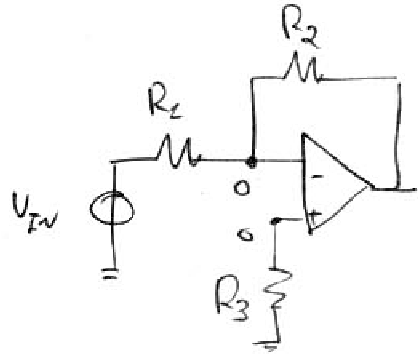
ESERCIZIO 1

1.A

$$\boxed{G} = -\frac{R_2}{R_1} = \boxed{-20}$$

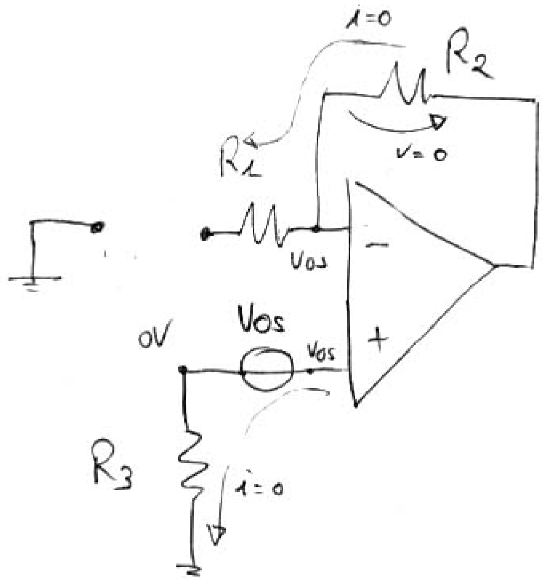


1.B

OFFSET TENSIONE COSTANTE →
→ CONDENSATO APERTI →
→ LO STADIO È UN BUFFER

$$\boxed{V_{OUT}} = V_{OS} = \boxed{\pm 12\,mV}$$

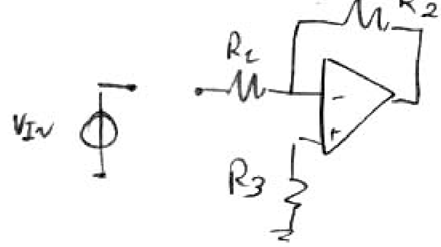
SEGNO NON NOTO A PRIORI



1.C

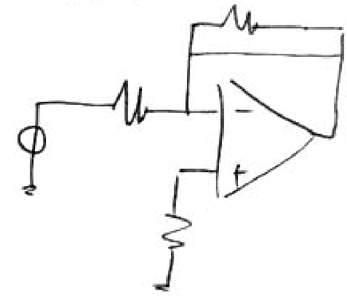
METODO 1

* A BASSA FREQ: I CONDENSATORI SONO APERTI:



$$\boxed{G_{ID}(0) = 0}$$

* AD ALTA FREQ: I CONDENSATORI SONO DEI CORTI



$$\boxed{G_{ID}(\infty) = 0}$$

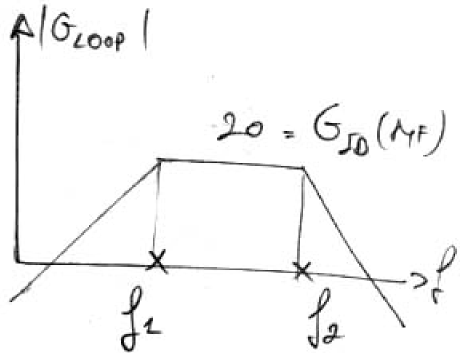
⊛ A MEDIA FREQ : $G_{ID}(MF) = -\frac{R_2}{R_1}$ (VEDI 1.A)

⊛ LO STADIO HA CERTAMENTE 2 POLI (2 CONDENSATORI), MA NON PUÒ AVERE ZERI PERCHÈ PARTE da ∅ a BASSA FREQ e ARRIVA a ∅ AD ALTA FREQ

POLI:

$$\tau_1 = R_1 C_1 = 1k\Omega \times 470nF = 470\mu s \rightarrow \boxed{f_1} = \frac{1}{2\pi\tau_1} = \boxed{338 Hz}$$

$$\tau_2 = R_2 C_2 = 20k\Omega \times 10pF = 200ns \longrightarrow \boxed{f_2} = \frac{1}{2\pi\tau_2} = \boxed{796 kHz}$$

