PROBLEMA P1

Dato il circuito riportato nella figura sottostante, determinare:

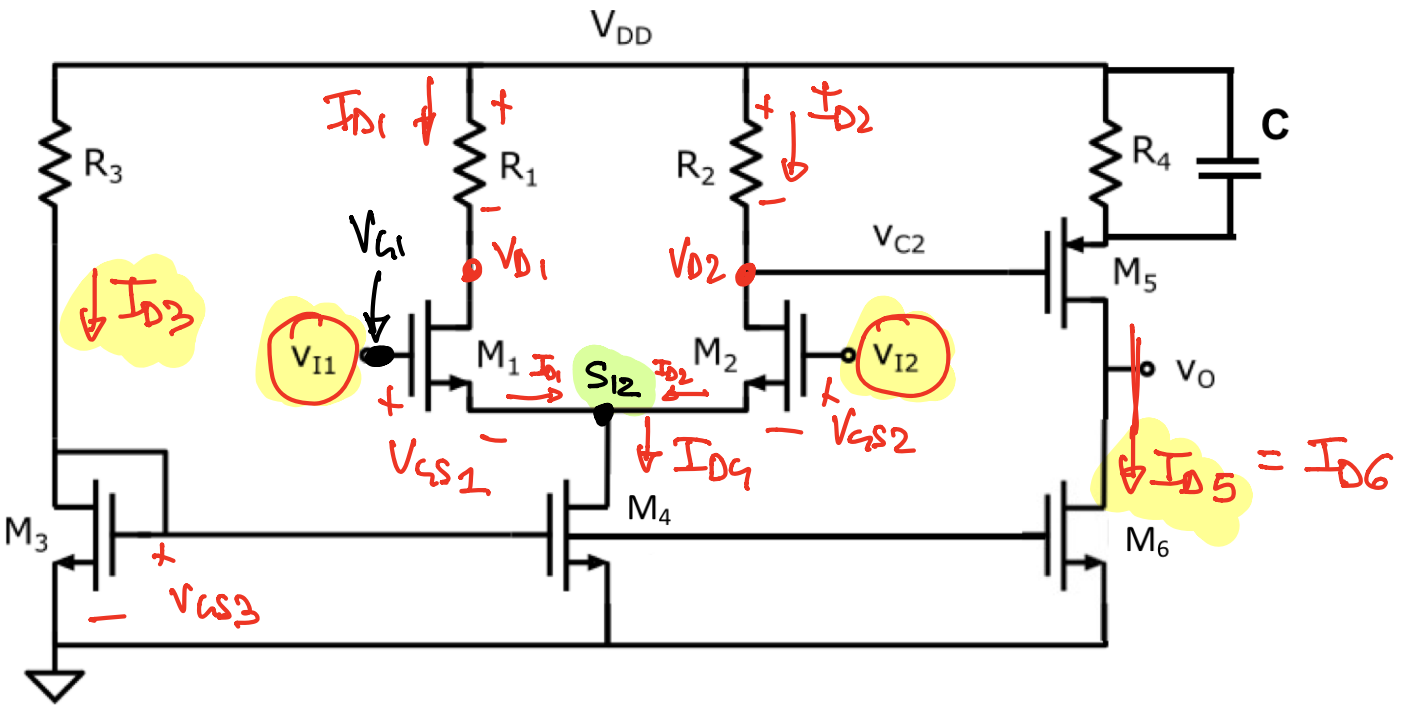
1) Il valore della resistenza R_4 e il punto di lavoro dei transistor M_1, M_2, M_3, M_4, M_5 e M_6 **sapendo che $V_O=V_{DD}/2$ (considerare $\lambda_n = 0$)**
2) il guadagno di tensione differenziale ai piccoli segnali ac $A_{vd}=v_o/v_{id}$;
3) il rapporto di reiezione del modo comune (CMRR) supponendo, solo in questo caso, che i M_4 e M_6 abbiano un parametro di modulazione della lunghezza di canale $\lambda_{n4,6}=0.002\ V^{-1}$.

Dati: $V_{DD}=15$ V, $V_{I1}= V_{I2}=6.5$ V, $R_1=R_2=2$ kΩ, $R_3=2.045$ kΩ,

$M_{1,2}$: $k_{n1}=4$ mA/V^2, $V_{tn1}=1$ V, $\lambda_{n1}=0$ V^{-1},

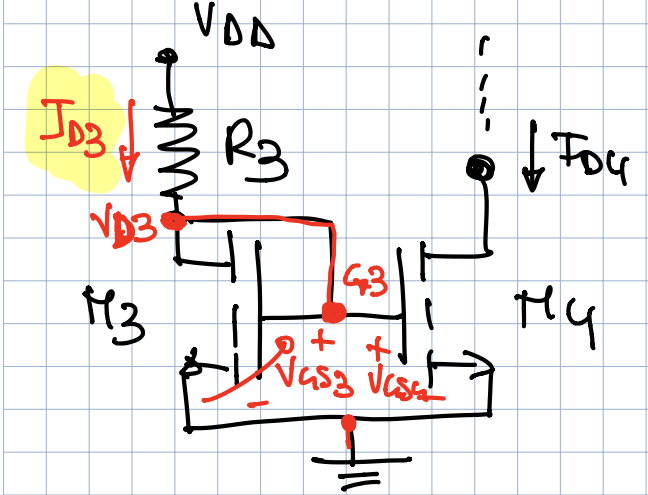
M_5: $k_{p5}=2$ mA/V^2, $V_{tp5}=-1$ V, $\lambda_{p5}=0$ V^{-1}

$M_{3,4,6}$: $k_{n3}=4$ mA/V^2, $V_{tn3}=1$ V, $\lambda_{n3}=0.002$ V^{-1},



POLARIZZAZIONE

CONSIDERO LO SPECCHIO



$V_{G3} = V_{GS3} = V_{D3} = V_{GS4}$

$$I_{D3} = \frac{V_{DD} - V_{GS3}}{R_3}$$

$$I_{D3} = \frac{K_{n3}}{2}\left(V_{GS3} - V_{tn3}\right)^2 \quad *$$

$$\frac{V_{DD} - V_{GS3}}{R_3} = \frac{K_{n3}}{2}\left(V_{GS3} - V_{TN3}\right)^2$$

$$\frac{2V_{DD}}{K_{n3}R_3} - \frac{2V_{GS3}}{R_3 K_{n3}} = V_{GS3}^2 + V_{TN3}^2 - 2V_{GS3}V_{TN3}$$

$$\boxed{V_{GS3}^2 + V_{GS3}\left(\frac{2}{R_3 K_{n3}} - 2V_{TN3}\right) + V_{TN3}^2 - \frac{2V_{DD}}{K_{n3}R_3} = 0}$$

