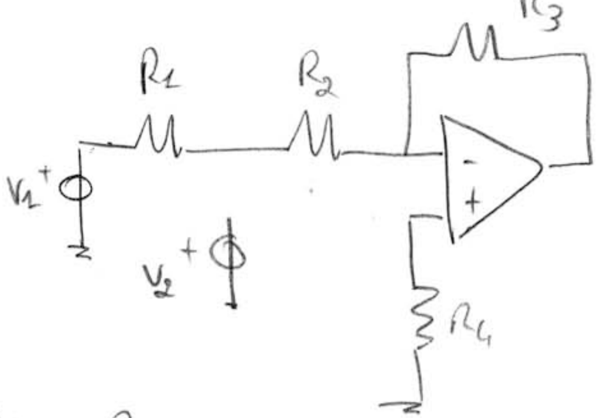
6/9/2006

(1)

ES 1

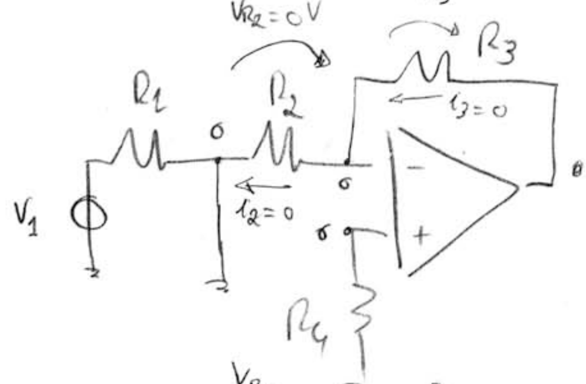
(A) LF



$$\boxed{G_1(0)} = -\frac{R_3}{R_1+R_2} = -\frac{100\,k\Omega}{5\,k\Omega} = \boxed{-20}$$

$$\boxed{G_2(0) = 0}$$

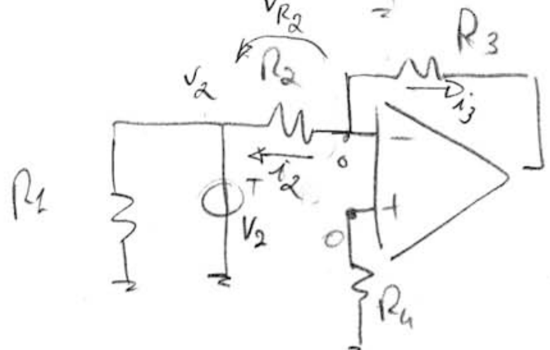
HF



$V^+ = 0 \rightarrow V^- = 0 \rightarrow V_{R_2} = 0 \rightarrow$

$\rightarrow i_2 = 0 \rightarrow i_3 = 0 \rightarrow V_{OUT} = V^+ + V_{R_3} = 0 \Rightarrow$

$$\boxed{G_1(\infty) = 0}$$

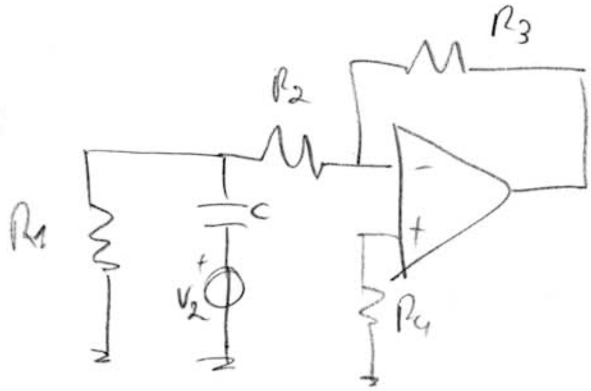


$V^+ = 0 \rightarrow V^- = 0 \rightarrow V_{R_2} = V_2 \rightarrow$

$\rightarrow i_2 = \frac{V_2}{R_2} = i_3 \rightarrow V_{OUT} = 0 - R_3 \frac{V_2}{R_2}$

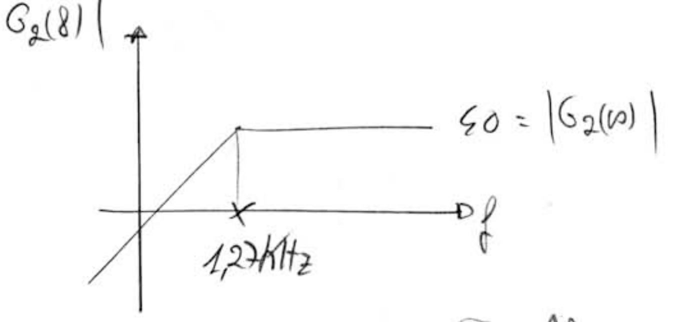
$$\boxed{G_2(\infty)} = -\frac{R_3}{R_2} = \boxed{-40}$$