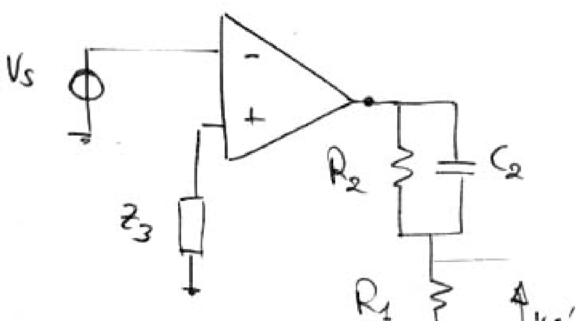


FILTRO PASSABANDA

METODO 2

$$|G_{ID}| = -\frac{Z_2(s)}{Z_1(s)} = -\frac{R_2 // \frac{1}{sC_2}}{R_1 + \frac{1}{sC_1}} = \dots = \boxed{-\frac{sC_1R_2}{(1+sC_1R_1)(1+sC_2R_2)}}$$

1.D

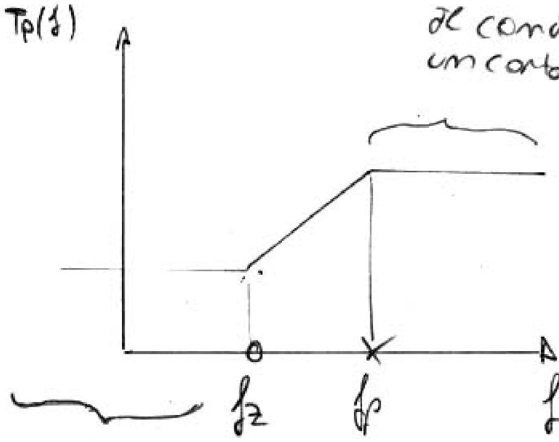


$$G_{LOOP}(s) = -A(s)\, T_p(s)$$ ← TRASFERIMENTO del PARTITORE IN USCITA

$$= -A(s) \frac{R_1}{R_1 + \left(R_2 // \frac{1}{sC_2}\right)} = \dots =$$

$$= -A(s) \frac{R_1}{R_1+R_2} \frac{1+sC_2R_2}{1+sC_2(R_1//R_2)}$$

Il condensatore è un corto → $T_p(\infty) = 1$



Il cond. è un aperto, quindi

$T_p(0) = \frac{R_1}{R_1 + R_2} = \frac{1}{21}$

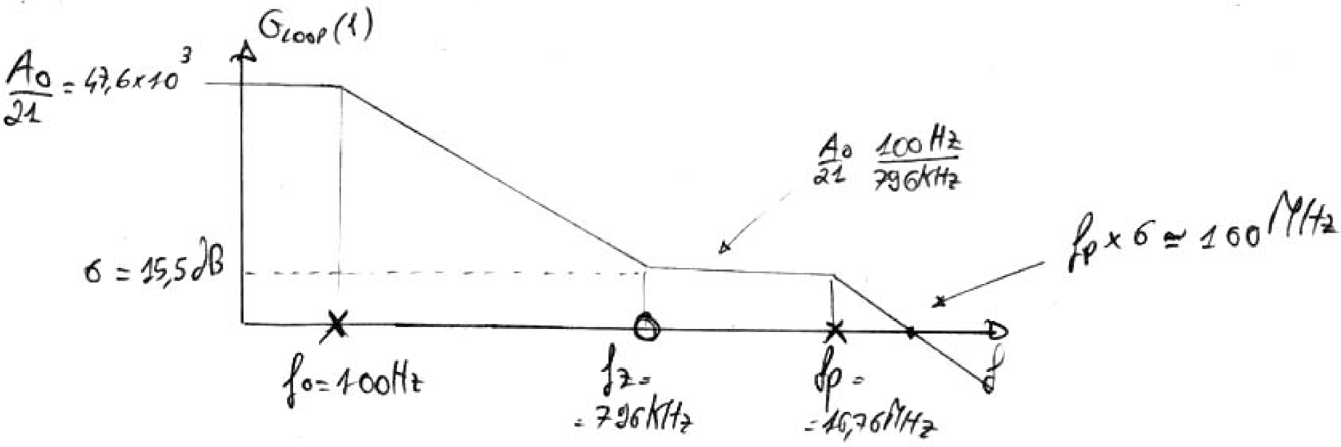
$$\tau_p = C_2 (R_1 // R_2) = 9{,}5 \text{ ns}$$

