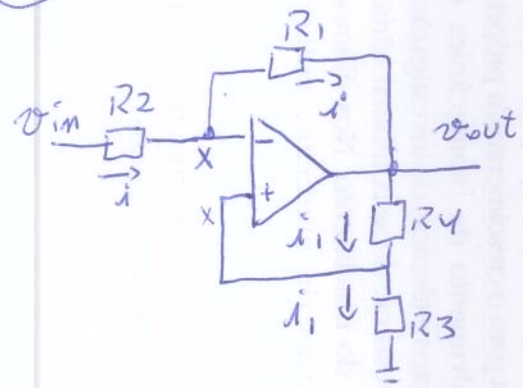


- $R_3 = 0$ $\quad \frac{v_{out}}{v_i} = -\frac{R_1}{R_2} \Rightarrow OK$



obs $\Rightarrow v_{R4} = 0 \Rightarrow i_{R4} = 0$
↳ terra virtual

(8.18) $A_0 \to \infty$



$$\begin{cases} i = \dfrac{v_{in} - v_x}{R_2} = \dfrac{v_x - v_{out}}{R_1} \\ i_1 = \dfrac{v_x}{R_3} \\ v_{out} = (R_3+R_4) \cdot i \Rightarrow v_{out} = \dfrac{R_3+R_4}{R_3} \cdot v_x \end{cases}$$

$$\begin{cases} R_1(v_{in} - v_x) = R_2(v_x - v_{out}) \\ v_x = \dfrac{R_3}{R_3+R_4} v_{out} \end{cases} \Rightarrow \begin{cases} R_1 v_{in} - R_1 v_x = R_2 v_x - R_2 v_{out} \\ v_x = \dfrac{R_3}{R_3+R_4} v_{out} \end{cases}$$

$$\begin{cases} R_1 v_{in} = v_x(R_2+R_1) - R_2(v_{out}) \\ v_x = \dfrac{R_3}{R_3+R_4} \cdot v_{out} \end{cases}$$

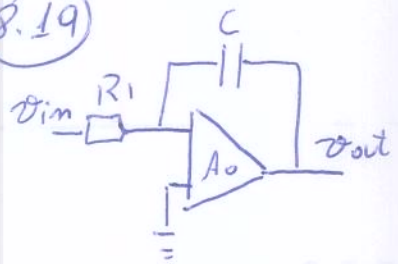
$$R_1 v_{in} = \frac{R_3}{R_3+R_4} v_{out}(R_2+R_1) - R_2 v_{out}$$

$$R_1 v_{in} = \left(\frac{R_3 \cdot (R_2+R_1)}{R_3+R_4} - R_2 \right) v_{out}$$

$$R_1 v_{in} = \frac{R_3(R_2+R_1) - R_2(R_3+R_4)}{R_3+R_4} \cdot v_{out}$$

$$\boxed{\frac{v_{out}}{v_{in}} = \frac{R_1 \cdot (R_3+R_4)}{R_3(R_2+R_1) - R_2(R_3+R_4)}}$$

(8.19)



$$\bullet\ A_v = \frac{v_{out}}{v_{in}} = \frac{-\frac{1}{SC}}{R_1} \Rightarrow \boxed{A_v = -\frac{1}{RCS}}$$

$$\Downarrow$$

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

$$v_{out}(t) = -\frac{1}{RC} \cdot \int_0^t V_0 \sin(\omega t)\,dt$$

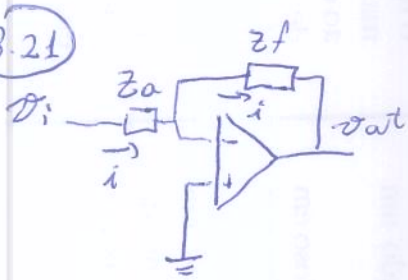
$$v_{out}(t) = -\frac{V_0}{RC} \cdot -\frac{\cos(\omega t)}{\omega} \Rightarrow \boxed{v_{out} = \frac{V_0 \cos(\omega t)}{RC\omega}}$$