$a = 1 \qquad b = -1{,}756 \qquad c = -2{,}667$

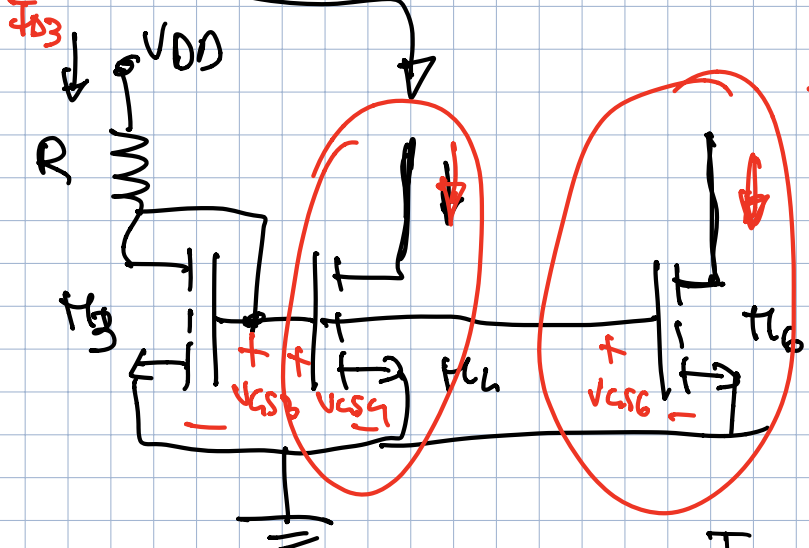
$$V_{GS3\,1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = 2{,}732\,V$$

$$I_{D3} = \frac{K_{n3}}{2}\left(V_{GS3} - V_{TN3}\right)^2 = 6\,mA$$

$$\boxed{I_{D4} = I_{D3} \cdot \frac{K_{n4}(1 + \lambda V_{DS4})}{K_{n3}(1 + \lambda V_{DS3})}} = I_{D3} = 6\,mA$$

$$I_{D1} = I_{D2} = \frac{I_{D4}}{2} = 3\,mA$$

$$I_{D5} = I_{D4} = 6\,mA = I_{D6}$$



$$I_{D6} = \frac{K_{n6}}{2}\left(V_{GS6} - V_{TN6}\right)^2$$

$V_{GS6} = V_{GS3}$

$$I_{D6} = \frac{K_{n6}}{2}\left(V_{GS6} - V_{TN6}\right)$$

$$I_{D3} = \frac{K_{n3}}{2}\left(V_{GS3} - V_{TN3}\right)$$

$$I_{D6} = I_{D3}\,\frac{K_{n6}}{K_{n3}} \cdot \frac{(1 + \lambda V_{DS6})}{(1 + \lambda V_{DS3})} = I_{D3}$$

$$V_{GS1} = V_{TN1} + \sqrt{\frac{2I_{D1}}{K_{n1}}} = 2{,}225\,V = V_{GS2}$$

$$V_{S12} \simeq V_{I1} - V_{GS1} \simeq 4{,}275\,V$$
$$\updownarrow$$
$$V_{I2} - V_{GS2} \simeq 4{,}275\,V$$

$$V_{D1} = V_{DD} - I_{D1}R_1 \simeq 8V = 15V - 3mA \cdot 2k\Omega = 8V = V_{D2}$$

$$V_{D2} = V_{DD} - I_{D2}R_2 \simeq 8V$$

$$V_{GS5} = V_{TP5} - \sqrt{\frac{2I_{D5}}{K_{P5}}} \simeq -3{,}45V$$

$$V_{S5} = V_{G5} - V_{GS5} = V_{D2} - V_{GS5} \simeq 8V - (-3{,}45V)$$
$$\updownarrow$$
$$\simeq 12{,}45V$$

$$I_{D5} = I_{D6} \simeq 6mA$$

$$\frac{V_{DD} - V_{S5}}{R_4} \simeq 6mA \Rightarrow R_4 = \frac{V_{DD} - V_{S5}}{6mA} = 425\Omega$$

$$V_{DS1} = V_{D1} - V_{S12} = 4{,}725\,V > V_{GS1} - V_{TN1}$$
$$V_{DS2} = V_{DS1} = 4{,}725 \simeq > V_{GS1} - V_{TN1}$$
$$V_{DS3} = V_{GS3} = 2{,}732\,V \Rightarrow V_{GS3} - V_{TN3}$$
$$V_{DS4} = V_{S12} = 4{,}275\,V > V_{GS4} - V_{TN4}$$
$$V_{DS5} = V_O - V_{S5} = \frac{V_{DD}}{2} - V_{SS}$$
$$= -4{,}95 \longrightarrow < V_{GS5} - V_{TP} \quad (\simeq -2{,}5)$$
$$V_{DS6} = 7{,}5V > V_{GS6} - V_{TN6}$$

M_1 ($I_{DS1} = 3mA$, $V_{DS1} = 4{,}73V$) M_4 ($I_{D4} = 6mA$, $V_{DS4} = 4{,}28V$)

M_2 ($I_{DS2} = 3mA$, $V_{DS2} = 4{,}73V$) M_5 ($I_{D5} = 6mA$, $V_{DS5} = -4{,}95V$)