$$\tau_z = C_2 R_2 = 200 \text{ ns}$$

$$\Downarrow$$

$$f_p = \frac{1}{2\pi \tau_p} = 16{,}76 \text{ MHz}$$

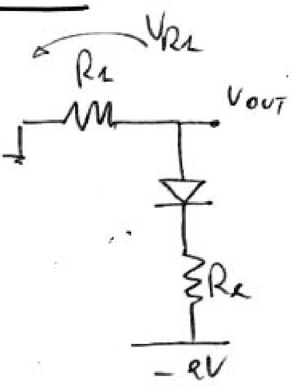
$$f_z = \frac{1}{2\pi \tau_z} = 796 \text{ kHz}$$



Il $G_{LOOP} = 1$ per $\bar{f} = 100$ MHz. Il circuito è ben reazionato quando G_{LOOP} è sufficientemente grande, per esempio quando $|G_{LOOP}| = 5$ → $f = \frac{100 \text{ MHz}}{5} = \boxed{20 \text{ MHz}}$

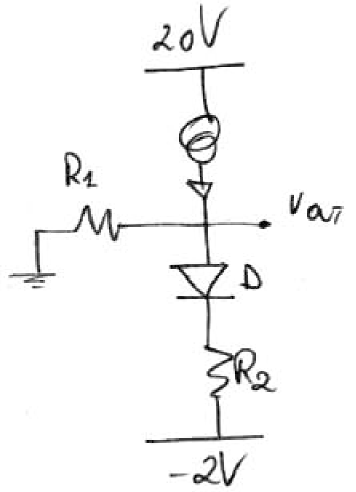
ESERCIZIO 2

2A



$$\boxed{V_{OUT}} = -V_{R1} = \left(-\frac{R_1}{R_1+R_2}\right)\left(2V - 0{,}7V\right) =$$
$$= -\frac{2{,}5k}{7{,}5k}\left(1{,}3V\right) = \boxed{-433mV}$$

2.B



- Se $I_{IN} > 0$: Inietto corrente nel nodo V_{OUT} → V_{OUT} sale → il diodo resta comunque acceso
- Se $I_{IN} < 0$: V_{OUT} scende → il diodo può spegnersi, se $V_{OUT} < -1{,}3V$

DIODO ON

Principio di sovrapposizione degli effetti: ai $-433mV$ si sovrappone l'effetto di I_{IN} iniettata in $R_1 // R_2$:

$$V_{OUT} = -433mV + I_{IN} \times R_1 // R_2$$

Valore di picco:

$$\boxed{V_{OUT}|_{pk}} = -433mV + 6mA \times \left(2{,}5k\Omega // 5k\Omega\right) = -433mV + 10V = \boxed{9{,}567V}$$