(B)

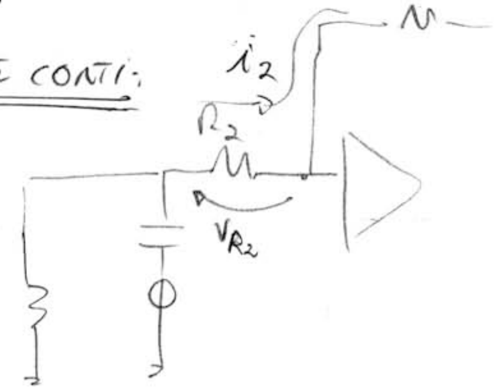


$\tau_p = C(R_1 // R_2) = 100\,nF \times 1{,}25\,k\Omega = 125\,\mu s$

$$\boxed{f_p} = \frac{1}{2\pi\tau_p} = \boxed{1{,}27\,kHz}$$



OPPURE CONTI:



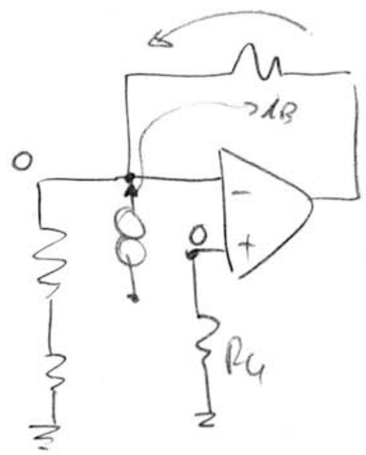
$$\begin{cases} V_{R2} = \dfrac{R_2 // R_1}{R_2 // R_1 + \dfrac{1}{sC}} V_2 \\ i_2 = \dfrac{V_{R2}}{R_2} \\ V_{OUT} = -V_{R3} = -R_3 i_2 \end{cases}$$

⇓

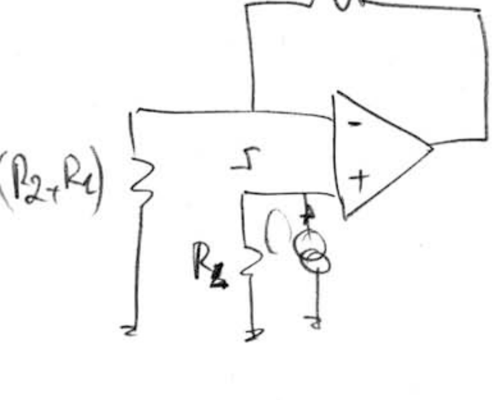
$$G_2(s) = -\frac{R_3}{R_2}\left[\frac{R_2 // R_1}{R_2 // R_1 + \frac{1}{sC}}\right] = -\frac{R_3}{R_2}\,\frac{R_2 R_1}{R_2 + R_1}\,\frac{sC}{1 + sC(R_1 // R_2)}$$

$$= \frac{-sCR_3R_1}{(R_2 + R_1)(1 + sC R_2 // R_1)}$$

(c)



$$V_{IB^-} = -I_B R_3 = -100\,nA \times 100\,k\Omega = -10\,mV$$



$$V_{IB^+} = I_B R_4 \left(1 + \frac{R_3}{R_2 + R_1}\right) = (100\,nA \times 1\,k\Omega)\left(1 + \frac{100\,k\Omega}{5\,k\Omega}\right) = 100\,\mu V \times 21 = 2{,}1\,mV$$

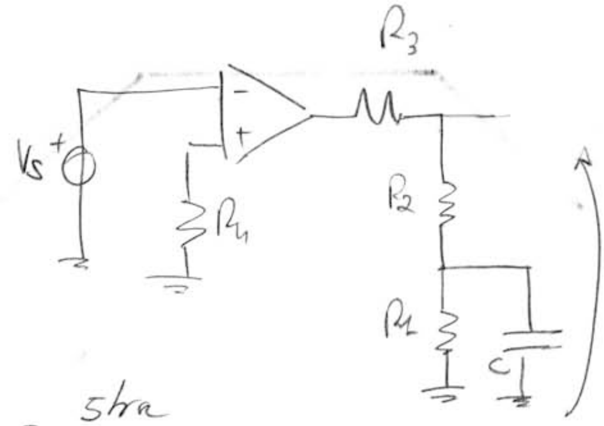
APPLICANDO IL PRINCIPIO di SOVRAPPOSIZIONE DEGLI EFFETTI:

$$\left|V_{OUT}\right|_{I_B}\right| = V\big|_{I_B^+} + V\big|_{I_B^-} = \boxed{-7,9\,mV}$$