(8.20)

$$\frac{v_0}{RC\omega} = 10 v_0 \Rightarrow 1 = 10RC\omega \Rightarrow \omega = \frac{1}{10 \cdot RC} \Rightarrow \omega = \frac{1}{10 \cdot 10 \cdot 10^{-9}}$$

$$\boxed{\omega = 10^7\ rad/s}$$

(8.21)



$$\bullet\ v_{out} = (\underbrace{v_+}_{0} - v_-) \cdot A_0 \Rightarrow \boxed{v_{out} = -A_0 v_-}$$

$$\bullet\ i = \frac{v_i - v_-}{Z_a}$$

$$\bullet\ i = \frac{v_- - v_{out}}{Z_f}$$

$$\frac{v_i - v_-}{Z_a} = \frac{v_- - v_{out}}{Z_f}$$

$$\frac{v_i - v_-}{Z_a} = \frac{v_- - (-A_0 v_-)}{Z_f} \Rightarrow Z_f \cdot v_i - Z_f v_- = Z_a v_- (1 + A_0)$$

$$v_i = \frac{v_- \left[(1+A_0) Z_a + Z_f\right]}{Z_f}$$

$$\bullet\ \frac{v_{out}}{v_i} = \frac{-A_0 Z_f}{(1+A_0) Z_a + Z_f} \cdot \frac{A_0^{-1}}{A_0^{-1}} \Rightarrow \frac{v_{out}}{v_i} = \frac{-Z_f}{\left(\frac{1}{A_0}+1\right) Z_a + \frac{Z_f}{A_0}} \cdot \frac{Z_a^{-1}}{Z_a^{-1}}$$

$$\frac{v_{out}}{v_i} = \frac{-Z_f/Z_a}{\frac{1}{A_0} + 1 + \frac{Z_f}{A_0 Z_a}} = \frac{\overbrace{-Z_f/Z_a}^{A_{vi}}}{\frac{1}{A_0} \cdot \left(1 + \frac{Z_f}{Z_a}\right) + 1} \Rightarrow \boxed{\frac{v_{out}}{v_i} = \frac{A_{vi}}{\frac{1}{A_0}(1 - A_{vi}) + 1}} ;\ A_{vi} = -\frac{Z_f}{Z_a}$$

$$\Rightarrow Z_a = R_1 \; ; \; Z_f = \frac{1}{sC_1} \Rightarrow A_{vi} = -\frac{1}{sR_1C_1}$$

$$\therefore \frac{v_{out}}{v_i} = \frac{-\frac{1}{sR_1C_1}}{\frac{1}{A_0}\left(1+\frac{1}{sR_1C_1}\right)+1} \cdot \frac{sR_1C_1}{sR_1C_1} = \frac{-1}{sR_1C_1 + \frac{sR_1C_1}{A_0} + \frac{1}{A_0}}$$

$$\frac{v_{out}}{v_i} = \frac{-1}{sR_1C_1\left(1+\frac{1}{A_0}\right)+\frac{1}{A_0}}$$

$$s_p = \frac{-\frac{1}{A_0} \cdot A_0}{R_1C_1\left(1+\frac{1}{A_0}\right) \cdot A_0} = \frac{-1}{R_1C_1(A_0+1)}$$

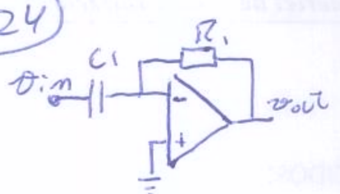
$$\boxed{s_p = \frac{-1}{R_1C_1(A_0+1)}}$$

- $f_c \leq 1\,Hz$

$$\frac{+1}{R_1C_1(A_0+1)} \leq 2\pi \cdot 1 \Rightarrow \frac{1}{10 \cdot 10^3 \cdot 1 \cdot 10^{-9}(A_0+1)} \leq 2\pi \Rightarrow A_0+1 \geq \frac{1}{2\pi \cdot 10^4 \cdot 10^{-9}}$$

$$\boxed{A_0 \geq 15.914}$$

(8.24)



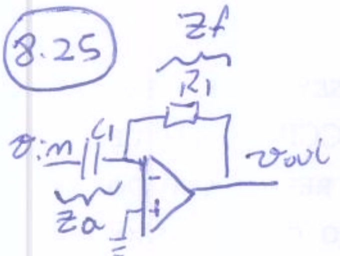
$|A_v| = 5$

- $v_{in} = v_o \cdot \operatorname{sen} \omega t$, $\quad \omega = 2\pi \cdot 10^6$

$$A_v = \frac{-R_1}{\frac{1}{sC_1}} \Rightarrow A_v = -R_1 C_1 s \Rightarrow A_v = -R_1 C_1 \cdot j\omega \Rightarrow |A_v| = +R_1 C_1 \omega$$

$$|A_v| = R_1 C_1 \cdot 2\pi \cdot f \Rightarrow 5 = R_1 C_1 \cdot 2\pi \cdot 10^6 \Rightarrow \boxed{R_1 C_1 = 7{,}9577 \cdot 10^{-7}\,s}$$