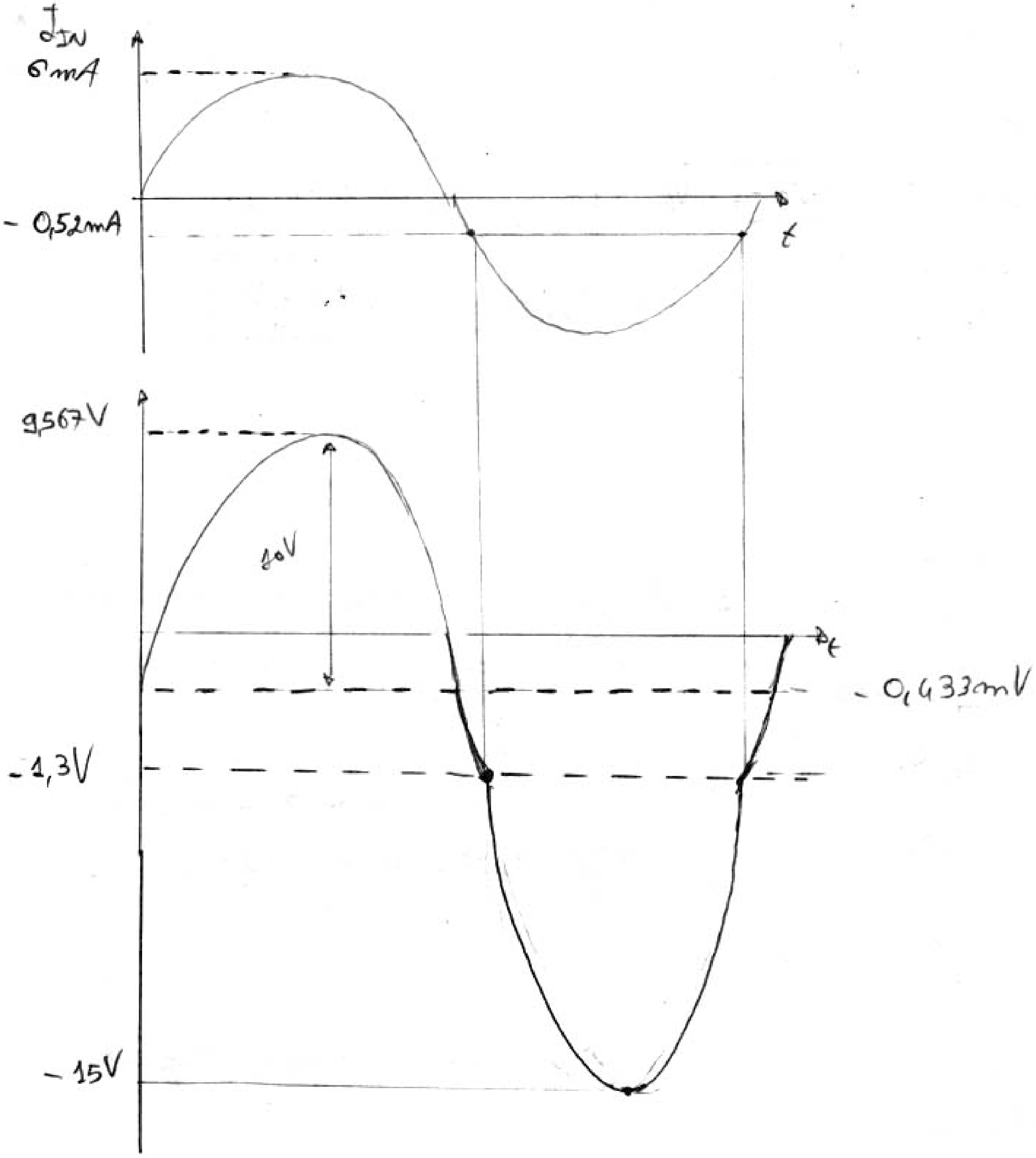
DIODO OFF

D si spegne quando $V_{OUT} = -1{,}3V$ corrispondente ad una corrente I_{IN}:

$$I_{IN} = \frac{V_{OUT} + 433mV}{R_1 // R_2} = \frac{-1{,}3V + 0{,}433V}{2{,}5k\Omega // 5k\Omega} = -522\mu A$$

Quando il diodo è aperto tutta la corrente fluisce in R_1:

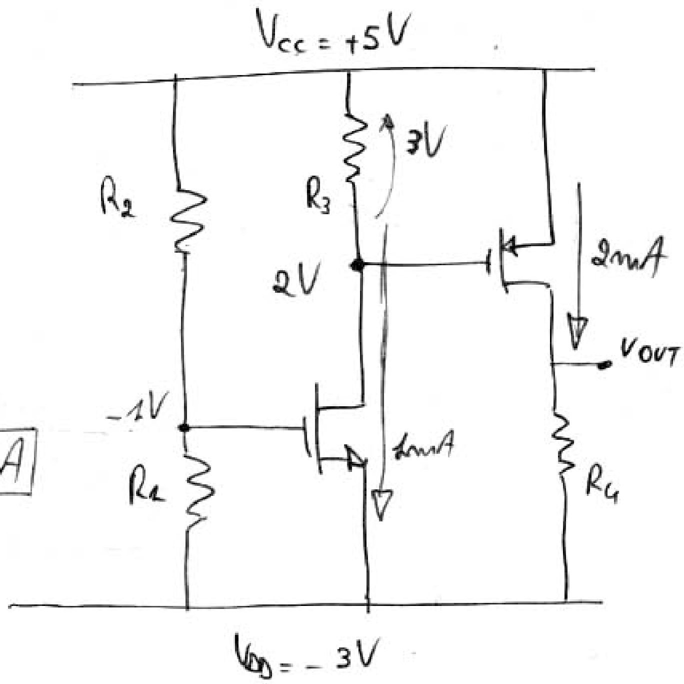
$$V_{OUT} = -R_1 I_{IN} \quad \rightarrow \quad \boxed{V_{OUT}|_{pk}} = -2{,}5k\Omega \times 6mA = \boxed{-15V}$$