Ⓓ

$$G_{LOOP}(s) = -A(s)\,T_p(s)$$

ove $T_p(s)$ è il trasferimento del partitore in uscita dell'OP-AMP

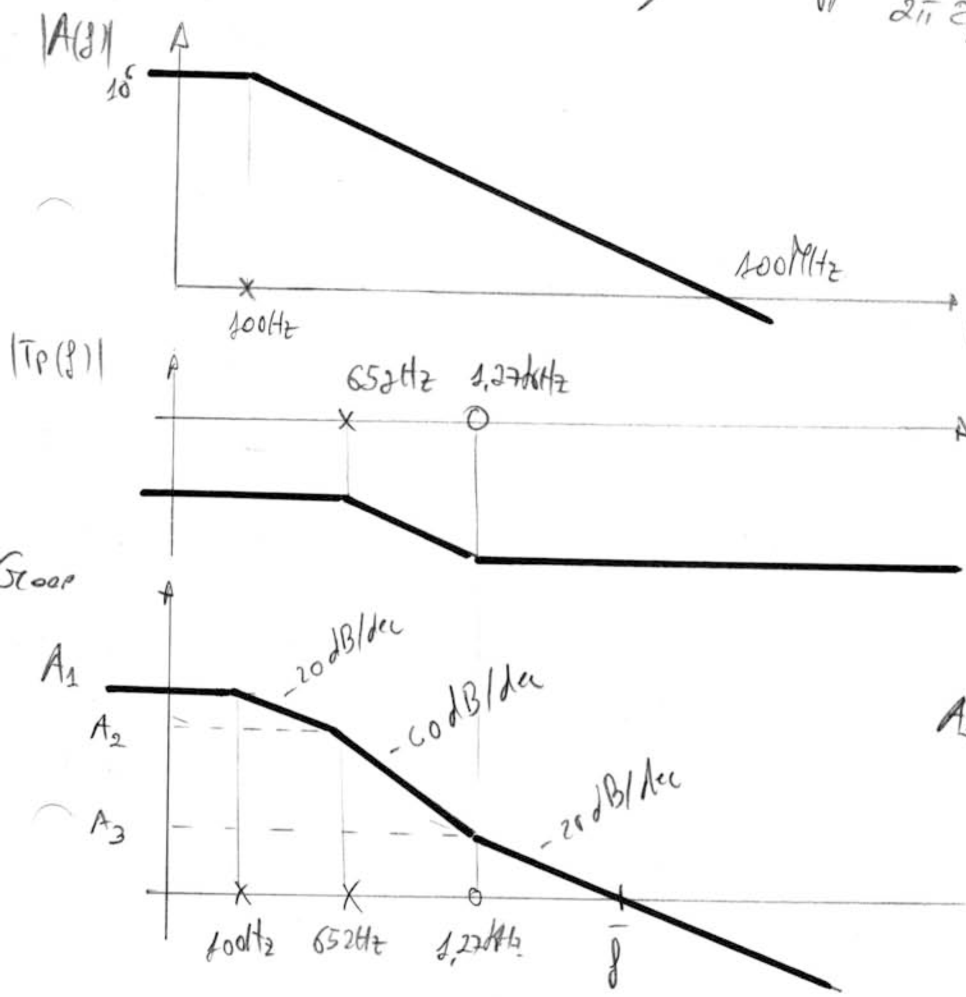


$f = 0$ C aperto $\rightarrow$ $T_p(0) = \dfrac{R_1 + R_2}{R_1 + R_2 + R_3} = \dfrac{5\,k\Omega}{105\,k\Omega}$

$f = \infty$ C corto $\rightarrow$ $T_p(\infty) = \dfrac{R_2}{R_2 + R_3} = \dfrac{2.5\,k\Omega}{102,5\,k\Omega}$

$\tau_p = C\left[R_1 // (R_2 + R_3)\right] = 244\,\mu s \rightarrow f_p = \dfrac{1}{2\pi\tau_p} = 652\,Hz$

