

$$V_{B1} = \frac{V_{CC} R_3}{R_1 + R_2 + R_3} = 4V$$

$$I_{E1} \approx I_{C1} = \frac{V_{B1} - V_{BE}}{R_E} = 3,3 \text{ mA}$$

$$V_{B2} = \frac{R_2 + R_3}{R_2 + R_3 + R_1} V_{CC} = 8V$$

$$V_{C2} = V_{B2} - V_{BE_{on}} = 7,3V$$

$$I_{Rc} = \frac{V_{CC} - V_{C2}}{R_C} = 3,13 \text{ mA}$$

$$I_{Rep} = \frac{V_{CC} - V_{E3}}{R_{ep}} = 8 \text{ mA}$$

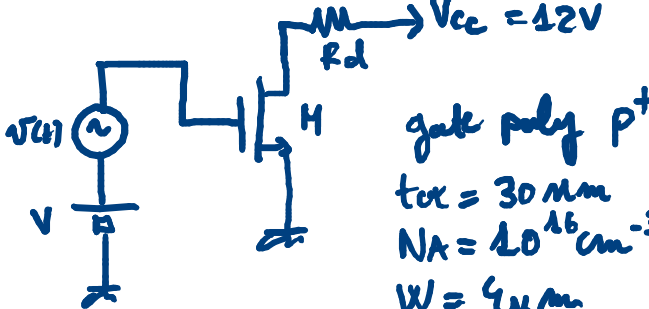
$$V_{EC3} = 8V > V_{CEsat}$$

$$I_{B3} = \frac{I_{Rep}}{\beta_{min}} = 26,7 \mu A$$

Q3 in zona attiva diretta

$$I_{C2} = I_{Rc} + I_{B3} = 3,157 \text{ mA}$$

$$I_{B2} = I_{C1} - I_{C2} = 143 \mu A > \frac{I_{C2}}{\beta}$$



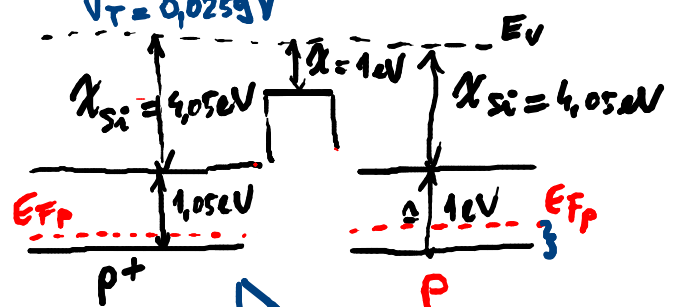
gate poly p^+
 $t_{ox} = 30 \text{ nm}$
 $N_A = 10^{16} \text{ cm}^{-3}$
 $W = 4 \mu\text{m}$
 $L = 4 \mu\text{m}$
 $\mu_n = 80 \text{ cm}^2/\text{Vs}$

$v(t) = V_m \cos(\omega t)$

$V_{GS} = V_G = V + V_m \cos(\omega t)$

$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} = \frac{\epsilon_{SiO_2} \cdot \epsilon_0}{t_{ox}} = 8,85 \cdot 10^{-12} \frac{\text{F}}{\text{m}^2} = 1,15 \cdot 10^{-3} \frac{\text{F}}{\mu\text{m}^2}$

$\psi_B = \frac{kT}{q} \ln\left(\frac{N_A}{n_i}\right) = 0,317 \text{ V}$
 $V_T = 0,0259 \text{ V}$
 $n_i = 1,5 \cdot 10^{10} \text{ cm}^{-3}$



$\phi_{MS} = E_F - E_V$

$p = N_V \exp\left(\frac{E_V - E_F}{k_B T}\right) \Rightarrow E_F - E_V = \frac{k_B T}{q} \ln \frac{N_V}{N_A} = 0,178 \text{ eV}$