(8.25)



$$\xrightarrow{\text{ex. } 8.21} A_v = \frac{A_{vi}}{\frac{1}{A_o}\left(1 - A_{vi}\right) + 1}$$

$$A_{vi} = \frac{-Z_f}{Z_a} = \frac{-R_1}{\frac{1}{sC_1}} \Rightarrow \boxed{A_{vi} = -R_1 C_1 s}$$

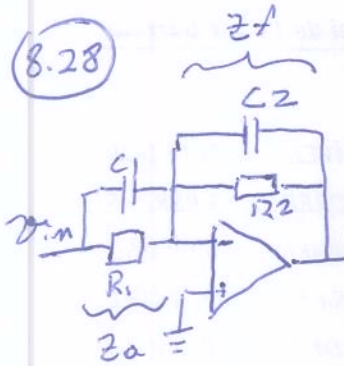
$$A_v = \frac{-R_1 C_1 s}{\frac{1}{A_o}\left(1 + R_1 C_1 s\right) + 1} = \frac{-R_1 C_1 s}{\frac{1}{A_o} + \frac{1}{A_o} R_1 C_1 s + 1} \cdot \frac{A_o}{A_o}$$

$$A_v = \frac{-A_o R_1 C_1 s}{1 + R_1 C_1 s + A_o} \Rightarrow s_p = \frac{-(A_o + 1)}{R_1 C_1}$$

- $$\frac{+(A_o + 1)}{R_1 C_1} = 2\pi \cdot 100 \cdot 10^6 \Longrightarrow \frac{A_o + 1}{1 \cdot 10^3 \cdot 1 \cdot 10^{-9}} = 2\pi \cdot 10^8$$

$$\boxed{A_o = 627{,}3185}$$

(8.28)



$\bullet\ Av_i = \dfrac{-Zf}{Za}$

$\bullet\ Zf = \dfrac{1}{sC_2} \| R_2 \Rightarrow \dfrac{\frac{R_2}{sC_2}}{R_2 + \frac{1}{sC_2}} = \dfrac{R_2/sC_2}{\frac{R_2C_2s+1}{sC_2}} \Rightarrow \boxed{Zf = \dfrac{R_2}{R_2C_2s+1}}$

$\bullet\ Za = \dfrac{1}{sC_1} \| R_1 \Rightarrow Za = \dfrac{R_1}{R_1C_1s+1}$.

$\bullet\ Av_i = -\dfrac{R_2}{R_2C_2s+1} \cdot \dfrac{R_1C_1s+1}{R_1}$ ou $Av_i = \dfrac{-\frac{1}{sC_2} \| R_2}{\frac{1}{sC_1} \| R_1}$

Para $Av_i = 1 \Rightarrow R_1 = R_2$ e $C_1 = C_2$

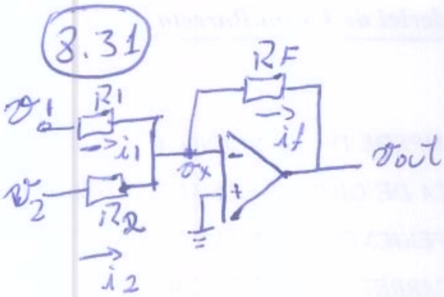
(8.29) $\xrightarrow{ex\ 8.21}$ $Av = \dfrac{Av_i}{\frac{1}{A_0}(1 - Av_i) + 1} \Rightarrow 1 = \dfrac{Av_i}{\frac{1}{A_0}(1 - Av_i) + 1}$

$\dfrac{1}{A_0} - \dfrac{Av_i}{A_0} + 1 = Av_i \Rightarrow Av_i\left(1 + \dfrac{1}{A_0}\right) = 1 + \dfrac{1}{A_0}$