$f_z = f_p \dfrac{T_p(0)}{T_p(\infty)} = 1,27\,kHz$



$A_1 = A_0 \times T_p(0) = 47,6 \times 10^3$

$A_2 = A_1 \dfrac{100\,Hz}{652\,Hz} = 7,3 \times 10^3$

$A_3 = A_2 \left(\dfrac{652\,Hz}{1,27\,kHz}\right)^2 = 1924$

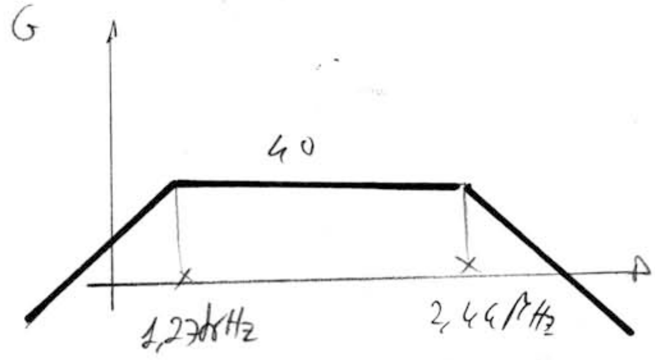
$\bar{f} = 1,27\,kHz \times 1924 =$

$= 2,44\,MHz$

Il guadagno reale → $\simeq G_{ID}$ dove $|G_{loop}| \gg 1$

→ ha un polo $\simeq$ dove $G_{loop} = 1$ $(= 0\,dB)$

Quindi

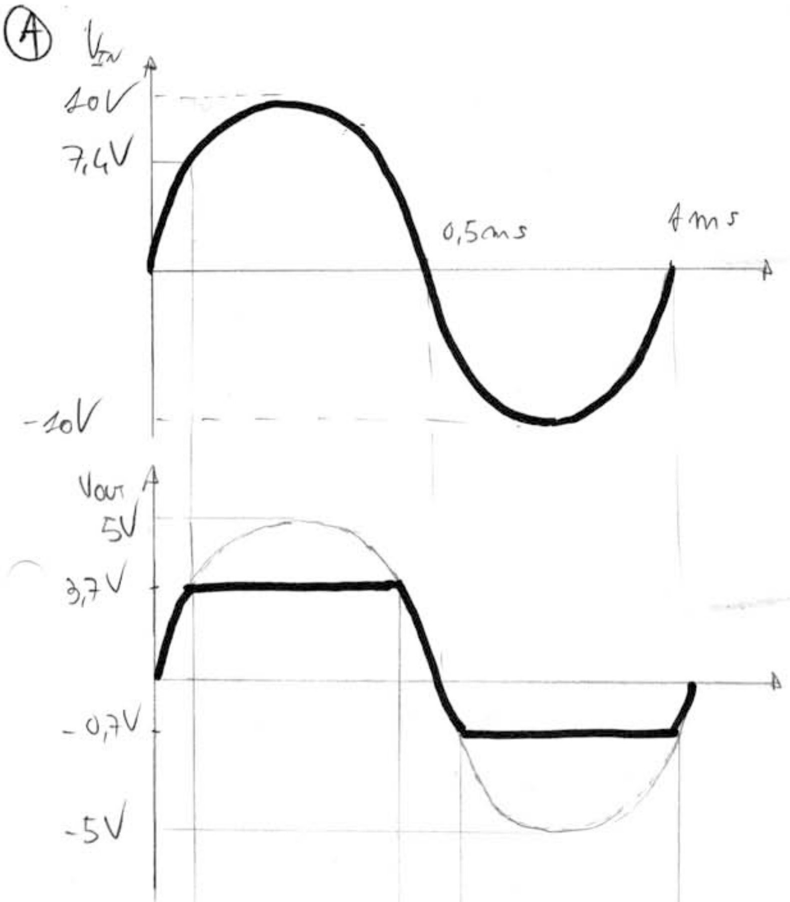


Si può ritenere il guadagno costante nell'intervallo

$$f \in [1{,}27\,kHz ;\ 244\,kHz]$$

ESERCIZIO 2

(A)



per $V_{OUT} < 3{,}7V \rightarrow D1$ OFF

per $V_{OUT} > -0{,}7V \rightarrow D2$ OFF

⇓

Quando D1 e D2 OFF:

$$V_{OUT} = V_{IN} \frac{R_1}{R_1+R_2} = \frac{1}{2} V_{IN}$$

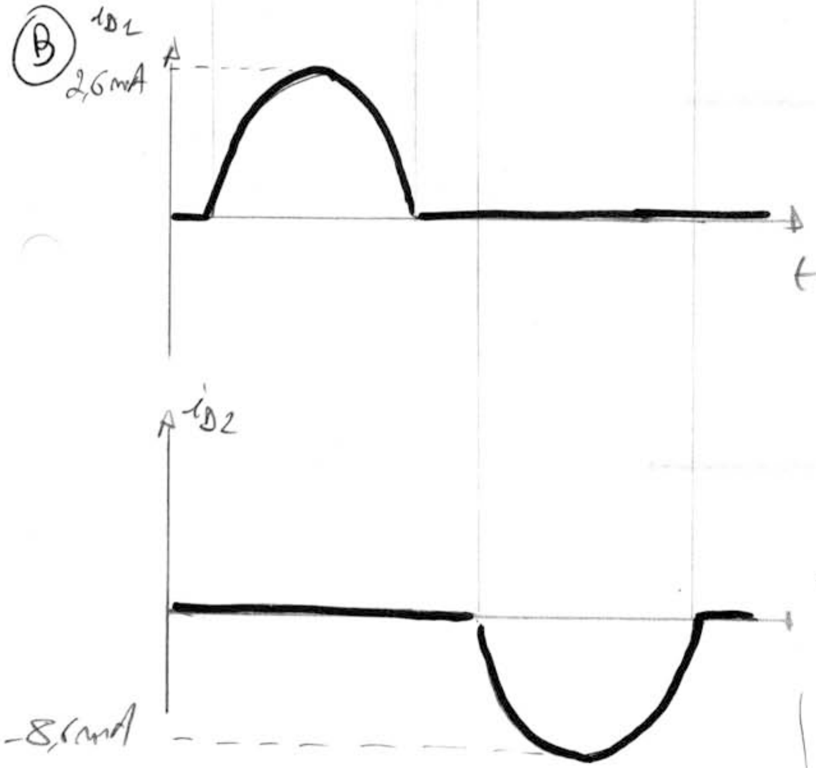
Quando D1 ON

$$V_{OUT} = 3V + 0{,}7V = 3{,}7V$$

Quando D2 ON

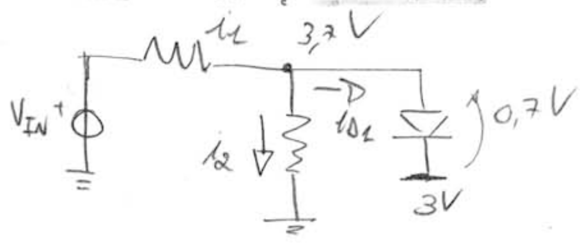
$$V_{OUT} = 0V - 0{,}7V = -0{,}7V$$

(B)



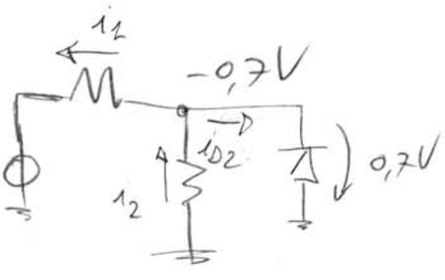
Quando D1 OFF → $i_{D1} = 0$

Quando D1 ON:



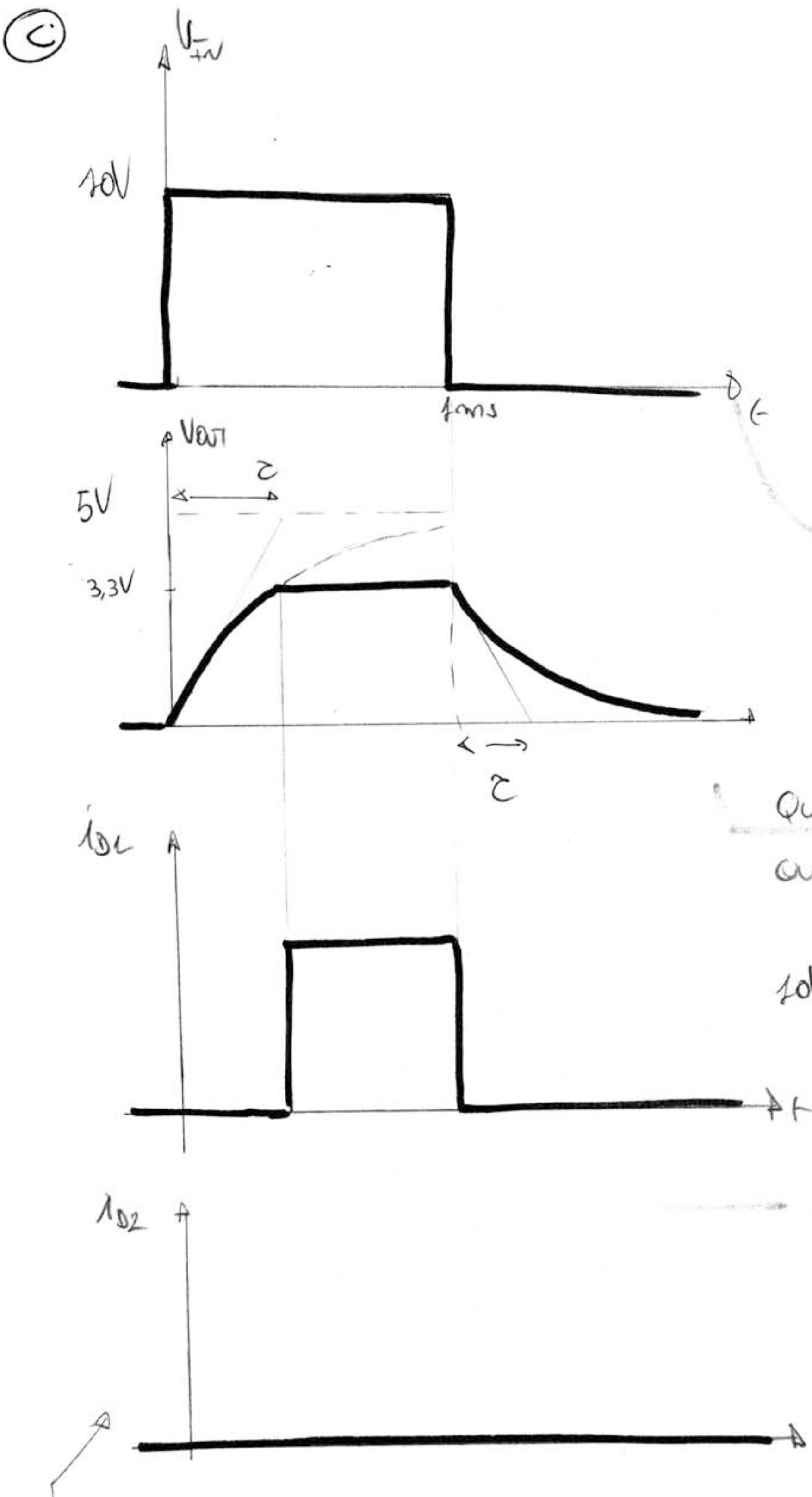
$$\begin{cases} i_1 = \dfrac{V_{IN} - 3{,}7V}{R_1} \\ i_2 = \dfrac{3{,}7V}{R_2} = 3{,}7mA \\ i_{D1} = i_1 - i_2 \end{cases}$$

