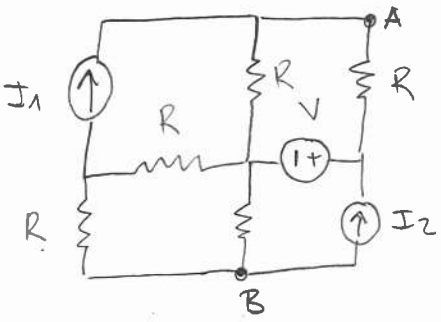
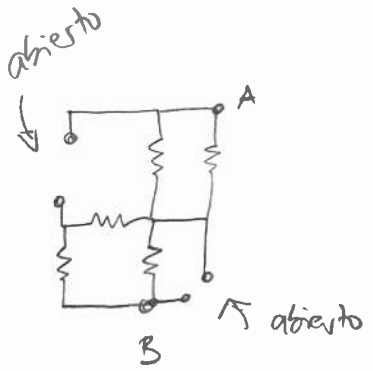
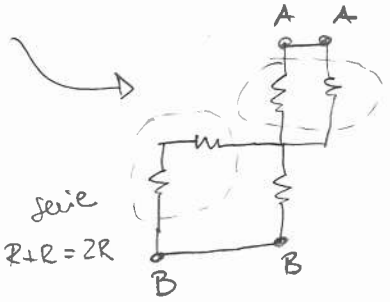
1.a) THÉVENIN



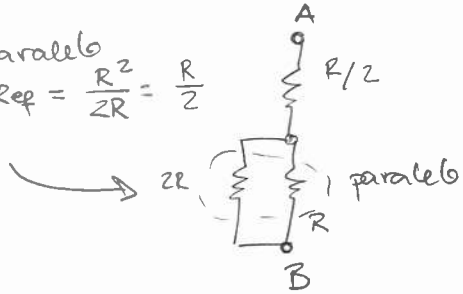
R_T →



Fuente corriente → circuito abierto
Fuente tensión → cortocircuito
} ANULACIÓN FUENTES

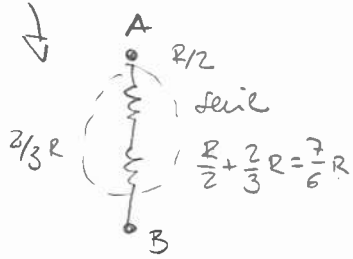


paralelo $R_{eq} = \frac{R^2}{2R} = \frac{R}{2}$



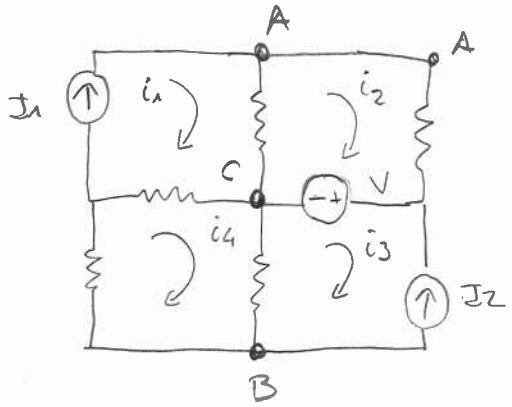
$\frac{2R^2}{3R} = \frac{2}{3}R$

$R_T = 2.33\,k\Omega = \frac{7}{3}k\Omega$



V_T

Mallas:



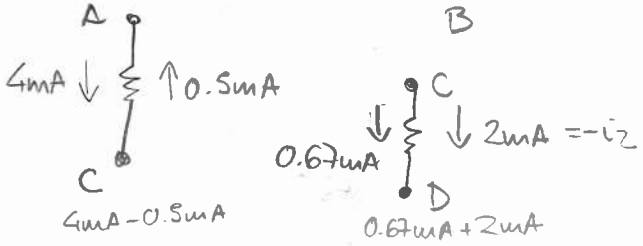
① $i_1 = I_1$ → resuelta → $i_1 = 4mA$

③ $i_3 = -I_2$ → resuelta → $i_3 = -2mA$

② $-V = R(i_2 - i_1) + i_2 R \Rightarrow -6\,V = 2k\Omega\,(i_2 - 4mA) + i_2 \cdot 2k\Omega$