I_{IN}
6mA
- 0,52mA
t
9,567V
10V
t
- 0,433mV
- 1,3V
- 15V

ESERCIZIO 3

3.A



$$\boxed{V_{Gn}} = V_{DD} + (V_{cc} - V_{DD}) \frac{R_1}{R_1 + R_2} =$$

$$= -3V + 8V \times \frac{20k\Omega}{20k\Omega + 60k\Omega} = \boxed{-1V}$$

$$\boxed{I_{Dn}} = k_n (V_{GSn} - V_{Tn})^2 = 1\frac{mA}{V^2}(2V - 1V)^2 = \boxed{1mA}$$

$$\boxed{V_{GSp}} = V_{R_3} = I_D R_3 = \boxed{3V}$$

$$\boxed{I_{Dp}} = k_p (V_{GSp} - V_{Tp})^2 = \frac{1}{2}\frac{mA}{V^2}(3V - 1V)^2 = \boxed{2mA}$$

$$\boxed{V_{OUT}} = V_{DD} + R_4 I_{Dp} = -3V + 2mA \times 1{,}5k\Omega = \boxed{0V}$$

VERIFICA SAT MOS:

N-MOS: $V_D = 2V$, $V_G = -1V$ → OK! (Visto che $V_D > V_G$)

P-MOS: $V_D = 0V$, $V_G = 2V$ → OK! (perché $V_D < V_G$)

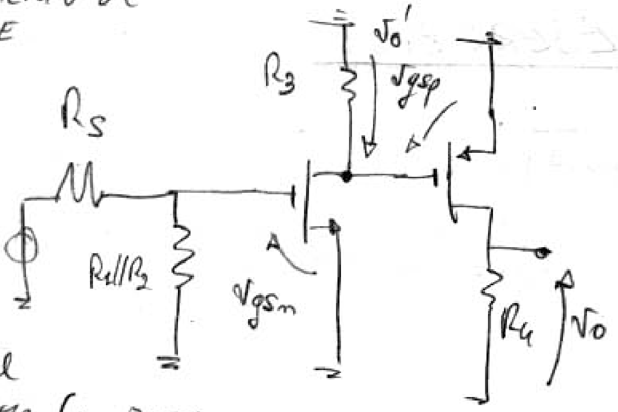
$$\boxed{g_{mN}} = \frac{2I_D}{(V_{GSn} - V_T)} = \frac{2mA}{2V - 1V} = \boxed{2\frac{mA}{V}} \rightarrow \frac{1}{g_{mn}} = 500\Omega$$

$$\boxed{g_{mp}} = \frac{2I_D}{(V_{GSp} - V_T)} = \frac{4mA}{(3V - 1V)} = \boxed{2\frac{mA}{V}} \rightarrow \frac{1}{g_{mp}} = 500\Omega$$

3.B

$$v_{gs} = \frac{R_1 /\!/ R_2}{R_1 /\!/ R_2 + R_S}\, v_{IN} = T_p\, v_{IN}$$

TRASFERIMENTO del PARTITORE



$$v_o' = v_{gs_n}\left(-g_{m_n} R_3\right) = G_n \cdot v_{gs}$$

GUADAGNO del SOURCE A MASSA (n-MOS)

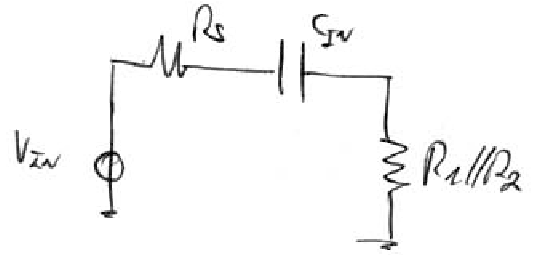
$$v_o = v_{gsp}\left(-g_{m_p} \cdot R_4\right) = G_p \cdot v_{gsp} = G_p \cdot v_o'$$

