Elektronik Elemanlar

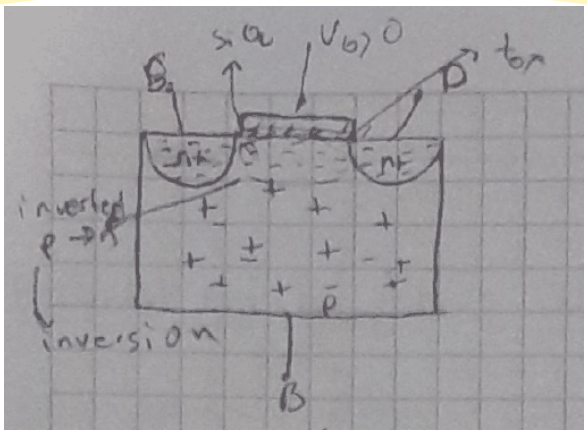
MOSFET: kanal, i–v karakteristiği, çalışma bölgeleri (s. 41–46)

Orijinal not: Elektronik-elemanlar-notlarim.pdf

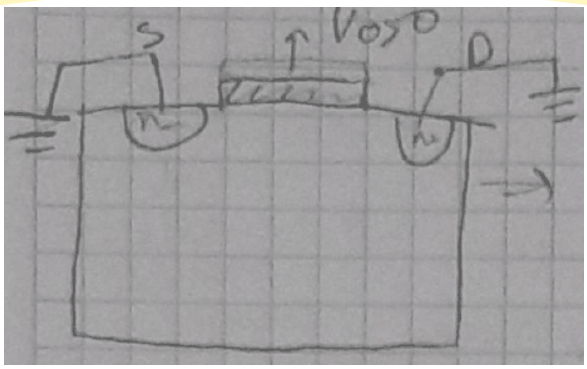
UYARI Bu belge, el yazısı ders notlarından Claude (Anthropic) yardımıyla dijitale aktarılmıştır. Yardımcı kaynak olarak hazırlanmıştır; hata veya eksik içerebilir. Lütfen orijinal notları ve ders kaynaklarını esas alın.

NOTICE *This document was transcribed from handwritten lecture notes with the help of Claude (Anthropic). It is meant as a supplementary resource and may contain errors or omissions. Always check against the original notes and official course material.*

orj. s. 41



orijinal çizim, s. 41



orijinal çizim, s. 41

$$V_{GS} - V_{TH} = V_{OV} \rightarrow \text{overdrive}$$

$$|Q| = C_{ox}(WL) \cdot V_{OV}$$

C_{ox} = Oxide capacitance of the device

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} \qquad (\varepsilon_{ox}: \text{elektriksel } ?\,\textit{geçirgenlik})$$

$$\Rightarrow \quad \varepsilon_{ox} = \underbrace{(3{,}9)}_{\varepsilon_r}(\varepsilon_0) = (3{,}9)(8{,}854 \times 10^{-12}) = \boxed{3{,}45 \times 10^{-11}\ \text{F/m}}$$

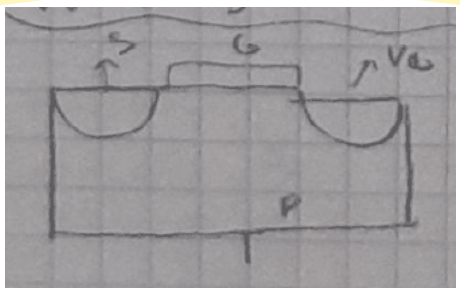
$$C_{ox} = \frac{3{,}45 \times 10^{-11}}{4 \times 10^{-9}} = 8{,}6 \times 10^{-3}\ \text{F/m}^2$$

$L = 0{,}18\ \mu\text{m} \qquad W = 0{,}72\ \mu\text{m}$

$C = C_{ox} W \cdot L = (8{,}6)(0{,}18)(0{,}72) = 1{,}1\ \text{fF} \qquad (\text{f} = 10^{-15})$