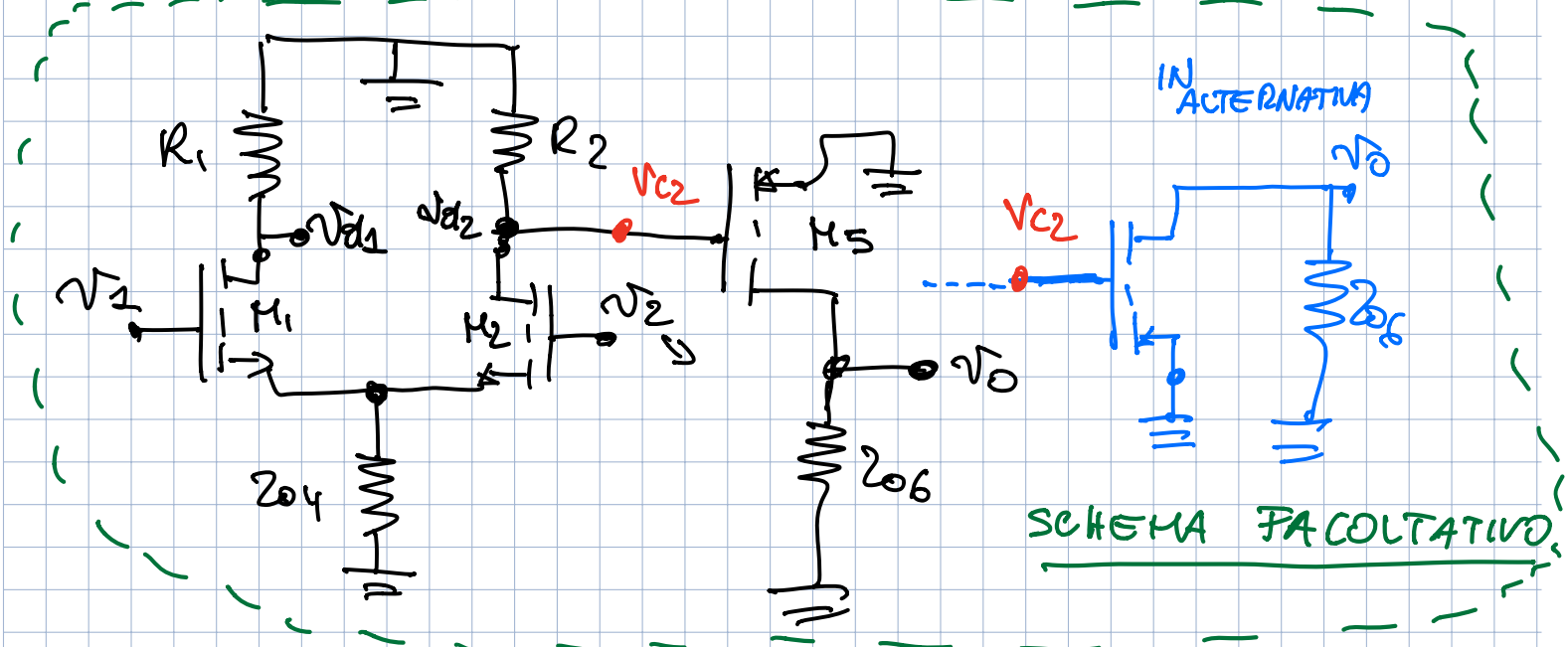
M_3 ($I_{D3} = 6mA$, $V_{DS3} = 2{,}73V$) M_6 ($I_{D6} = 6mA$, $V_{DS6} = 7{,}5V$)

CALCOLO PARAMETRI AL PICCOLO SEGNALE

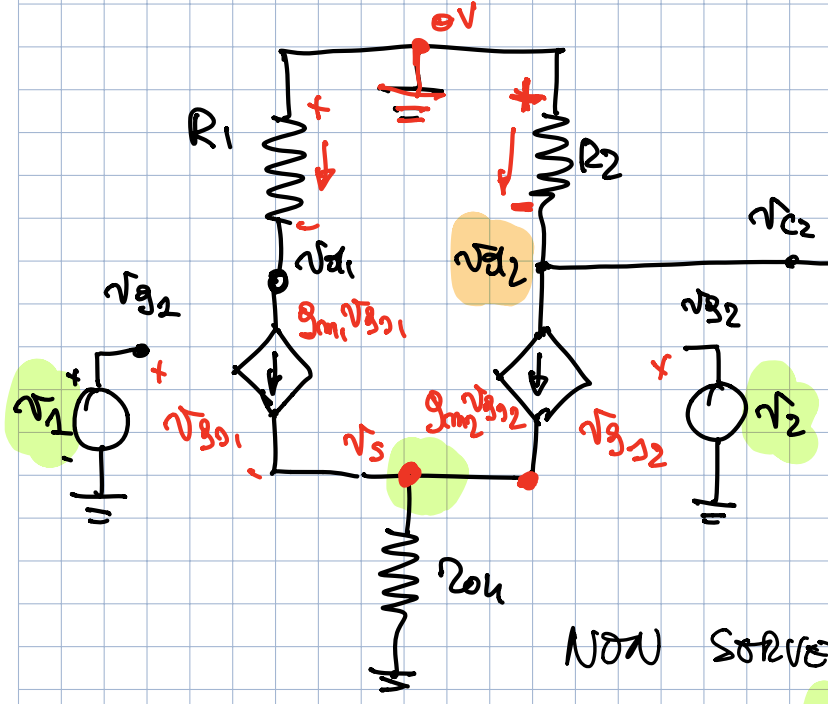
$$g_{m_1} = g_{m_2} \simeq \frac{2I_{D1}}{V_{GS1} - V_{TN1}} = 4{,}9\ mS$$

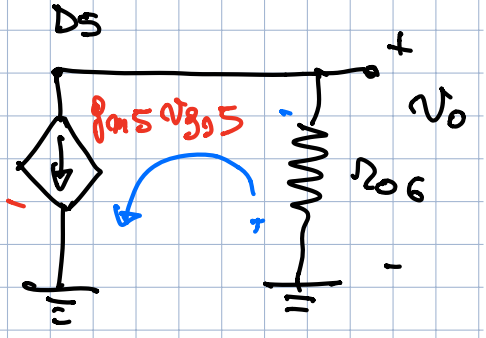
$$g_{m5} = + \frac{2I_{D5}}{|V_{GS5} - V_{TP5}|} = 4{,}9\ mS$$

$$r_{o4} = \frac{\frac{1}{\lambda_{n4}} + V_{DS4}}{I_{D4}} = 84\ k\Omega \qquad r_{o6} = \frac{\frac{1}{\lambda_{n6}} + V_{DS6}}{I_{D6}} = 84{,}6\ k\Omega$$



SCHEMA FACOLTATIVO





NON SERVE FARE SCHEMA PICCOLI

$+\frac{V_{id}}{2}$ $-\frac{V_{id}}{2}$ V_{ic} V_{ic}

$$A_d = \frac{v_o}{v_{id}} = \frac{v_o}{v_{GS}} \cdot \frac{v_{GS}}{v_{id}} = A_{vt}^{CS} \cdot A_{d1}$$

$$A_c = \frac{v_o}{v_{ic}} = \frac{v_o}{v_{GS}} \cdot \frac{v_{GS}}{v_{ic}} = A_{vt}^{CS} \cdot A_{c1}$$

Nel modo Diff.