$$\Rightarrow i_{D1}|_{pk} = \frac{10V - 3{,}7V}{1k\Omega} - 3{,}7mA = 2{,}6mA$$



Analogamente $i_{D2}|_{pk} = \dfrac{0{,}7V}{1k\Omega} - \dfrac{9{,}3V}{1k\Omega} = -8{,}6mA$

(c)

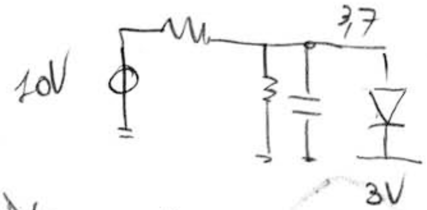


$\tau = C \times (R_1 // R_2)$

$= 1\mu F \times 500\,\Omega = 0{,}5\ ms$

QUANDO D1 è OFF → $i_{D1} = 0$

QUANDO D1 è ON:



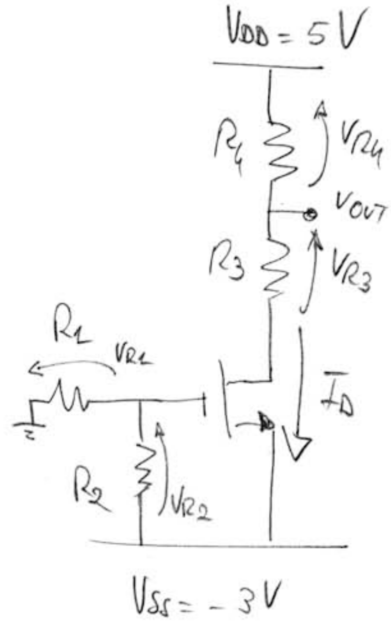
La corrente nel condensatore è ∅ perché la tensione ai suoi capi è costante → procedendo in modo analogo al punto (B):

$i_{D1} = 2{,}6\ mA$

D2 è sempre spento → $i_{D2} = \varnothing$

ESERCIZIO 3

(A)



$$V_{R1} = 3V \times \frac{R_1}{R_1 + R_2} = 1,5V$$

$$V_G = -V_{R1} = -1,5V$$

$$V_{GS} = V_G - V_S = -1,5V - (-3V) = 1,5V$$

$$I_D = K_{n1}(V_{GS} - V_T)^2 = 450 \frac{\mu A}{V^2}(1,5V - 0,5V)^2 = 450 \mu A$$