$\phi_{MS} = \frac{E_F - E_V}{q} = 0,178 \text{ V}$

$V_{TH} = \frac{\sqrt{2 \epsilon_S q N_A} \psi_B + 2\psi_B + \phi_{MS}}{C_{ox}} = 1,29 \text{ V}$

$V_{DS} \geq V_{GS} - V_{TH}$

$V_{DS} = V_{GS} - V_{TH}$

$V_S = 0 \text{ V} \Rightarrow V_{DS} = V_D$

$V_D = V_{CC} - R I_{DS}$

$I_{DS} = \frac{K}{2} (V_{GS} - V_{TH})^2 \quad K = \mu_n C_{ox} \frac{W}{L} = 9,2 \frac{\mu\text{A}}{\text{V}^2}$

$V_D = V_{CC} - \frac{R K}{2} (V_{GS} - V_{TH})^2$

$V_{GS} - V_{TH} = \sqrt{\frac{2(V_{CC} - V_D)}{R K}}$

$R = \frac{V_{CC} - (V_{GS} - V_{TH})^2 \frac{R K}{2}}{\frac{K}{2} (V_{GS} - V_{TH})^2} = 13093 \Omega$

$$C_{ox} \quad V_T \equiv V_{TH}$$

$$Q_{TOT} = C_{ox} (V_{GS} - V_T) \cdot W \cdot L = 6,8 \cdot 10^{-14} \text{ C}$$

$$\begin{cases} I_{DS} = k (V_{GS} - V_T) V_{DS} = k (V_{GS} - V_T) V_D \\ V_D = V_{CC} - R I_{DS} \end{cases}$$

$$I_{DS} = k (V_{GS} - V_T) (V_{CC} - R I_{DS})$$

$$I_{DS} [1 + k (V_{GS} - V_T) R] = k (V_{GS} - V_T) V_{CC}$$

$$I_{DS} = \frac{k (V_{GS} - V_T) V_{CC}}{[1 + k (V_{GS} - V_T) R]} = 1,16 \cdot 10^{-4} \text{ A}$$

$$V_{DS} = V_D = \underline{0,34 \text{ V}} \quad \text{Hp zona lineare OK}$$

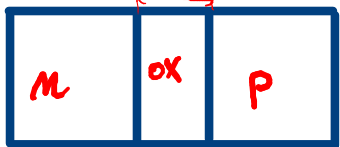
$$I_G : V_m = 50 \text{ mV} \quad \text{e} \quad f = 10 \text{ MHz}$$

$$\omega = 2\pi f$$

$$C_{diff} = \frac{\delta Q}{\delta V_{GS}} = W L C_{ox}$$

$$i_{GS}(t) = \frac{\delta Q}{\delta t} = \frac{d}{dt} [W L C_{ox} (V_{GS}(t) - V_T)]$$

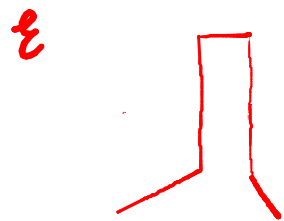
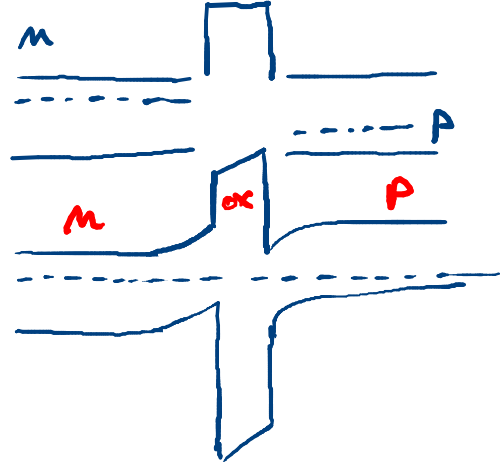
$$V_{GS} = V_m \cos \omega t + V$$
$$= -W L C_{ox} \omega \sin(\omega t)$$



$$N_D = 5 \times 10^{15} \text{ cm}^{-3} \quad N_A = 10^{16} \text{ cm}^{-3}$$

$$t_{ox} = 30 \text{ nm}$$

$$V_{mp} = 0V \quad V_0 = \frac{kT}{q} \ln\left(\frac{N_D N_A}{n_i^2}\right) = 0,677V$$