$-6V = 2k\Omega \cdot i_2 - 8V + 2k\Omega\, i_2 = -8V + 4k\Omega\, i_2$

$\Rightarrow i_2 = 0.5\,mA$



④ $0 = i_4 R + (i_4 - i_1)R + (i_4 - i_3)R = 2k\Omega\,(i_4 + i_4 - 4mA + i_4 - (-2mA))$

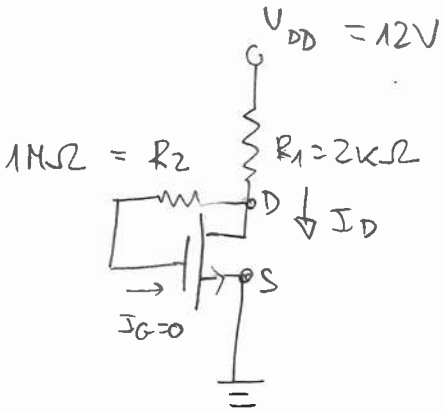
$\Rightarrow 0 = 2k\Omega\,(3i_4 - 2mA) = 6k\Omega \cdot i_4 - 4V \Rightarrow i_4 = 0.67\,mA$

$V_A - V_B = (V_A - V_C) + (V_C - V_B) = R(i_1 - i_2) + R(i_3 + i_4) = 2k\Omega\,[(4mA - 0.5mA) + (2mA + 0.67mA)] = 7V + 5.34V =$

$= 12.34V$

6) NORTON: $I_N = \frac{V_T}{R_T} = 5.3\,mA$

2.



$V_T = 3V$

$K = 0.48 \cdot 10^{-3} A/V^2$

MOSFET: $I_G = 0 \Rightarrow V_G = V_D = V_{DD} - I_D R_1 \rightarrow I_D = \frac{V_{DD} - V_D}{R_1} =$

$V_S = 0$

$= \frac{12 - V_D}{2 \cdot 10^3}$

Sup. SAT $\Rightarrow I_D = \frac{K}{2}(V_{GS} - V_T)^2 = \frac{K}{2}(V_D - V_T)^2 = 0.24 \cdot 10^{-3}(V_D - 3)^2$

Pt. $V_{DS} > V_{GS} - V_T$ sempre! (ii)

V_{DS}

$\frac{12 - V_D}{2 \cdot 10^3}$

$\Rightarrow 12 - V_D = 2 \cdot 10^3 \cdot 0.24 \cdot 10^{-3}(V_D - 3)^2 = 0.48 V_D^2 + 4.32 - 2.88 V_D$

$0.48 V_D^2 - 7.68 - 1.92 V_D = 0 \rightarrow 0.24 V_D^2 - 3.84 - 0.96 V_D = 0 \rightarrow 0.03 V_D^2 + 0.1175 V_D - 0.48 = 0$

$V_D = \frac{0.1175 \pm \sqrt{0.1175^2 - 4 \cdot 0.03 \cdot (-0.48)}}{2 \cdot 0.03} = \frac{0.1175 \pm \sqrt{0.014 + 0.0576}}{0.06} =$

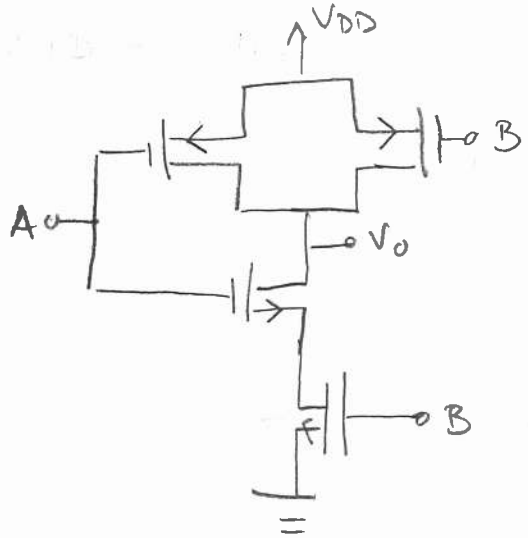
$= \frac{0.1175 \pm \sqrt{0.0716}}{0.06} = \frac{0.1175 \pm 0.268}{0.06} = \begin{cases} 6.42\ V \\ -0.16\ V \end{cases}$ ($\sqrt{0.0716} = 0.268$)