$v_1 = \frac{v_{id}}{2}$; $v_2 = -\frac{v_{id}}{2}$; $v_s = 0$ $\Rightarrow$ $v_{gs1} = \frac{v_{id}}{2}$ $\quad v_{gs2} = -\frac{v_{id}}{2}$

$$v_{d2} = -g_{m2} v_{gs2} R_2 = +g_{m2} \frac{v_{id}}{2} R_2$$

$$A_{d2} = \frac{v_{d2}}{v_{id}} = \frac{g_m R_2}{2} = 4{,}9$$

Nel modo Comune

$v_1 = v_{ic}$; $v_2 = v_{ic}$ $\quad v_{gs1} = v_{gs2}$

$$v_{d2} = -g_{m2} v_{gs2} R_2$$

$$v_{ic} = v_{gs2} + g_{m2} v_{gs2} 2R_{o4} = v_{gs2}\left(1 + g_{m2} 2R_{o4}\right)$$

$$\Rightarrow v_{gs2} = \frac{v_{ic}}{1 + g_{m2} 2R_{o4}}$$

$$A_{c2} = \frac{v_{d2}}{v_{ic}} = \frac{-g_m R_2}{1 + 2 g_{m2} R_{o4}} = -0{,}012$$

Secondo stadio: source comune senza Rs

$$v_o = -g_{m5} v_{gs5} R_{o6} \qquad v_{gs5} = v_{G5}$$

$$\Rightarrow v_o = -g_{m5} v_{G5} R_{o6}$$

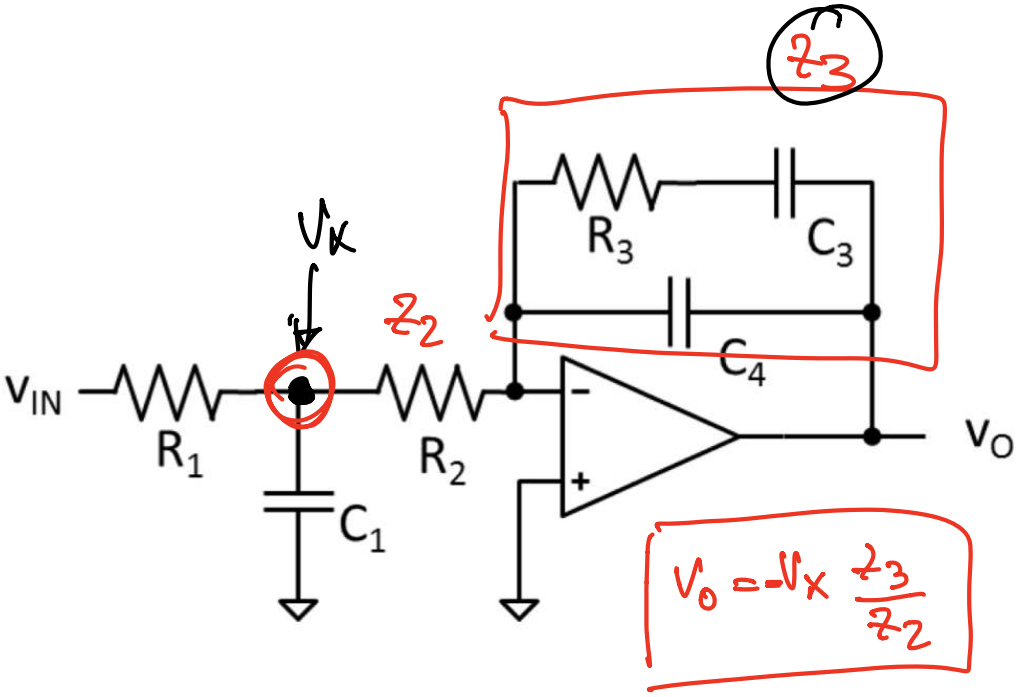
$$\frac{v_o}{v_{gs}} = A_{v_t}^{CS} = -g_{m5}\,2o_6 \simeq -414{,}4$$

$$A_d = \frac{v_o}{v_{id}} = \frac{v_o}{v_{gs}} \cdot \frac{v_{gs}}{v_{id}} = -2030$$

$$A_c = \frac{v_o}{v_{ic}} = \frac{v_o}{v_{gs}} \cdot \frac{v_{gs}}{v_{ic}} = +4{,}92$$

$$CMRR = \left|\frac{A_d}{A_c}\right| = 412{,}27$$

$$20\log_{10} CMRR = 52{,}3\ dB$$



DATI:

R_1=4kΩ,

R_2=4kΩ,

R_3=33kΩ,

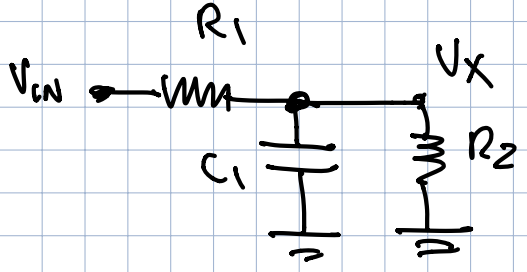
C_1=500pF,

C_3=300nF,

C_4=3nF

ESERCIZIO COMPLESSO CHE IL PROF NON PROPONE MAI IN COMBINAZIONE CON ES. SOPRA

$V_+ = V_- = 0$



$$Z_{EQ_2} = Z_{C_1} \| Z_{R_2} = \frac{\frac{1}{sC_1} \cdot R_2}{\frac{1}{sC_1} + R_2} = \frac{R_2}{1 + sC_1R_2}$$