$\therefore Av_i = 1 \Rightarrow$ mesma condição do ex 8.28

$\Rightarrow R_1 = R_2$ e $C_1 = C_2$

8.31



$$\bullet\ i_f = i_1 + i_2$$

$$\frac{v_x - v_{out}}{R_f} = \frac{v_1 - v_x}{R_1} + \frac{v_2 - v_x}{R_2}$$

$$\frac{v_x}{R_f} + \frac{v_x}{R_1} + \frac{v_x}{R_2} = \frac{v_1}{R_1} + \frac{v_2}{R_2} + \frac{v_{out}}{R_f}$$

$$v_x \cdot \underbrace{\left(\frac{1}{R_f} + \frac{1}{R_1} + \frac{1}{R_2}\right)}_{(R_f \parallel R_1 \parallel R_2)^{-1}} = \frac{v_1}{R_1} + \frac{v_2}{R_2} + \frac{v_{out}}{R_f} \Rightarrow \boxed{v_x = (R_f \parallel R_1 \parallel R_2)\left(\frac{v_1}{R_1} + \frac{v_2}{R_2} + \frac{v_{out}}{R_f}\right)}$$

$$v_{out} = A_o(0 - v_x) \Rightarrow v_{out} = -A_o v_x$$

$$v_{out} = -A_o(R_f \parallel R_1 \parallel R_2) \cdot \left(\frac{v_1}{R_1} + \frac{v_2}{R_2} + \frac{v_{out}}{R_f}\right)$$

$$v_{out} \cdot \left(1 + \frac{A_o(R_f \parallel R_1 \parallel R_2)}{R_f}\right) = -A_o(R_f \parallel R_1 \parallel R_2)\left(\frac{v_1}{R_1} + \frac{v_2}{R_2}\right)$$

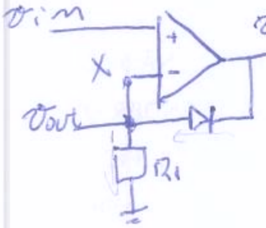
$$v_{out} = \frac{-A_o(R_f \parallel R_1 \parallel R_2) \cdot \left(\frac{v_1}{R_1} + \frac{v_2}{R_2}\right)}{\frac{R_f + A_o(R_f \parallel R_1 \parallel R_2)}{R_f}} \Rightarrow v_{out} = \frac{-A_o R_f \cdot (R_f \parallel R_1 \parallel R_2) \cdot \left(\frac{v_1}{R_1} + \frac{v_2}{R_2}\right)}{R_f + A_o(R_f \parallel R_1 \parallel R_2)}$$

$$v_{out} = -\left(\frac{v_1}{R_1} + \frac{v_2}{R_2}\right) \frac{R_f \cdot A_o(R_f \parallel R_1 \parallel R_2)}{R_f + A_o(R_f \parallel R_1 \parallel R_2)}$$ → produto pela soma

$$\boxed{v_{out} = -\left(\frac{v_1}{R_1} + \frac{v_2}{R_2}\right) \cdot \left\{ R_f \parallel \left[A_o(R_f \parallel R_1 \parallel R_2)\right] \right\}}$$

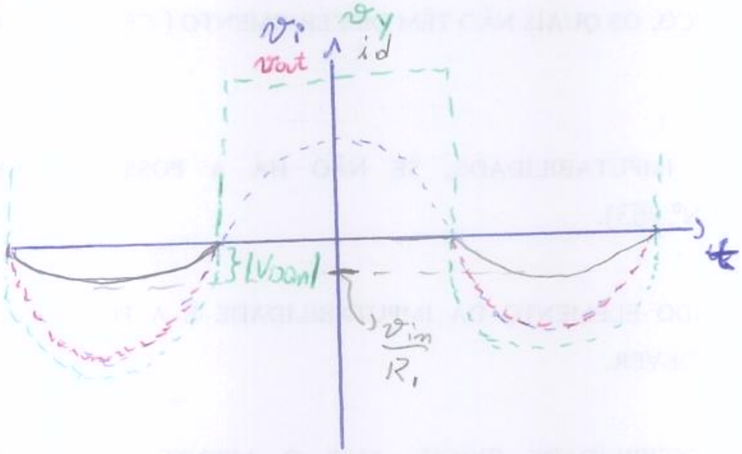
Un

(8.37)



