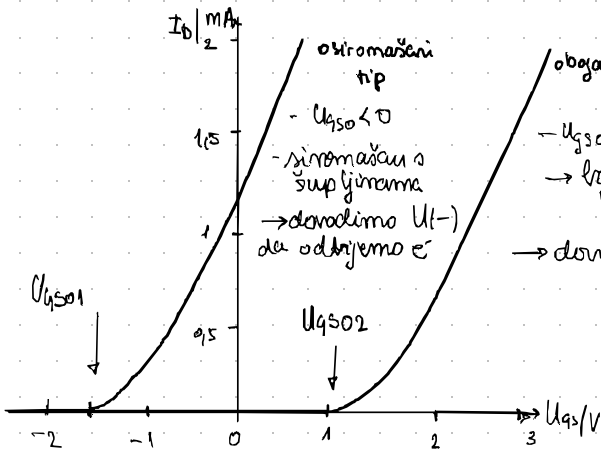


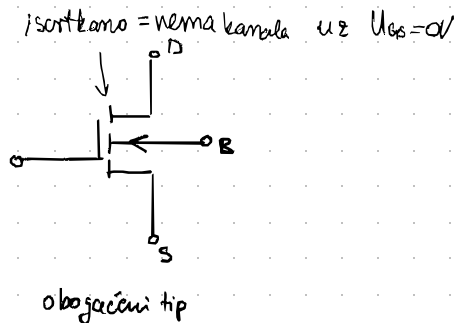
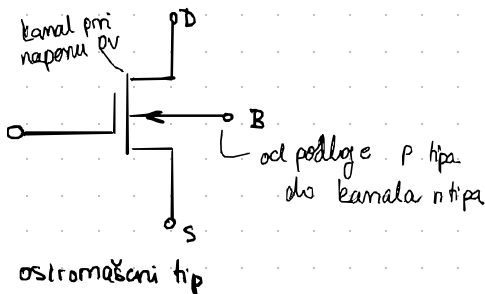
5.2 MOSFETI

Vrste n-kanalnih MOSFET-a



* n-kanalni MOSFET vodi struju uz $U_{gs} > U_{gs0}$

→ Simboli n-kanalnih MOSFETA



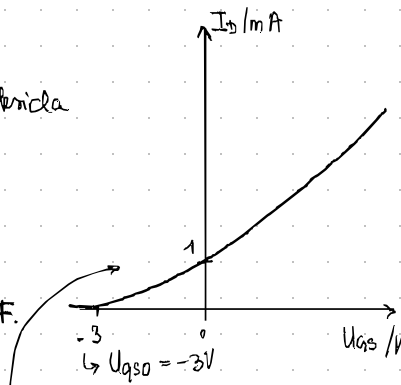
Primer 1.)

$t_{ox} = 20 \times 10^{-9} \text{ m}$ - debljina oksida

$\mu = 400 \text{ cm}^2/\text{Vs}$

a) $W/L = ?$

b) $L = ? \rightarrow C_g \leq 20 \text{ fF}$



$I_D = 1 \text{ mA} \rightarrow U_{gs} = 0 \text{ V}$ (iz grafik)

$I_D = 0 \text{ mA} \quad U_{gs} = U_{gs0} = -3 \text{ V}$

$U_{gs0} < 0 \rightarrow$ ostromašeni šupljinom
- dovodimo $U(-)$
- odvojimo e^- privlačimo $+$

\Rightarrow n-kanalni tranzistori:

$\mu_n = 400 \text{ cm}^2/\text{Vs}$

* $U_{gs} \uparrow, I_D \uparrow \rightarrow$ n-kanalni

kapacitet upravljanje elektr.