$\rightarrow \boxed{V_{DS} = 6.42V} > 6.42V - 3V > 0$ ✓ SAT, ON

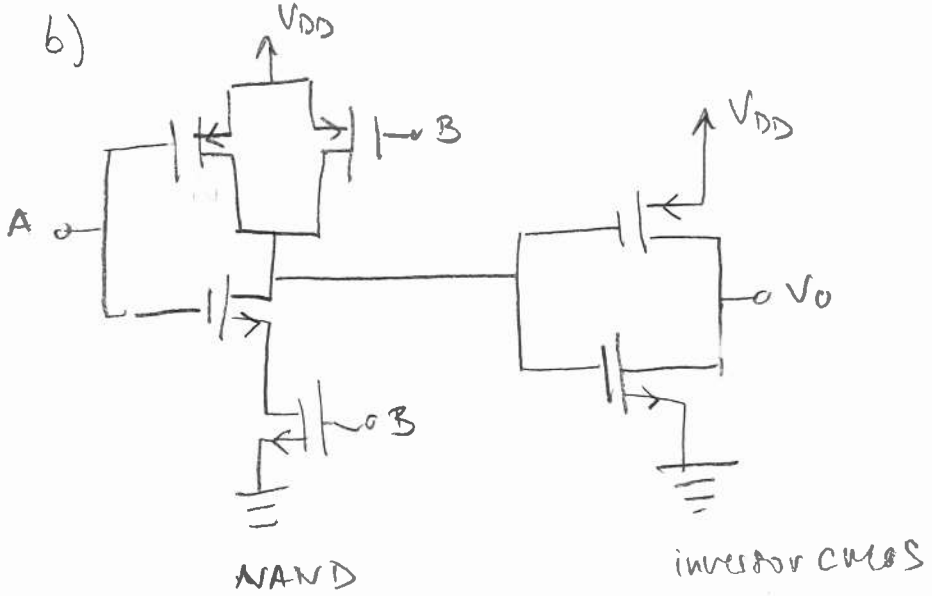
$\rightarrow V_{DS} = -0.16 = V_{GS} < V_T \Rightarrow$ OFF.

$I_D = \frac{12 - 6.42}{2 \cdot 10^3} = 2.79 \cdot 10^{-3} A = \underline{2.79\ mA}.$

3. a) NAND. (transparencia 43 del Tema 5)

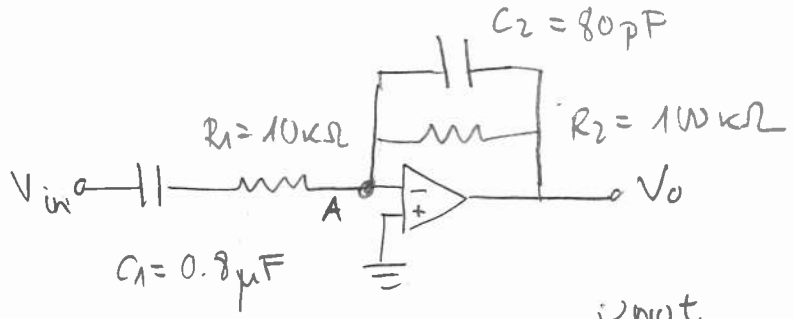


b)



c) (resuelto en MOODLE) : $f = \overline{A \cdot B + C}$

4.