Kenar notu: * ? okunamadı

Applying some V_{DS}



orijinal çizim, s. 41

$$|E| = \frac{V_{DS}}{L}$$

$$\text{Elektron drift velocity} = \underbrace{\mu_n}_{\text{mobility}} \frac{V_{DS}}{L}$$

$$i_D = \Big[\underbrace{\mu_n C_{ox}}_{\substack{\text{process} \\ \text{transconductance} \\ \text{parameter}}} \underbrace{\left(\frac{W}{L}\right)}_{\substack{\text{aspect} \\ \text{ratio}}} \underbrace{V_{OV}}_{\substack{\text{Overdrive} \\ \text{voltage}}} \Big] V_{DS}$$

$$\boxed{V_{OV} = V_{GS} - V_{TH}}$$

Deep triode Region

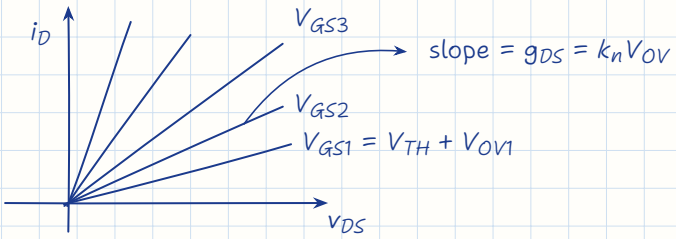
$$V_{DS} \ll 2V_{OV}$$

orj. s. 42

$$\underset{\text{conductance}}{g_{DS}} = \mu_n C_{ox}\left(\frac{W}{L}\right) V_{OV}$$

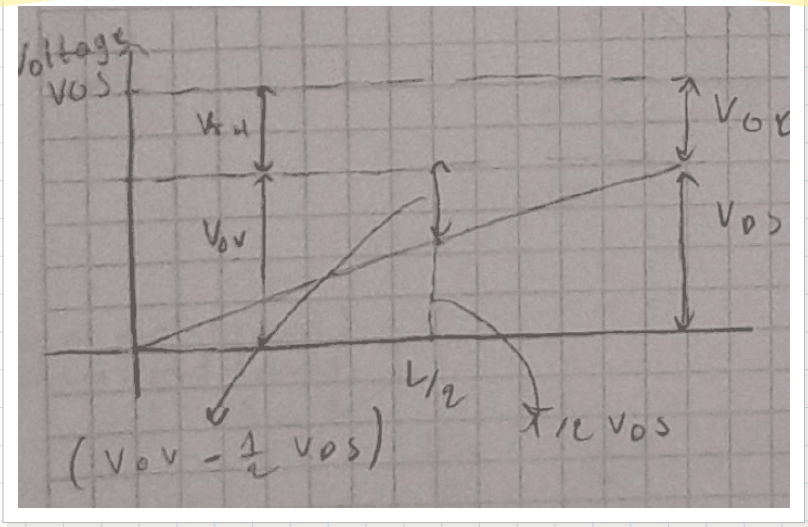
$$= \mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS} - V_{TH})$$

$$r_{DS} = \frac{1}{g_{DS}} = \frac{1}{\mu_n C_{ox}\left(\frac{W}{L}\right) V_{OV}}$$