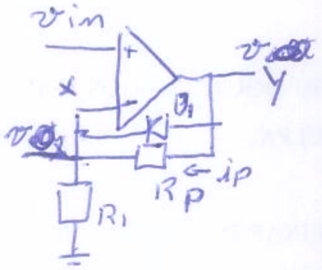
• $v_{in} > 0 \Rightarrow$ corrente de $Y \to X \Rightarrow$ diodo aberto $\begin{cases} v_y = V_{cc},\ v_+ > v_- \\ v_x = v_{in} \to v_{out} \\ i_d = 0 \end{cases}$

• $v_{in} < 0 \Rightarrow$ corrente de $x \to y \Rightarrow$ diodo fechado $\begin{cases} v_y = v_{in} - V_{Don} \\ v_{out} = v_{in} \\ i_d = \dfrac{v_{in}}{R_1} \end{cases}$



(8.38)

• Com R_p, a realimentação sempre existirá, portanto $v_{out} = v_x = v_{in}$, independente de v_{in}.



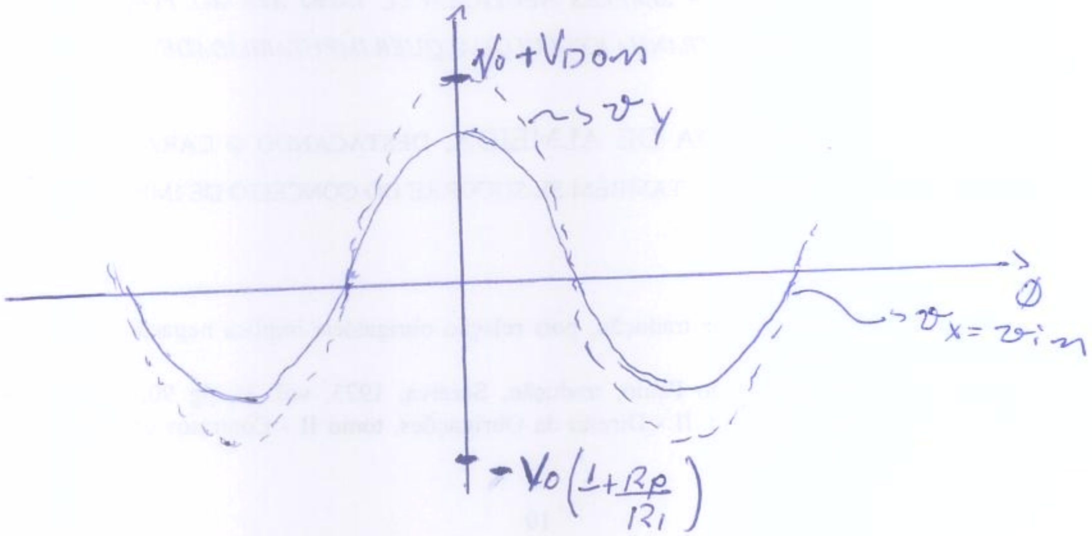
• O diodo somente conduz no ciclo positivo, quando $v_{R_p} > V_{DON} \Rightarrow R_p i_p > V_{Don} \Rightarrow R_p \cdot \frac{v_{in}}{R_1} > V_{Don}$

$\Rightarrow v_{in} > \frac{R_1}{R_p} \cdot V_{Don}$

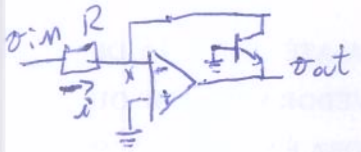
• $v_{in} < \frac{R_1}{R_p} \cdot V_{Don} \Rightarrow \begin{cases} V_y = v_{in} \cdot \left(1 + \frac{R_p}{R_1}\right) \\ V_x = v_{in} \end{cases}$

• $v_{in} > \frac{R_1}{R_p} \cdot V_{Don} \Rightarrow \begin{cases} V_y = v_{in} + V_{Don} \\ V_x = v_{in} \end{cases}$