$$V_{R4} = I_D R_4 = 1,8V$$

$$V_{R3} = I_D R_3 = 450 mV$$

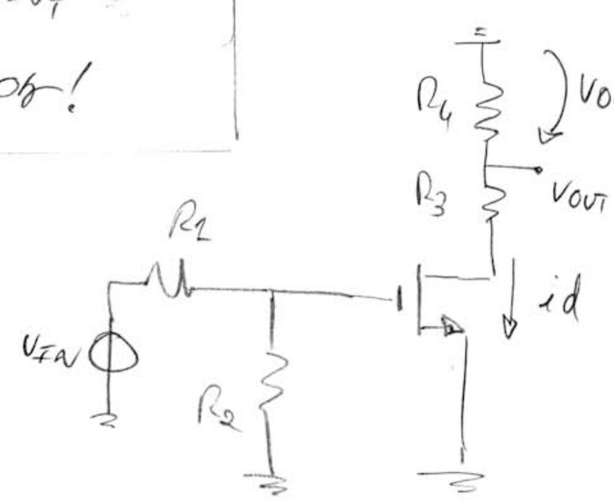
$$V_{OUT} = V_{DD} - V_{R4} = 3,2V$$

$$V_D = V_{OUT} - V_{R3} = 2,75V$$

VERIFICA SATURAZIONE : $V_{DS} \overset{?}{>} V_{GS} - V_T$

$$(2,75V + 3V) \overset{?}{>} 1V \rightarrow ok!$$

(B)



$$\begin{cases} v_{gs} = v_{IN} \frac{R_2}{R_2 + R_1} \\ id = v_{gs} \times g_m \\ v_{OUT} = -R_4 \, id \end{cases} \Rightarrow$$

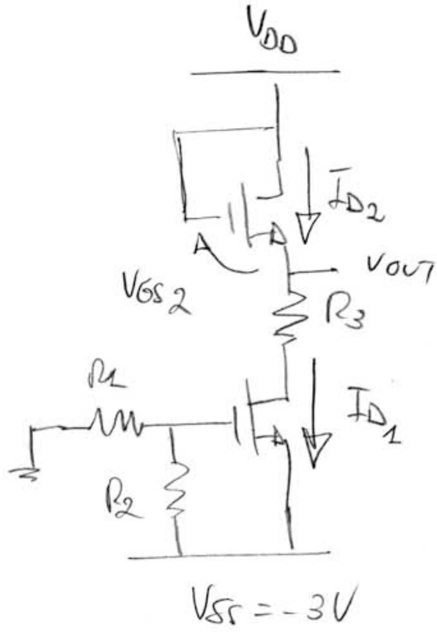
$$v_{OUT} = -g_m R_4 \frac{R_1}{R_1 + R_2} v_{IN}$$

$$\Downarrow$$

$$G = \frac{v_{OUT}}{v_{IN}} = \left| -g_m R_4 \frac{R_1}{R_1 + R_2} \right| = \frac{-2 \times 450 \mu A/V}{1V} \times 4 k\Omega \times \frac{1}{2} = \boxed{-1,8}$$

(C) • PROCEDENDO COME NEL PUNTO (A) si può CALCOLARE I_{D1}. Si ottiene ancora.

$$I_{D1} = 450\,\mu A$$



• PER LA LEGGE DI KIRCHHOFF DELLE CORRENTI, DEVE ESSERE $I_{D2} = I_{D1}$, QUINDI

$$I_{D2} = 450\,\mu A$$

• LA V_{GS} DEL MOS M2 "SI SISTEMA" IN MODO CHE M2 PORTI PROPRIO 450 µA.

$$I_{D2} = K_{m2}\left(V_{GS2} - V_T\right)^2 \rightarrow V_{GS2} = V_T + \sqrt{\frac{I_{D2}}{K_{m2}}} = 3{,}5\,V$$

• $\boxed{V_{OUT}} = V_{DD} - V_{GS2} = 5V - 3{,}5V = \boxed{1{,}5V}$

• $V_{D1} = V_{OUT} - V_{R3} = 1{,}05V - 450\,mV = 1{,}05V$ → NOTARE CHE M1 è ANCORA IN SATURAZIONE

• NOTARE CHE M2 è IN SATURAZIONE PERCHÉ $V_G = V_D$

(D) $$g_{m2} = \frac{2I_D}{(V_{GS2} - V_T)} = \frac{900\,\mu A}{3V} = 300\,\frac{\mu A}{V}$$