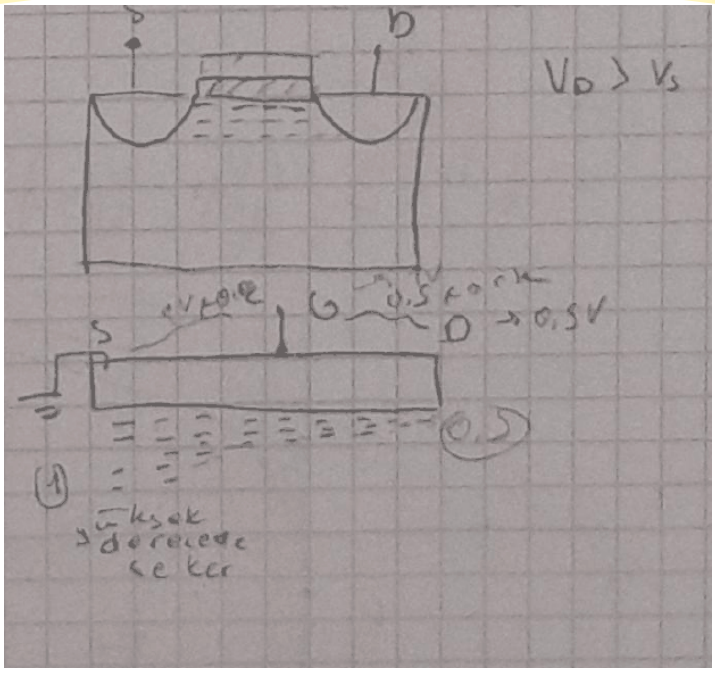


$$k'_n = \mu_n C_{ox}$$

$$k_n = \mu_n C_{ox} \frac{W}{L} = \beta$$



orijinal çizim, s. 42



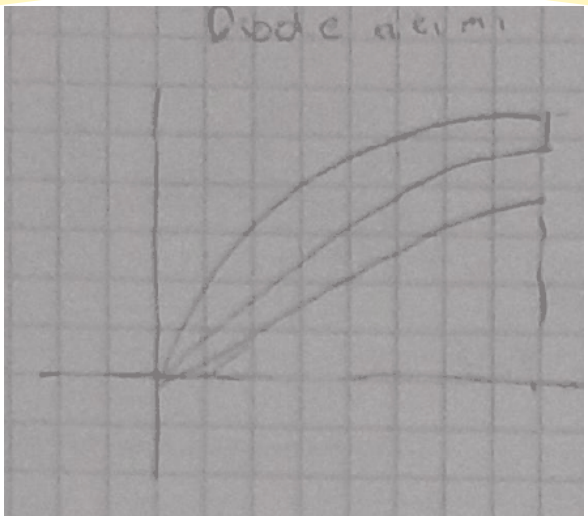
orijinal çizim, s. 42

orj. s. 43

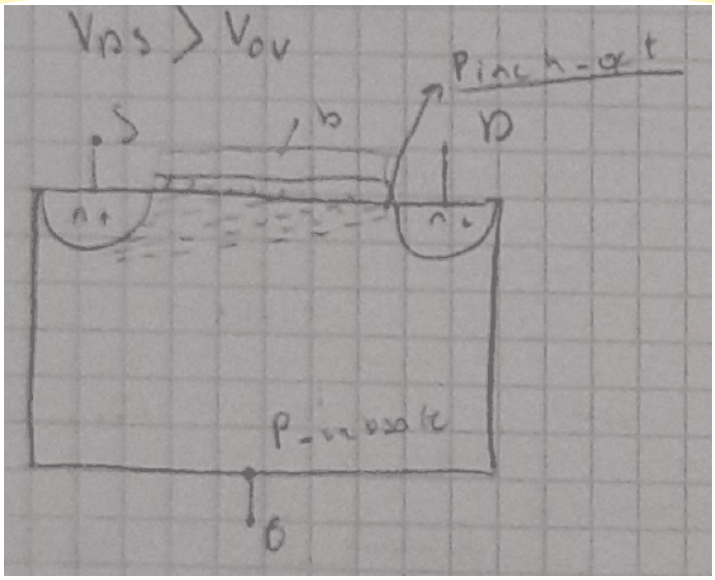
$$i_D = k'_n\left(\frac{W}{L}\right)\left(V_{OV}\cdot V_{DS} - \frac{1}{2}V_{DS}^2\right)$$

$$i_D = k'_n\left(\frac{W}{L}\right)\left[(V_{GS} - V_{TH})V_{DS} - \frac{1}{2}V_{DS}^2\right] \quad \leftarrow \textit{(Triode)}$$