GUADAGNO del SOURCE A MASSA (p-MOS)

$$\Rightarrow \boxed{G} = \frac{v_o}{v_{IN}} = \ldots = \boxed{T_p \cdot G_n \cdot G_p} = \frac{20k/\!/60k}{20k/\!/60k + 5\,k\Omega}\left(-\frac{2mA}{V}\, 3\,k\Omega\right)\left(-\frac{2mA}{V}\, 1{,}5\,k\Omega\right)$$

$$= \frac{3}{4} \times (-6) \times (-3V) = \boxed{13{,}5}$$

3.C Considerando C l'unico termine del trasferimento che si modifica è T_p:

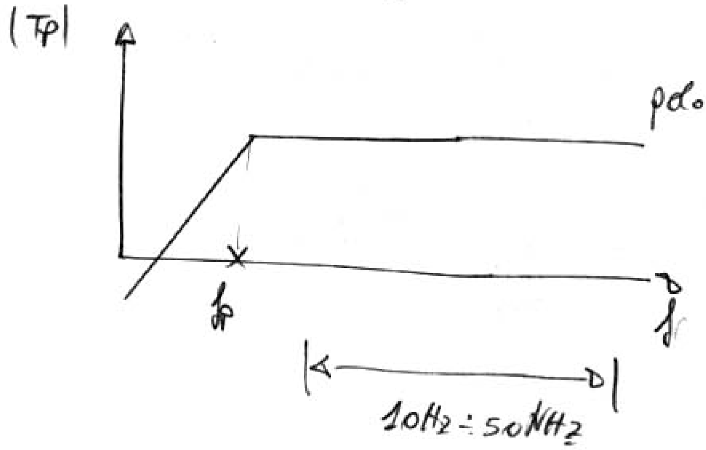


$T_p(0) = 0$ (CONDENSATORE APERTO)

$$T_p(\infty) = \frac{R_1/\!/R_2}{R_1/\!/R_2 + R_S}$$

polo: $\tau_p = C_{IN}\left(R_S + R_1/\!/R_2\right)$

$$f_p = \frac{1}{2\pi \tau_p}$$



↳ AFFINCHÉ IL CIRCUITO AMPLIFICHI CORRETTAMENTE LA BANDA 10Hz ÷ 50kHz, OCCORRE CHE IL POLO f_p SIA ALMENO UNA DECADE PRIMA dei 10Hz

$f_p = 1Hz \Rightarrow \frac{1}{2\pi \tau_p} = 1Hz \Rightarrow \boxed{C_{in}} = \frac{1}{2\pi \cdot 1Hz \cdot (R_S + R_1 // R_L)} = \boxed{27,6\,\mu F}$

$\boxed{3.D}$ $V_{Gp} = 2V$

Per rimanere in saturazione, il drain del P-MOS può al massimo arrivare ad una soglia sopra il gate:

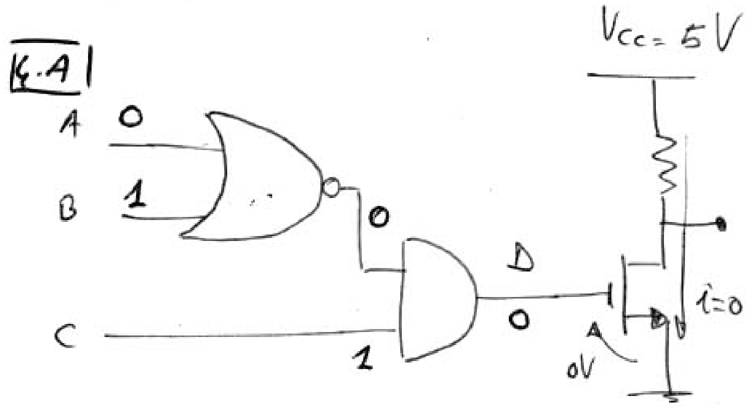
$V_D|_{MAX} = V_{Gp} + |V_{Tp}| = 2V + 1V = 3V \quad (\Rightarrow V_{R_4}|_{MAX} = V_D|_{MAX} - V_{DD} = 6V)$

Quindi:

$\boxed{R_4|_{MAX}} = \frac{V_{R_4}|_{MAX}}{I_{D_1}} = \frac{6V}{2mA} = \boxed{3k\Omega}$