b) $L = ? \quad C_g = C_{ox} \cdot W \cdot L$

a) strujni koeficijent $K = \mu C_{ox} \left(\frac{W}{L} \right)$

$$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} = \frac{\epsilon_0 \cdot \epsilon'_{ox}}{t_{ox}}$$

$$\frac{W}{L} = \frac{K}{\mu \cdot C_{ox}}$$

$$\text{Zaricenje: } I_D = \frac{K}{2} (U_{gs} - U_{gs0})^2$$

$$10^{-3} \cdot 2 = K (0 + 3)^2$$

$$K = \frac{2}{9} 10^{-3}$$

$$\frac{W}{L} = \frac{\frac{2}{9} 10^{-3}}{400 \cdot \frac{\epsilon_0 \cdot \epsilon'_{ox}}{t_{ox}}} \rightarrow \frac{W}{L} = 3.22 \times 10^{-12}$$

$$L = \frac{C_g}{C_{ox} \cdot W} = \frac{C_g}{C_{ox} \cdot 3.22 \times 10^{-12} \cdot L}$$

$$L^2 = \frac{C_g}{\frac{\epsilon_0 \cdot \epsilon'_{ox}}{t_{ox}} \cdot 3.22 \times 10^{-12}}$$

$$L = \sqrt{\frac{20 \times 10^{-15}}{\frac{\epsilon_0 \cdot \epsilon'_{ox}}{t_{ox}} \cdot 3.22 \times 10^{-12}}}$$

$$L = 1.9 \mu \text{ m}$$

p-kanalni MOSTET

→ inverzijski sloj tvore ŠUPLJINE (p) →

* obrnuto od prej

→ p⁺ umesto n⁺
n podloga / p podloga

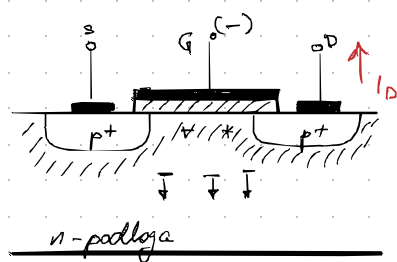
→ dovodimo NEGATIVAN (-) napon

odgovorno e⁻

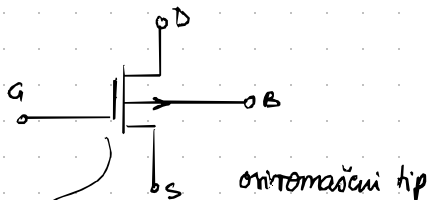
privlačno p⁺

→ na odvodu je tačkoter (-)

⇒ $I_D < 0$ jer "struja izlazi"

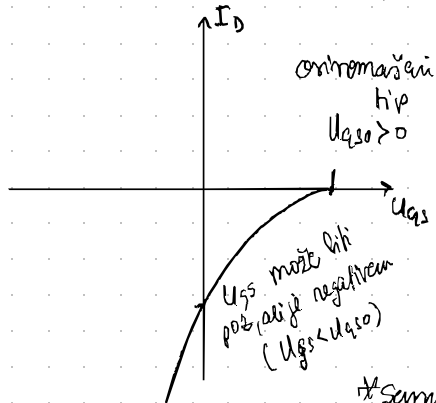


simboli p-kanalnih MOSFETA



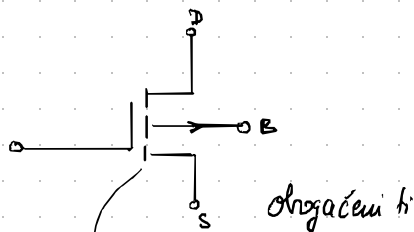
može postojati kanal ako nema napona na GATE-u