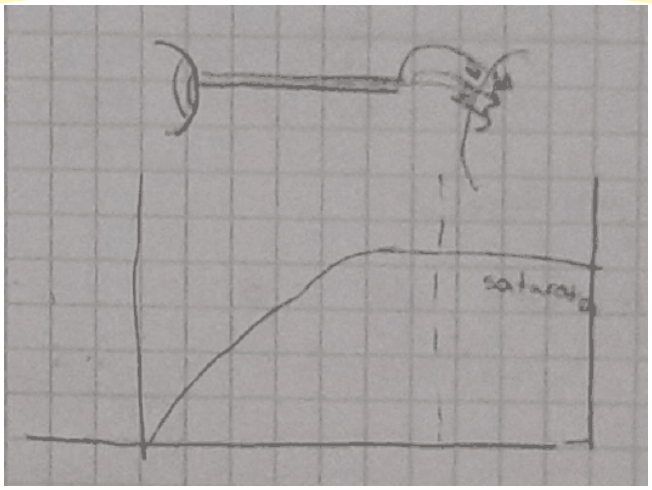
? Drain akımı



orijinal çizim, s. 43

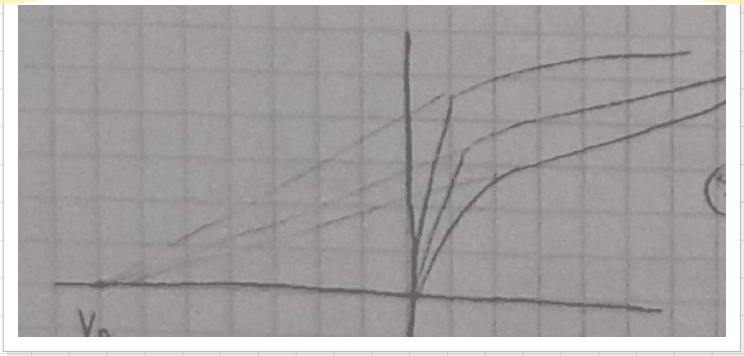


orijinal çizim, s. 43



orijinal çizim, s. 43

$$i_D = \frac{1}{2} k'_n \left(\frac{W}{L}\right)(V_{GS} - V_{TH})^2$$

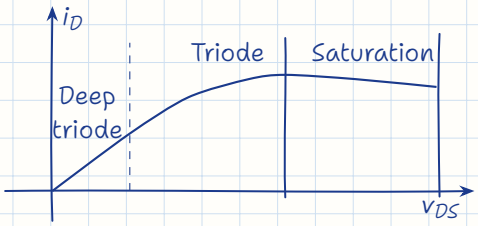


orijinal çizim, s. 43

$$(50\,V) \leftarrow V_A = \frac{1}{\lambda}$$

$$i_D = \frac{1}{2} k'_n \left(\frac{W}{L}\right)(V_{GS} - V_{TH})^2 (1 + \lambda v_{DS})$$

Not (sağ üstte, ok ile $(1 + \lambda v_{DS})$ terimine işaret ediyor): "Channel length modulation (kanal boyu modülasyonu)"[1]



$$i_D = \frac{1}{2} k'_n \left(\frac{W}{L}\right)(V_{GS} - V_{TH})^2 \quad \leftarrow \textbf{saturation}$$

[1] Satırların sonu 43. sayfa fotoğrafında kesilmiş; devamı 44. sayfa fotoğrafının sol kenarında kısmen görülüyor.

orj. s. 44

Örnek 5.1

$L_{min} = 0{,}4\ \mu m$ $\qquad t_{ox} = 8\ nm$

$\mu_n = 450\ cm^2/V \cdot s$ $\qquad V_{TH} = 0{,}7\ V$

a) Find C_{ox} and k'_n

b) $\frac{W}{L} = \frac{8\ \mu m}{0{,}8\ \mu m} \rightarrow V_{OV}, V_{GS}, V_{DS\,min} \rightarrow$ needed to operate the transistor in the sat. region $\rightarrow$ $I_D = 100\ \mu A$