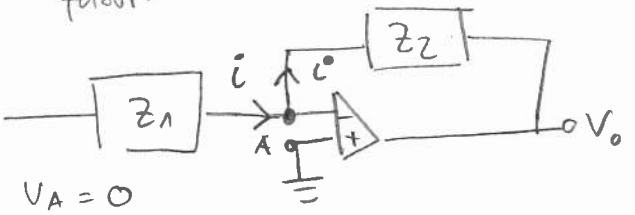


A.O. ideal $\Rightarrow V_+ = V_-$

$i_+ = i_- = 0$.

$V_{in} = \text{sen}(2000t)V = \underbrace{V_{in}}_{\text{fasor}} e^{j2000t}$ V, $V_{in} = 1V$ $(\varphi = 0)$

$V_+ = V_- = 0$:



$\Rightarrow \frac{V_{in} - 0}{Z_1} = \frac{0 - V_{out}}{Z_2} \Rightarrow \boxed{V_{out} = -\frac{Z_2}{Z_1} V_{in}}$

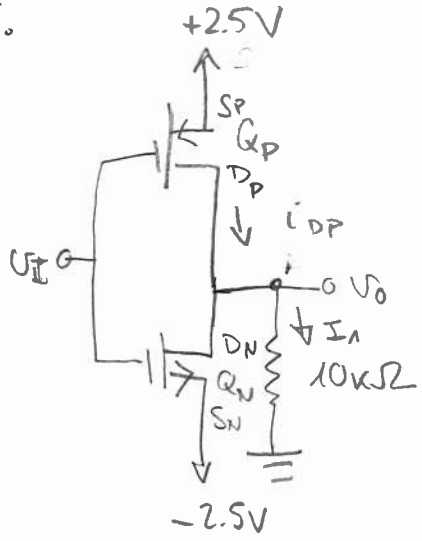
$$\boxed{Z_1 = Z_{C_1} + Z_{R_1} = \frac{1}{j\omega C_1} + R_1 = \left(\frac{-j}{2\cdot 10^3 \cdot 0.8 \cdot 10^{-6}} + 10^4\right)\Omega = \left(10^4 - \frac{j}{1.6\cdot 10^{-3}}\right)\Omega = (-0.625j + 10)\cdot k\Omega = 10^4 e^{-j0.062}\,\Omega}$$

$$Z_2^{-1} = Z_{C_2}^{-1} + Z_{R_2}^{-1} = j\omega C_2 + \frac{1}{R_2} = (16j\cdot 10^{-7} + 10^{-5})\,\Omega^{-1} \Rightarrow \boxed{Z_2 = \frac{1}{10^{-5} + 16\cdot 10^{-8}}\,\Omega = (10^{+5} - 16\cdot 10^{+2}j)\,\Omega = 10^5 e^{-j1.6\cdot 10^{-2}}\,\Omega}$$

$$\frac{Z_2}{Z_1} = \frac{10^5 e^{-j1.6\cdot 10^{-2}}}{10^4 e^{-j0.062}} = 10\, e^{j0.046} \Rightarrow V_o = \underbrace{-}_{e^{j\pi}} 10\, e^{j0.046} = 10 e^{j3.19}\ V \quad (V_{in} = 1V)$$

$$\boxed{v_o(t) = 10\, e^{j0.39}\, e^{j2000t} = 10\,\text{sen}(2000t + 3.19)\,V}$$

5.



Q_P: $V_{SP} = +2.5\,V$ | $|V_{GS}| > |V_T|$ ON | $K_n = K_p = 1\,mA/V^2$, $V_{Tn} = -V_{Tp} = 1V$

$V_{DP} = V_{DN}$ | $|V_{DS}| < |V_{GS}| - |V_T|$ LIN

$V_{GP} = V_{GN}$ | $|V_{DS}| > |V_{GS}| - |V_T|$ SAT

Q_N: $V_{SN} = -2.5V$ | $V_{GS} > V_T$ ON

$V_{DN} = V_{DP}$ | $V_{DS} < V_{GS} - V_T$ LIN

$V_{GN} = V_{GP}$ | $V_{DS} > V_{GS} - V_T$ SAT

a) $V_I = +2.5\,V \Rightarrow V_{GN} = V_{GP} = +2.5V \Longrightarrow$

Q_P: $V_{GS} = V_{GP} - V_{SP} = +2.5V - 2.5V = 0V < |V_{Tp}| = +1V \Rightarrow Q_P$ OFF.