$$V_X = V_{IN} \cdot \frac{Z_{EQ_2}}{R_1 + Z_{EQ_2}} = \frac{\frac{R_2}{1+sC_1R_2}}{R_1 + \frac{R_2}{1+sC_1R_2}} \cdot V_{IN} = \frac{R_2}{R_1 + R_2 + sC_1R_1R_2} \cdot V_{IN}$$

$$= \frac{R_2}{R_1+R_2} \cdot \frac{1}{1 + sC_1\frac{R_1R_2}{R_1+R_2}} V_{IN}$$

$$V_X = \left[\frac{R_2}{R_1+R_2} \cdot \frac{1}{1+sC_1R_1\|R_2} \cdot V_{IN} \right]$$

$$Z_3 = (R_3 + Z_{C_3}) \| Z_{C_4}$$

$$= \left(R_3 + \frac{1}{sC_3}\right) \| \frac{1}{sC_4} \Rightarrow \frac{1+sC_3R_3}{sC_3} \| \frac{1}{sC_4}$$

$$\frac{\frac{1+sC_3R_3}{sC_3} \cdot \frac{1}{sC_4}}{\frac{1+sC_3R_3}{sC_3} + \frac{1}{sC_4}} = \frac{1+sC_3R_3}{(1+sC_3R_3)(sC_4) + sC_3}$$

$$= \frac{1+sC_3R_3}{sC_3 + sC_4 + s^2C_3C_4R_3}$$

$$= \frac{1+sC_3R_3}{s\left[C_3 + C_4 + sC_3C_4R_4\right]} = \frac{1+sC_3R_3}{s(C_3+C_4)\left[1 + s\frac{C_3C_4}{C_3+C_4}R_3\right]}$$

$$V_o = -V_x \frac{Z_3}{R_2} =$$

$$= -\frac{R_2}{R_1+R_2} \cdot \frac{1}{1+sC_1 R_1 \| R_2} V_{IN} \cdot \frac{1+sC_3R_3}{sR_2(C_3+C_4)\left[1+s\frac{C_3C_4}{C_3+C_4}R_3\right]}$$

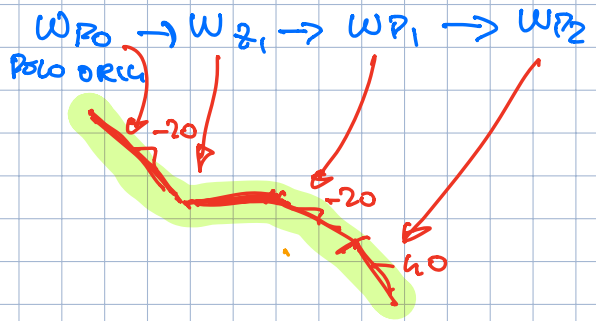
$$W(s) = \frac{V_o}{V_{IN}} = -\frac{1+sC_3R_3}{s(R_1+R_2)(C_3+C_4)\left(1+sC_1 R_1\|R_2\right)\left(1+sR_3\frac{C_3C_4}{C_3+C_4}\right)}$$

$$\omega_{P_0} = \frac{1}{(R_1+R_2)(C_3+C_4)} = 412{,}5 \ \text{rad/sec} \rightarrow 20\log_{10} 412 = 52\text{dB}$$

$$\omega_{P_1} = \frac{1}{R_3 \cdot \frac{C_3C_4}{C_3+C_4}} = 10^4 \ \text{rad/sec} \quad (1{,}02 \cdot 10^4 \ \text{rad/sec}$$

$$\omega_{P_2} \rightarrow \frac{1}{R_1\|R_2 C_4} = 10^6 \ \frac{\text{rad}}{\text{sec}} \qquad \omega_{z_1} = \frac{1}{R_3C_3} = 10^2 \ \text{rad/sec}$$

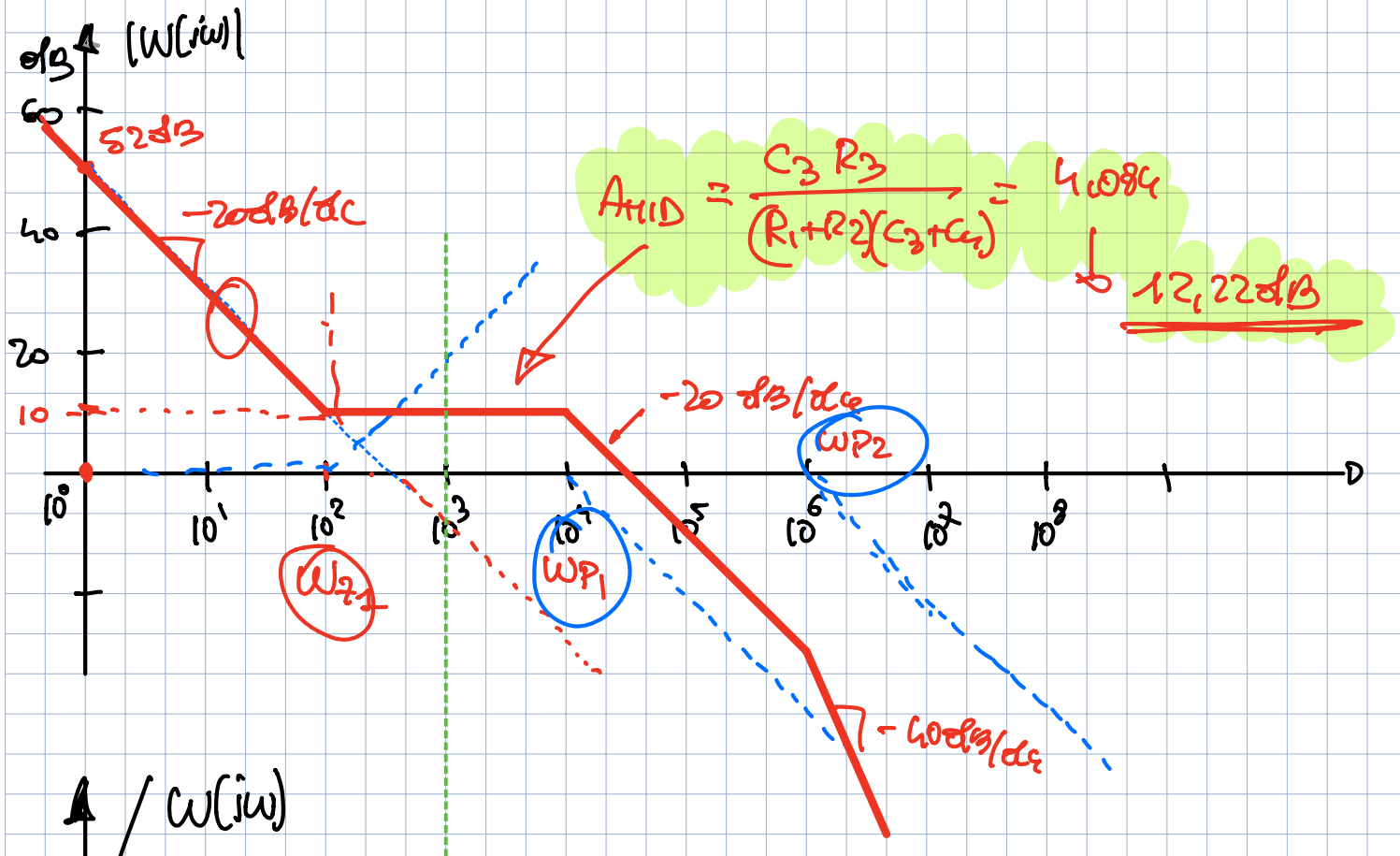
$$\angle W(0) = -\pi - \frac{\pi}{2} = -\frac{3}{2}\pi = +\frac{\pi}{2}$$