$v_{in} = V_0 \cdot \cos \omega t$

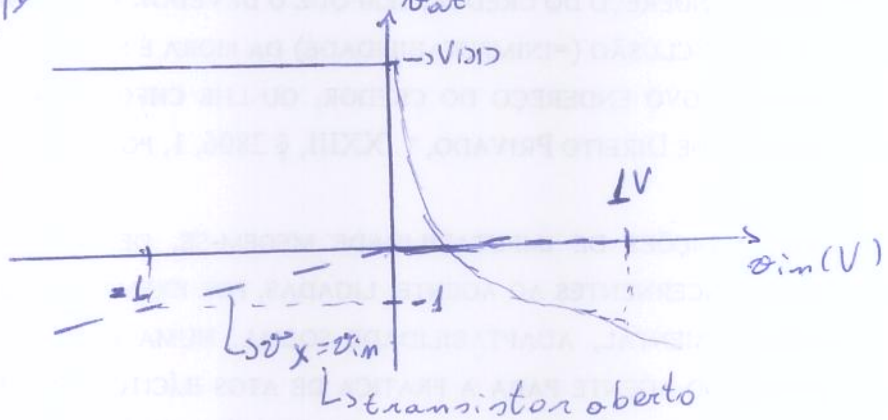


8.40



$$v_{out} = -V_T \cdot \ln \frac{v_{in}}{RI_S}$$

$v_x - 0 = \frac{v_{out}}{A_0}$



8.41

$$i = \frac{v_{in} - v_x}{R}$$

$$v_{out} = -V_{BE} = -V_T \ln \frac{\frac{v_{in} - v_x}{R}}{I_S} \Rightarrow \boxed{v_{out} = -V_T \ln \frac{v_{in} - v_x}{RI_S}}$$

$$A_0(0 - v_x) = v_{out} \Rightarrow v_x = -\frac{v_{out}}{A_0}$$

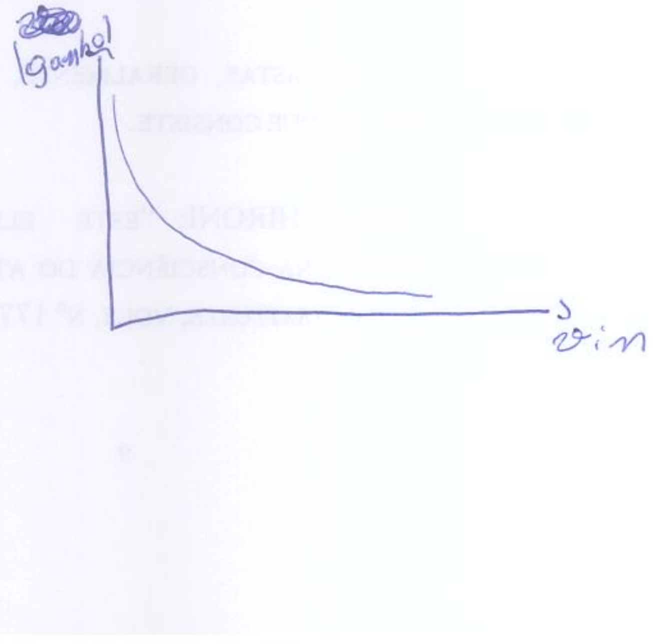
$$\boxed{v_{out} = -V_T \ln \frac{v_{in} + \frac{v_{out}}{A_0}}{RI_S} \Rightarrow v_{out} = -V_T \ln \frac{A_0 v_{in} + v_{out}}{RI_S A_0}}$$

8.43

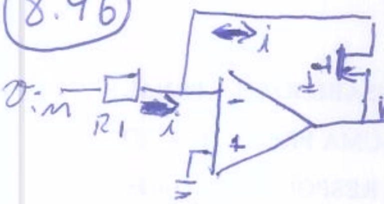
$$V_{out} = -V_T \ln \frac{v_{in}}{RI_S}$$

$$V_{out} = -V_T \left[\ln v_{in} - \ln(RI_S) \right.$$

$$\frac{dV_{out}}{dv_{in}} = -\frac{V_T}{v_{in}}$$



8.46



$\bullet\ v_{in} < 0 \Rightarrow$

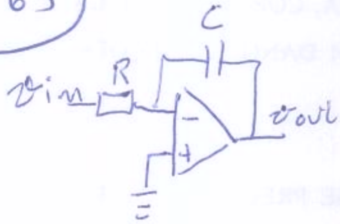
$$i = -\frac{v_{in}}{R}$$

$$i = \frac{1}{2}\mu_p C_{ox} \frac{W}{L} \cdot (|V_{GS}| - |V_{TH}|)^2$$

$$|V_{GS}| = v_{out} = \sqrt{\frac{2i}{\frac{W}{L}\mu_p C_{ox}}} + |V_{TH}|$$

$$\boxed{v_{out} = \sqrt{\frac{-2 \cdot v_{in}}{R \cdot \frac{W}{L}\mu_p C_{ox}}} + |V_{TH}|} \quad ; v_{in} < 0$$