c) (b) deki transistör için V_{OV} ve V_{GS} gerilimlerini hesaplayınız

↪ 1000 Ω Resistor

Çözüm: a) $C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} \rightarrow \varepsilon_{ox} = \varepsilon_r \cdot \varepsilon_0$ (ε_r: 3,9 for SiO_2; ε_0: $8{,}85 \cdot 10^{-12}$ F/m)

$$= \frac{3{,}45 \cdot 10^{-11}}{8 \times 10^{-9}} = 4{,}32 \times 10^{-3}\ F/m^2 = 4{,}32\ fF/\mu m^2$$

$$k'_n = \mu_n C_{ox} = (450\ cm^2/V \cdot s)(4{,}32\ fF/\mu m^2)$$

$$= 194 \times 10^{-6}\ F/V \cdot s \qquad \rightarrow C = \frac{Q}{V} \Rightarrow \frac{F}{V \cdot s}$$

$$= 194\ \mu A/V^2$$

$$\Rightarrow \frac{Q}{V^2 \cdot s} = \frac{I \cdot s}{V^2 \cdot s} = \frac{I}{V^2}$$

$$I = \frac{Q}{s} \rightarrow \frac{dq}{dt} = i$$

b) Sat

$$I_D = \frac{1}{2} k'_n (V_{OV})^2$$

$$100 = \frac{1}{2} \times 194 \times \frac{8}{0{,}8} (V_{OV})^2$$

$$V_{OV} = 0{,}32\ V$$

$$V_{GS} = \underset{0{,}7}{V_{TH}} + \underset{0{,}32}{V_{OV}} = 1{,}02\ V$$

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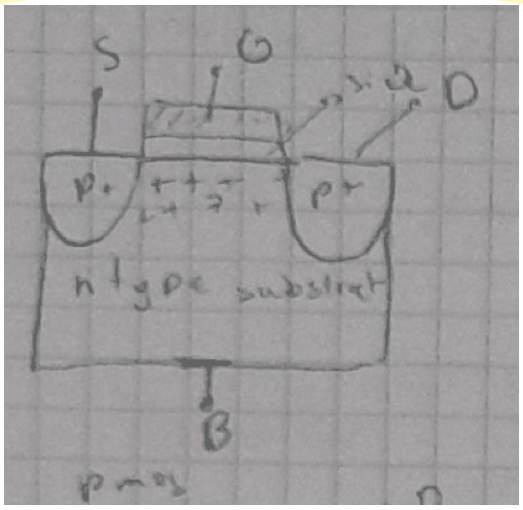
* Sat: $V_{DS} \geq V_{OV}$, $V_{DS} \geq V_{GS} - V_{TH}$ satürasyon için

orj. s. 45

c) Transistor in deep triode region

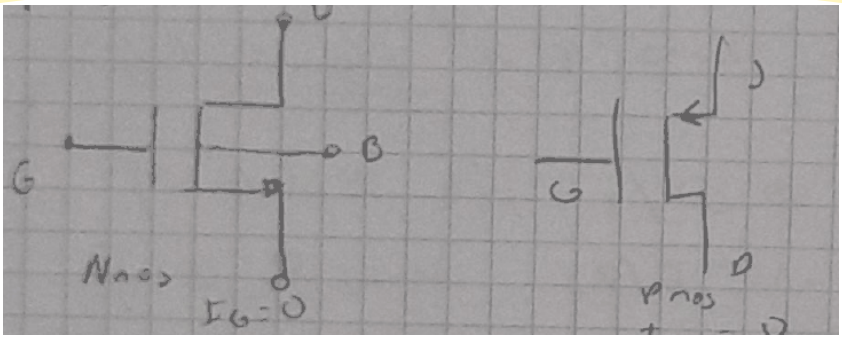
$$\underset{1000\ \Omega}{r_{DS}} = \frac{1}{k'_n \frac{W}{L} V_{OV}} \rightarrow \boxed{\begin{aligned} V_{OV} &= 0{,}52\ V \\ V_{GS} &= 1{,}22\ V \end{aligned}}$$