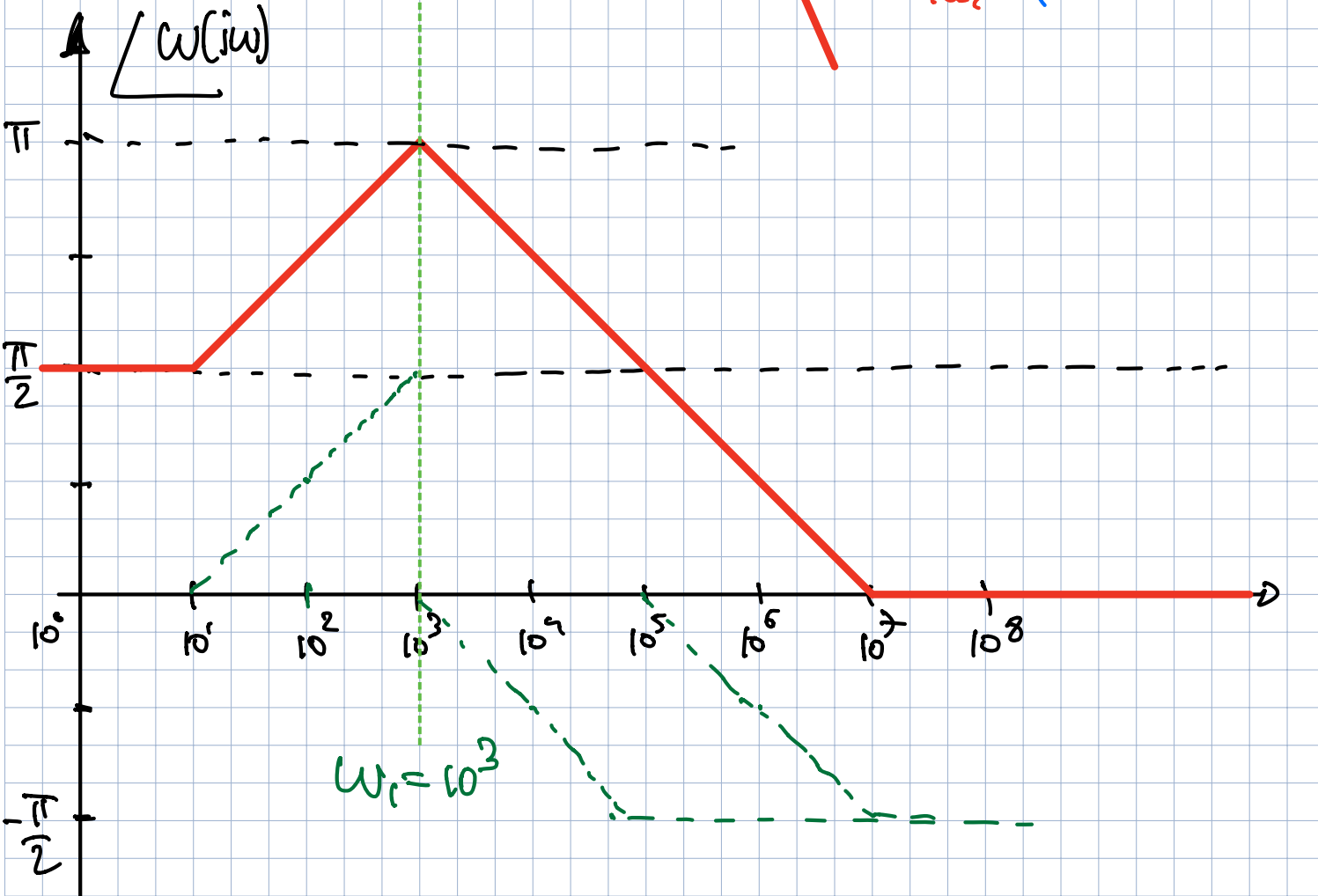


$$W(s) = \frac{V_o}{V_{IN}} = -\frac{1+sC_3R_3}{s(R_1+R_2)(C_3+C_4)\left(1+sC_1 R_1\|R_2\right)\left(1+sR_3\frac{C_3C_4}{C_3+C_4}\right)}$$

$$= -\frac{C_3R_3}{(R_1+R_2)(C_3+C_4)} \cdot \frac{\frac{1}{C_3R_3}+s}{s} \cdot \frac{1}{\left(1+sC_1 R_1\|R_2\right)\left(1+sR_3\frac{C_3C_4}{C_3+C_4}\right)}$$

$A_{MID}!$ $\qquad F_L(s) \qquad F_H(s)$





$V_{in} = 0,25V \cdot \cos(\omega_1 t)$.