Q_N: $V_{GS} = V_{GN} - V_{SN} = 2.5 - (-2.5) = 5V > V_{TN} = 1V \Rightarrow Q_N$ ON

- Sup. SAT: $I_{DN} = \frac{K}{2}(V_{GS} - V_T)^2$

$\hookrightarrow I_{DN} = \frac{K}{2_1}(5-1)^2 = 0.5\,\frac{mA}{V^2} \cdot 16V^2 = 8\,mA.$

nudo A: $-I_{DN} = I_1 = \frac{V_O - 0}{10k\Omega} \Rightarrow V_O = -8\cdot10^{-3}\cdot10^4\,V = -80V = V_{DN}$

$-I_{DN} = -8mA$

$\Rightarrow V_{DS} = -80 - (-2.5) = -77.5\,V < V_{GS} - V_T = 1$

$\Rightarrow$ ~~SAT~~

- Sup LIN: $I_D = \frac{K}{2}\left[2(V_{GS} - V_T)V_{DS} - V_{DS}^2\right] = 0.5\cdot10^{-3}\left[2.4\,V_{DS} - V_{DS}^2\right] = -\frac{V_D}{10^4}$

$-V_D = 10^4 \cdot 0.5\cdot10^{-3}\left[8(V_D + 2.5) - (V_D + 2.5)^2\right] = 5\left[8V_D + 20 - (V_D^2 + 6.25 + 5V_D)\right] =$

$= 5\left[3V_D + 13.75 - V_D^2\right] = 15V_D - 5V_D^2 + 68.75 \Rightarrow \boxed{5V_D^2 - 16V_D - 68.75 = 0}$

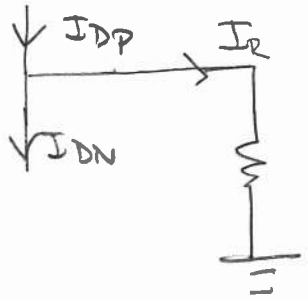
$\Rightarrow 5V_D^2 - 16V_D - 68.75 = 0 \Rightarrow V_{D_N} = \begin{cases} V_{DN}|_1 = -2.44V \rightarrow V_{DN1} - V_{SN} = -2.44 - (-2.5) = 0.06V < \\ V_{DN}|_2 = 5.64V \rightarrow V_{DN2} - V_{SN} > 4V \times \end{cases} < V_{GS_1} = 4V \checkmark$

$\Rightarrow V_{DS} = 0.06\ V$ (pequeño pq $V_{DS_N} << V_{GS_N}$)

$\Rightarrow I_{DN1} = -\frac{V_D}{10} = 0.244\ mA.$

b) Igual que a) (simétrico)

c)



simétrico: $I_{D_P} = I_{D_N}$

$I_{D_P} = I_{D_N} + I_R \longrightarrow I_R = 0 \Rightarrow V_D = 0$

Q_N: $V_{GS}|_N = 0 - (-2.5) = 2.5\ V > 1\ V$ ON

$V_{DS}|_N = 0 - (-2.5) = 2.5\ V = V_{GS} \Rightarrow$ siempre SAT.

$\Rightarrow \boxed{I_{D_N} = \frac{K}{2}(V_{GS} - V_T)^2 = \ldots = 1.125 mA.}$

Q_P: $V_{GS}|_P = 0 - 2.5 = -2.5V$ ON

$V_{DS}|_P = 0 - 2.5 = -2.5\ V = V_{GS}$ SAT $\Rightarrow \boxed{I_{D_P} = 1.125 mA.}$