* reč je formiranom kanalu pri napenu 0V



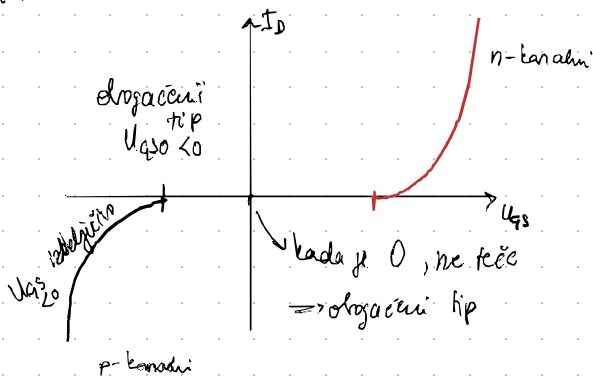
otromošćeni tip
 $U_{GS0} > 0$

* samo kraka od n-kanalnog



otročćeni ti

ne postoji kanal kad je napon na GATE-u 0V



otročćeni tip
 $U_{GS0} < 0$

p-kanalni

triodno područje: $U_{GS} - U_{GS0} \leq U_{DS} \leq 0$

$$I_D = K \left[(U_{GS} - U_{GS0}) U_{DS} - \frac{U_{DS}^2}{2} \right]$$

područje zasiććujć: $U_{DS} \leq U_{GS} - U_{GS0}$

$$I_D = \frac{K}{2} (U_{GS} - U_{GS0})^2$$

područje zapirćujć $U_{GS} > U_{GS0}$

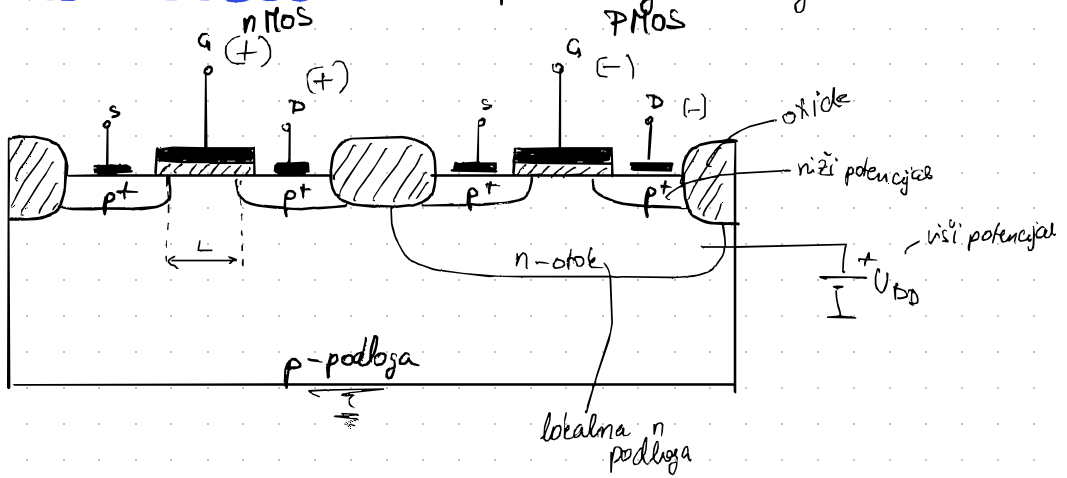
$$I_D = 0$$

koećicient strćejć

$$K = -\mu_p C_{ox} \cdot \frac{W}{L}$$

CMOS struktura

complementary MOS (oly) struktura



Primer $K = 0,4 \text{ mA/V}^2$

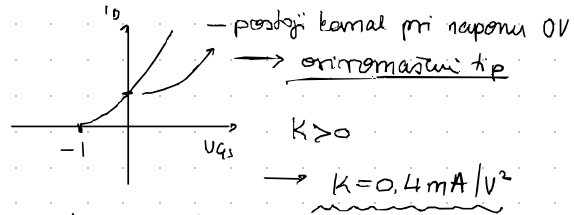
$$U_{qso} = -1 \text{ V}$$

→ natančne lastne karakteristike

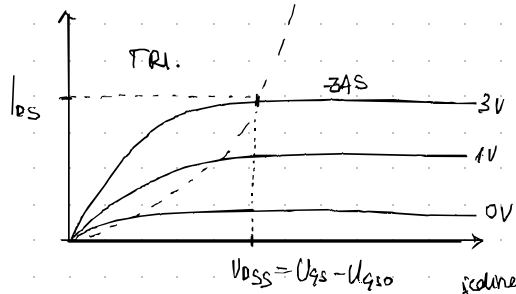
a) n-kanalni

b) p-kanalni

a) nMOS, $U_{qso} = -1 \text{ V}$



izlastne karakteristike:



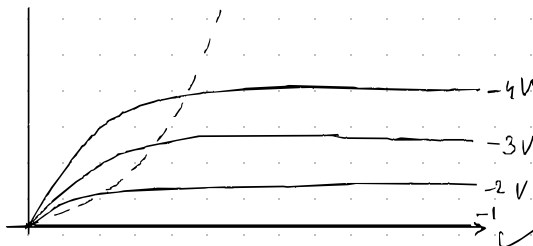
ječina U_{GS} kaže
ima natančno gledati
ali ali $> U_{qso}$

$$I_D = \frac{K}{2} (U_{GS} - U_{qso})^2$$

$$U_{GS} = 0 \text{ V} \rightarrow I_D = \frac{K}{2} (0 + 1)^2$$

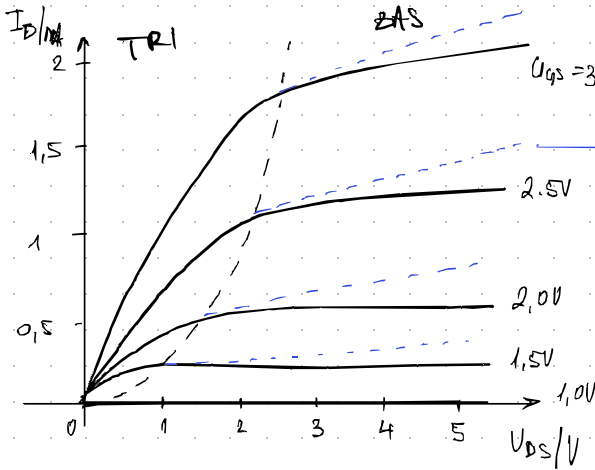
$$I_D = 0,2 \text{ mA}$$

$$I_D = \frac{K}{2} (U_{GS} - U_{qso})^2 \rightarrow \text{gledamo } U_{GS} < U_{qso}$$



lasti u zep/ravje tako je $U_{GS} > U_{qso}$!

Potencijal struje u zračuju

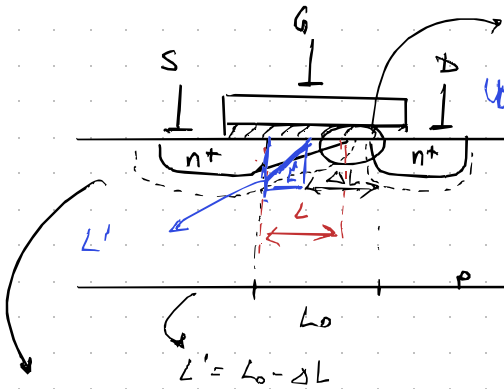


* dosad smo mislili da u zračuju I_D ne zavisi od U_{gs}

za kanal s kraccim kanalom

↓
kako je $L \gg \Delta L$,
nagib je minimalan

Modulacija dužine kanala



zračuje: dolazi do prekida

$U_{gs} \uparrow$

$$I_D = \frac{k}{2} (U_{gs} - U_{gs0})^2$$

$$= \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (U_{gs} - U_{gs0})^2$$

dužina kanala L'

$\rightarrow L' = f(U_{gs}) \rightarrow$ kanal se skraćuje s naponom U_{gs}

• točka dolazna pomici se prema uvodu

\rightarrow u kanalu se e^- ubrzavaju naponom $U_{ds} = U_{dss} = U_{gs} - U_{gs0}$

$$\Rightarrow I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L - \Delta L} (U_{gs} - U_{gs0})^2 = I_{D0} \cdot \frac{1}{1 - (\frac{\Delta L}{L})}$$

$U_{gs} \uparrow \Rightarrow \Delta L \uparrow \Rightarrow I_D \uparrow$

↓
 U_{gs} modulira dužinu kanala