$|W(j\omega_1)| = 4,1 = 12,2dB$

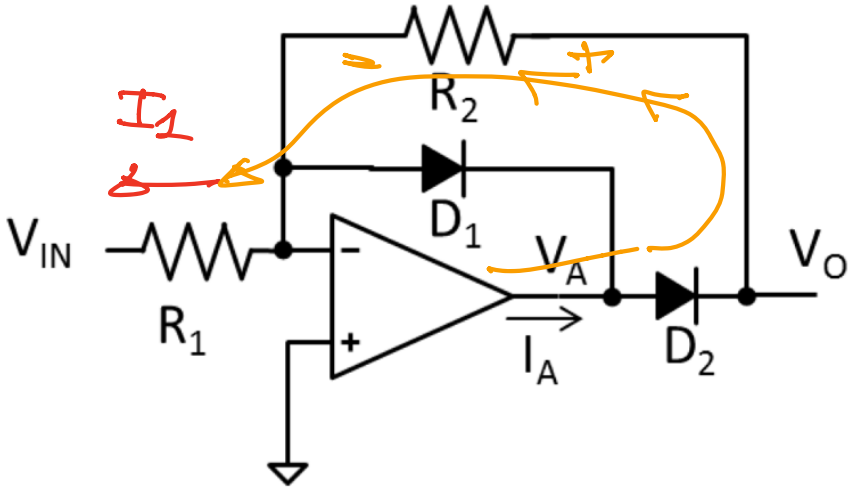
$\angle W(j\omega_1) = \pi$

$\Rightarrow V_o = 0,25V \, |W(j\omega_1)| \cos(\omega_1 t + \angle W(j\omega_1))$

$= 1,02V \cos(\omega_1 t + \pi)$

PROBLEMA Q1

Dato il circuito riportato nella figura sottostante, supponendo che l'amplificatore operazionale sia ideale, determinare lo stato dei diodi, le tensioni V_O e V_A e la corrente I_A erogata dal morsetto di uscita dell'operazionale quando $V_{IN} = -2$ V.



DATI:

R_1=10kΩ, R_2=20kΩ,

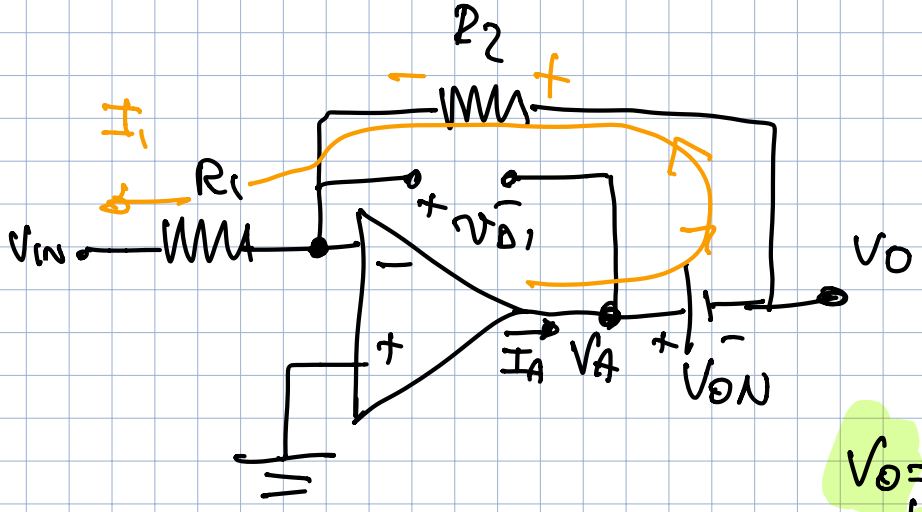
$D_{1,2}$:

tensione di accensione V_{ON}=0.7V

CON $V_{IN} < 0$ $I_1 > 0$

POSSO IPOTIZZARE

D_1 = OFF D_2 = ON



$I_1 = -\frac{V_{IN}}{R_1} = \frac{2V}{10k\Omega} = 0{,}2mA$

$I_{D2} = I_1 > 0$ OK D1 = ON

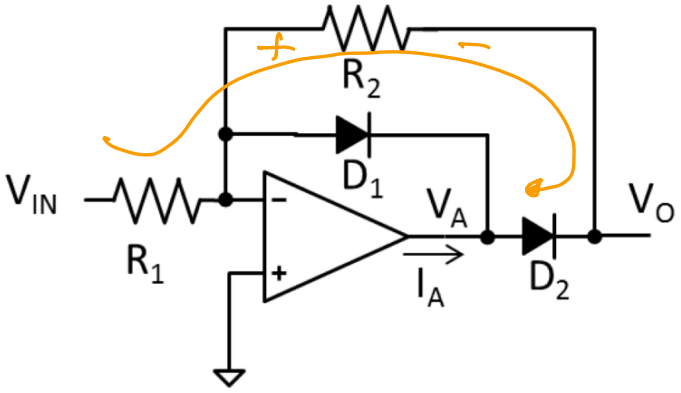
$V_O = I_1 R_2 = -V_{IN}\frac{R_2}{R_1} = 4V$

$\Rightarrow V_A = V_O + V_{ON} = 4{,}2V$

$\Rightarrow V_{D1} = 0 - V_A = -4{,}2V < V_{ON} \Rightarrow$ OK D_2 = OFF

$I_A = I_1 = 0{,}2mA$

E SE FOSSE STATO $V_{IN} = +2V$?