* Sat → r_{os}

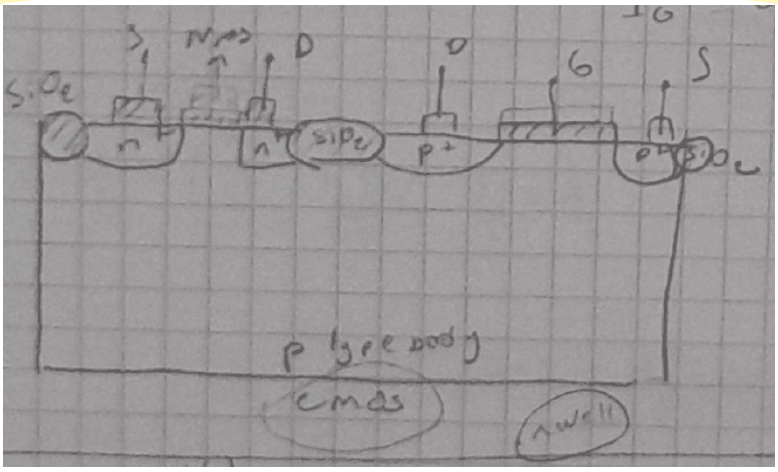


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pmos + nmos → cmos → ?complementary mos

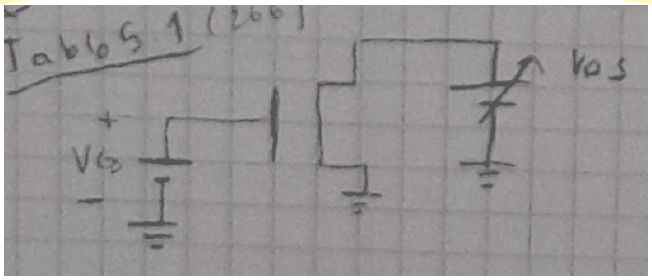


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orijinal çizim, s. 45

* Table 5.1 (266)



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$V_{GS} < V_{TH}$ → no channel, transistor in cutoff ? $i_D = 0$

$V_{GS} = V_{TH} + V_{OV}$ – a channel is induced → triode or saturation

Triode Region

$V_{GS} > V_{TH}$

$V_{DS} < V_{OV}$

$$I_D = k'_n\left(\frac{W}{L}\right)\left(V_{OV} - \frac{1}{2}V_{DS}\right)V_{DS}$$

Saturation Region[a]

$V_{GS} \leq V_{TH}$

$V_{DS} \geq V_{OV}$

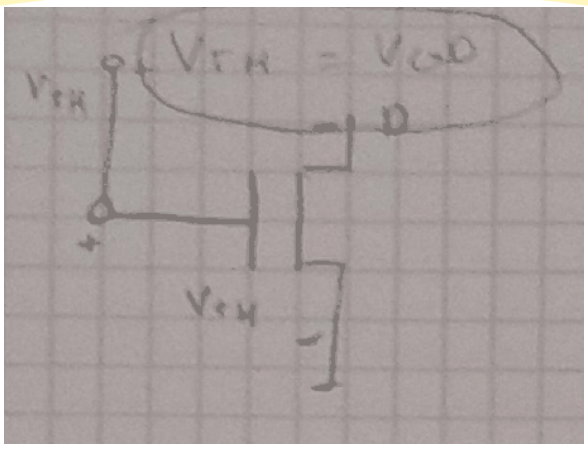
$$I_D = \frac{1}{2}k'_n\left(\frac{W}{L}\right)(V_{GS} - V_{TH})^2$$

[a] Claude notu: ilk koşul muhtemelen $V_{GS} \geq V_{TH}$ olmalı.

orj. s. 46

$$V_{DS} = V_{GS} - V_{TH}$$
$$V_D - V_S = V_G - V_S - V_{TH}$$
$$V_{TH} = V_G - V_D$$

$$\boxed{V_{TH} = V_{GD}}$$



orijinal çizim, s. 46