8.63



$$|v_{out}(t)| = \underbrace{\alpha}_{\sim> 10V/\mu s}\, t = \left|-\frac{1}{RC}\right| \cdot t$$

$$0 < |v_{out}(t)| < \underbrace{v_o}_{L> 1V}$$

$$\underbrace{|v_{out}| = \left|-\frac{1}{RC}\right| \cdot t}_{\text{AMP.OP.IDEAL}} = \frac{10V}{\mu s} \cdot t \Rightarrow \frac{1}{RC} = \frac{10}{10^{-6}} \Rightarrow \boxed{RC = 10^{-7} s}$$

AMP OP não ideal ~> ex 8.21

$$|v_{out}| = v_i(s) \frac{1}{sRC\left(1 + \frac{1}{A_0}\right) + \frac{1}{A_0}} \cdot \frac{A_0}{A_0} \Rightarrow |v_{out}| = v_i(s) \frac{A_0}{sRC(A_0+1)+1}$$

$$|v_{out}(s)| = \frac{1}{s} \cdot \frac{A_0}{sRC(A_0+1)+1} = \frac{A}{s} + \frac{B}{sRC(A_0+1)+1}$$

$$A = \frac{1}{s} \frac{A_0}{sRC(A_0+1)+1} \cdot s \Big|_{s=0} \Rightarrow \boxed{A = A_0}$$

$$B = \frac{1}{s} \frac{A_0}{sRC(A_0+1)+1} \cdot [sRC(A_0+1)+1] \Big|_{s = -\frac{1}{RC(A_0+1)}} \Rightarrow B = -RC(A_0+1) A_0$$

$$\therefore v_{out}(s) = \frac{A_0}{s} - \frac{RC \cdot (A_0+1) A_0}{sRC(A_0+1)+1} \cdot \frac{(RC(A_0+1))^{-1}}{(RC(A_0+1))^{-1}} \Rightarrow \boxed{v_{out}(s) = \frac{A_0}{s} - \frac{A_0}{s + \frac{1}{RC(A_0+1)}}}$$

$v_{out}(t) = A_0 - e^{\frac{-t}{RC(A_0+1)}} \cdot A_0$

$v_{out}(t) = A_0 \left(1 - e^{\frac{-t}{RC(A_0+1)}}\right)$

$\rightarrow p/\ v_0 = 1V \Rightarrow \cancel{\frac{v_{out}}{v_{o\rightarrow 1}} \cdot \frac{0,1}{100} \cdot v_{out} = 10^{-3}}$

$\Rightarrow \underbrace{V_0}_{1} - V_{out} = \frac{0,1}{100} \cdot 1V \Rightarrow V_{out} = 1 - 10^{-3} \Rightarrow \boxed{v_{out} = 0,999\,V}$

$\Rightarrow V_0 = \frac{10}{10^{-6}} \cdot t \rightarrow 1 = \frac{10}{10^{-6}} t \rightarrow \boxed{t = 10^{-7}\,s}$

~~0,999 = A_0~~

$\therefore\quad 0,999 = A_0 \cdot \left(1 - e^{-\frac{10^{-7}}{10^{-7}(A_0+1)}}\right)$

$A_0 - A_0 e^{\frac{-1}{A_0+1}} - 0,999 = \emptyset \Rightarrow \boxed{A_0 \cong 1500}$

↳ Para achar 1500, o erro do método numérico tem que ser muito baixo
↳ na dúvida, utilize bipartição

(8.65) $v_{in}: [0,1V \quad 2V]$
$v_{out}: [-0,5V \quad -1]$

$v_{out} = -V_T \ln \frac{v_{in}}{RI_S} \Rightarrow -0,5 = -26 \cdot 10^{-3} \ln \frac{0,1}{RI_S}$

$\Rightarrow \boxed{RI_S = 4,4482 \cdot 10^{-10}\,V}$

$\rightarrow v_{out} = -26 \cdot 10^{-3} \ln \frac{2}{4,4482 \cdot 10^{-10}} \Rightarrow v_{out} = -0,5779V$

$\Rightarrow p/\ v_{in} = [0,1V \quad 2V] \Rightarrow v_{out}[-0,5 \quad -0,5779V]$