DATI:

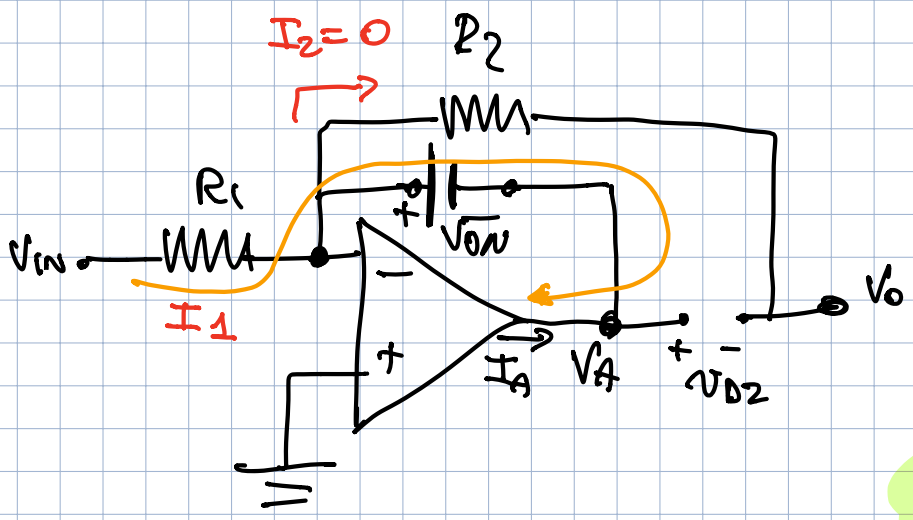
R_1=10kΩ, R_2=20kΩ,

$D_{1,2}$:

tensione di accensione V_{ON}=0.7V

POTREI IPOTIZZARE

D1 = ON , D2 = OFF



$I_1 = \frac{V_{IN}}{R_1} = 0{,}2\,mA$

$I_{D1} = I_1 > 0$ OK D_1=ON

$v_+ = v_- = 0V$

$I_2 = 0 \Rightarrow V_{R_2} = 0$

$\Rightarrow V_O = 0V$

$V_A = v_- - V_{ON}$

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

$\Rightarrow v_{D2} = V_A - V_O = -V_{ON} < 0$ OK D2=OFF

$I_A = -I_1 = -0{,}2\,mA$

PROBLEMA Q2

Data la seguente mappa di Karnaugh;

1) Trovare una F minimizzata
2) Disegnare la rete logica minimizzata tramite porte logiche fondamentali.

AB \ CD	00	01	11	10
00	**1**	0	0	**1**
01	**1**	0	0	**1**
11	**1**	**1**	**1**	0
10	**1**	**1**	0	0

AB \ CD	00	01	11	10
00	1	0	0	1
01	1	0	0	1
11	1	1	1	0
10	1	1	0	0

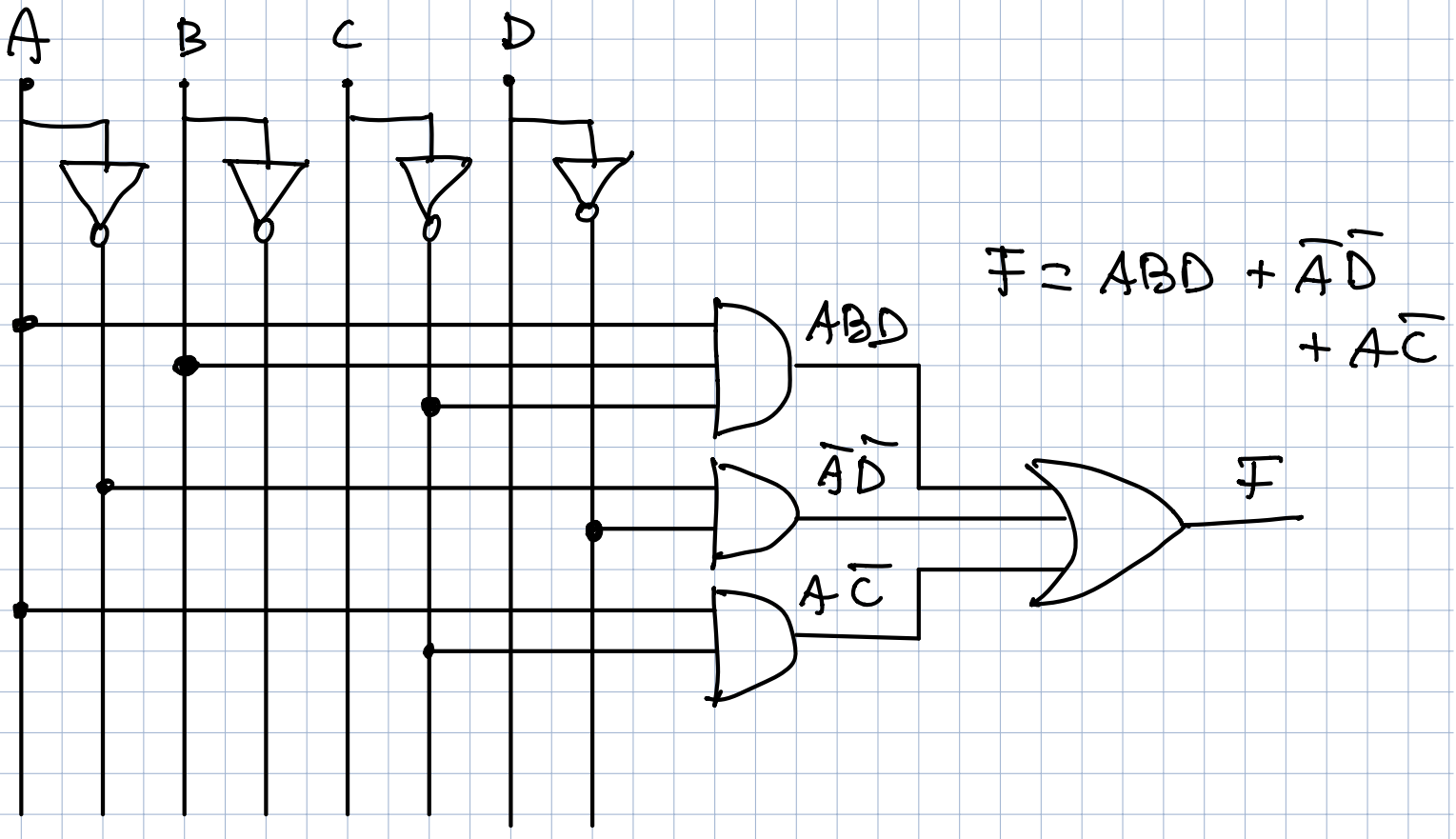
$\rightarrow \bar{A}\bar{D}$

ABD

$A\bar{C}$

$$F = ABD + \bar{A}\bar{D} + A\bar{C}$$

$$F = A(BD + \bar{C}) + \bar{A}\bar{D}$$



$$F = ABD + \bar{A}\bar{D} + A\bar{C}$$

$$F = A\left(BD + \bar{C}\right) + \bar{A}\bar{D}$$