ESERCIZIO 4

4.A

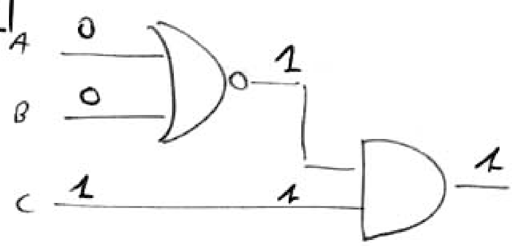


$D = 0$ logico $\Rightarrow 0V \rightarrow$

$\Rightarrow V_{GS} = 0V \Rightarrow \boxed{\text{MOS OFF}}$

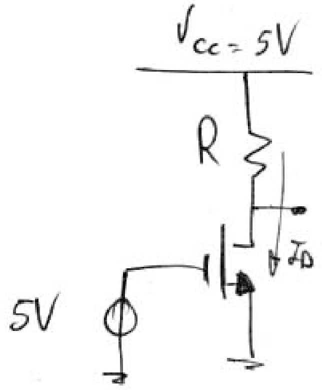
$\Rightarrow i = 0 \Rightarrow \boxed{V_{OUT} = V_{CC} = 5V}$

4.B



$D = 1$ logico $\Rightarrow 5V \rightarrow$

$\Rightarrow V_{GS} = 5V$



IPOTIZZANDO IL MOS IN SATURAZIONE:

$$I_D = K(V_{GS} - V_T)^2 = \frac{1mA}{V^2}(5V - 2V)^2 = 9mA$$

$$V_{OUT} = V_{CC} - R I_D = 5V - 9mA \times 16{,}5k\Omega =$$

$$= -143{,}5V$$ ← NON È POSSIBILE ⇒ IL MOS NON È IN SATURAZ, MA IN ZONA OHMICA

$$\begin{cases} I_D = \dfrac{V_{CC} - V_{OUT}}{R} = \dfrac{V_{CC} - V_{DS}}{R} \\ I_D = K\left[2(V_{GS} - V_T)V_{DS} - V_{DS}^2\right] \end{cases} \Leftrightarrow$$

$$\frac{V_{CC} - V_{DS}}{R} = K\left[2(V_{GS} - V_T)V_{DS} - V_{DS}^2\right] \Leftrightarrow$$

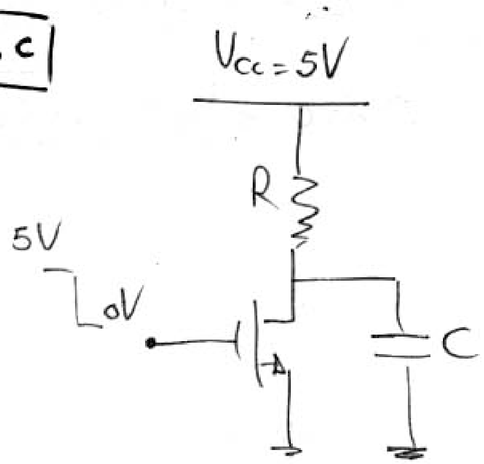
$$(16.5\,V^{-1})V_{DS}^2 - 100\,V_{DS} + 5V = 0$$

$$V_{DS} = \begin{cases} \rightarrow 6V \rightarrow \text{NO } \grave{e} > V_{CC} \\ \rightarrow 50{,}4mV \end{cases}$$

Quindi

$$\boxed{V_{OUT} = 50.4\,mV}$$

4.c



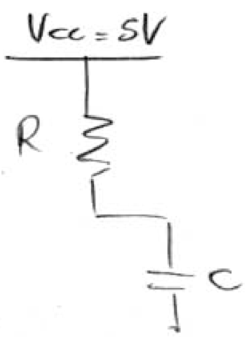
INIZIALMENTE,

$V_G = 5V \rightarrow$ MOS ACCESO $\rightarrow V_{OUT} = 50.4\,mV$

INGRESSO COMMUTA,

IL MOS SI SPEGNE $\Rightarrow$ IL CIRCUITO SI RIDUCE AD UN RC

$\Downarrow$



$$V_o(t) = \left[V_o(\infty) - V_o(0)\right]\left(1 - e^{-t/\tau}\right) + V_o(0) \iff$$

$$t = -\tau \ln \frac{V_o(\infty) - V_o(t)}{V_o(\infty) - V_o(0)} =$$

50% dell'escursione, quindi: $V_o(\infty) - V_o(t) = 0.5 \times [V_o(\infty) - V_o(0)]$

$$= -\tau \ln(0,5) = \boxed{0,69\,\tau}$$

$$t = 0,69 \times R \times C = 0,69 \times 16,5\,k\Omega \times 10\,pF =$$

$$= \boxed{113,85\,ns}$$