$$V_{mp} = 0V \quad \psi_{sm} \text{ e } \psi_{sp}$$

$$V_{mp} = \psi_{sm} + \frac{|Q|}{C_{ox}} + \psi_{sp} - V_0$$

$$V_{mp} = 0V \quad V_0 = \psi_{sm} + \frac{|Q|}{C_{ox}} + \psi_{sp}$$

$$|Q_n| = |Q_p|$$

$$\sqrt{2\epsilon_{si} q N_D \psi_{sm}} = \sqrt{2\epsilon_{si} q N_A \psi_{sp}}$$

$$N_D \psi_{sm} = N_A \psi_{sp}$$

$$\psi_{sm} = \frac{N_A}{N_D} \psi_{sp}$$

$$V_0 = \frac{N_A}{N_D} \psi_{sp} + \frac{\sqrt{2\epsilon_{si} q N_A \psi_{sp}}}{C_{ox}} + \psi_{sp}$$

$$\psi_{sp} = 0,159V \Rightarrow \psi_{sm} = 0,318V$$

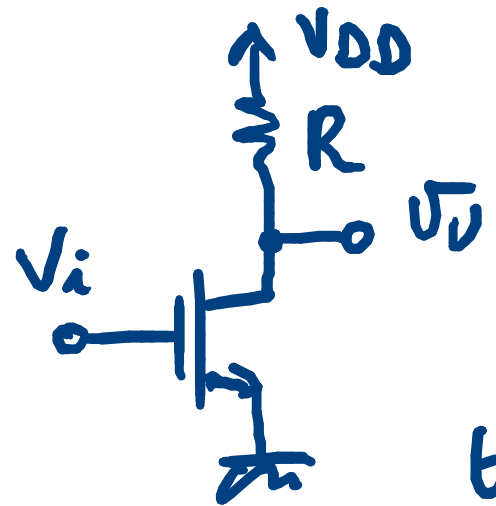
$$V_{ox} = \frac{\sqrt{2\epsilon_{si} q N_A \psi_{sp}}}{C_{ox}} = 0,202V$$

$$V_{mp} = 5V$$

$$\psi_{sm} = 2\phi_{B_n} = 2V_T \ln\left(\frac{N_D}{n_i}\right) = 0,658V$$

$$\psi_{sp} = 2\phi_{B_p} = 2V_T \ln\left(\frac{N_A}{n_i}\right) = 0,694V$$

$$V_{ox} = V_{mp} - \psi_{sm} - \psi_{sp} + V_0 = 4,32V$$



$$V_{DD} = 5V$$

$$R = 10k\Omega$$

$$N_A = 10^{16} \text{ cm}^{-3}$$

$$t_{ox} = 30 \text{ nm}$$

$$\mu_n = 800 \text{ cm}^2/\text{Vs}$$

$$W = 10 \mu\text{m}$$

$$L = 1 \mu\text{m}$$

$$V_i = V_{GS} = 5V$$

$$\phi_B = \frac{kT}{q} \ln\left(\frac{N_A}{n_i}\right) = 0,347V$$

$$\phi_{MS} = 0V$$

$$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} = 1,15 \times 10^{-3} \text{ F/m}^2$$

$$V_{TH} = \frac{\sqrt{2\epsilon_{si}qN_A} \cdot 2\phi_B}{C_{ox}} + 2\phi_B = 1,4V$$

$$I_{DS} = k(V_{GS} - V_{TH})V_{DS}$$

$$k = \mu_n C_{ox} \frac{W}{L} = 920 \mu\text{A}/\text{m}^2$$

$$V_{DS} = V_{DD} - R I_{DS} = V_D$$

$$I_{DS} = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})(V_{DD} - R I_{DS})$$

$$I_{DS} = 0,486 \text{ mA}$$

$$V_{DS} = V_D = 0,13V$$