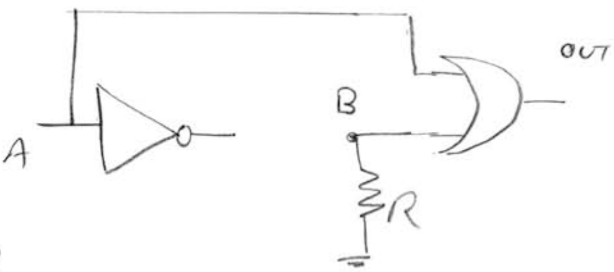
IL CALCOLO DEL GUADAGNO è ANALOGO AL PTO (B) CON L'UNICA DIFFERENZA CHE LA CORRENTE i_D SI INIETTA NELL'IMPEDENZA VISTA DAL SOURCE DI M2, CIOÈ $1/g_{m2}$:

$$\boxed{G} = -g_{m1} \times \frac{1}{g_{m2}} \times \frac{R_1}{R_1 + R_2} =$$

$$= -900\,\frac{\mu A}{V} \times \frac{1\,V}{300\,\mu A} \times \frac{1}{2} = \boxed{-1{,}5}$$

ESERCIZIO 4

(A) • TABELLA DELLE VERITÀ ⇒
⇒ COMPORTAMENTO A REGIME ⇒
⇒ I CONDENSATORI SI COMPORTANO COME CIRCUITI APERTI



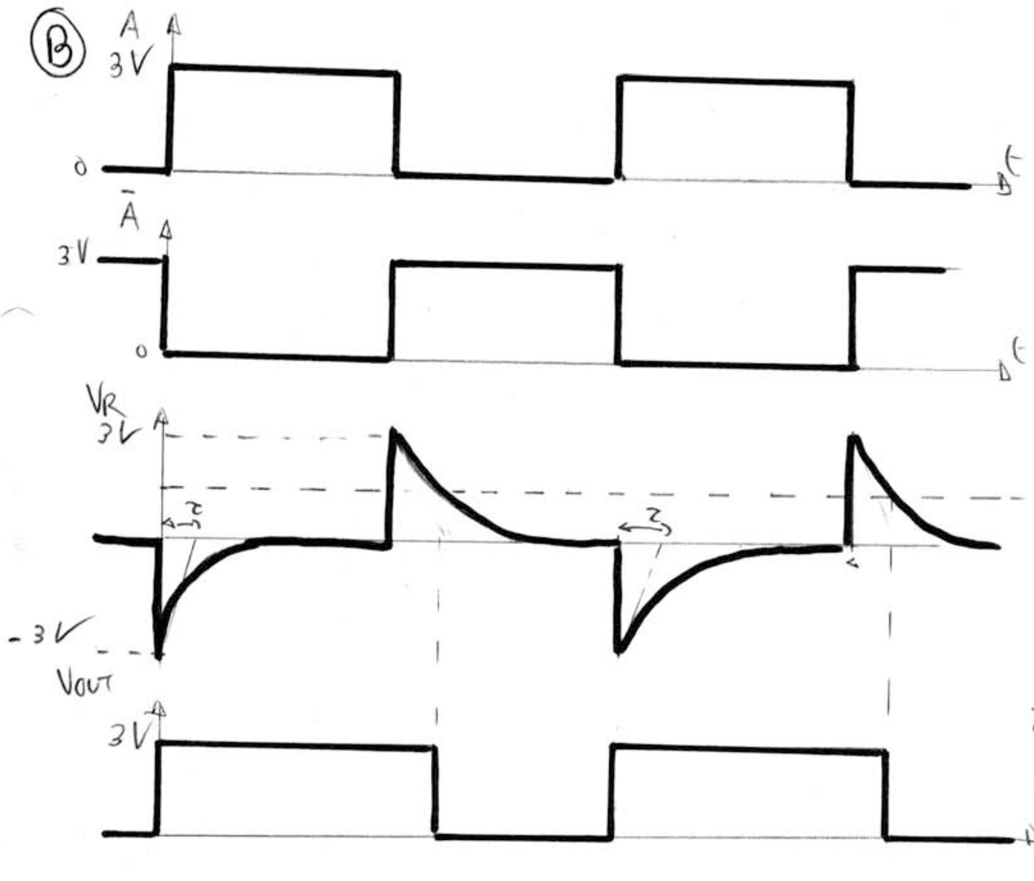
• IL NODO B È TENUTO A ØV DALLA RESISTENZA R IN CUI NON PUÒ SCORRERE CORRENTE (ALL'INTERNO C'È IL GATE di UN MOS!)

Quindi:

$A = 0 \rightarrow OUT = 0$

$A = 1 \rightarrow OUT = 1$

(B)



$\tau = RC = 500 ms$

SOGLIA DELLA PORTA LOGICA $= \frac{3V}{2} = 1{,}5V$

↓

QUANDO $V_R > V_{TH}$, LA PORTA LOGICA LO INTERPRETA COME "1", ALTRIMENTI COME "0"

(C) $P_{DISS} = C_L V_{CC}^2 \cdot f = 50pF \times (3V)^2 \times 10KHz = 4{,}5 \mu W$