Short channel MOSFETS

General Design (a starting point)

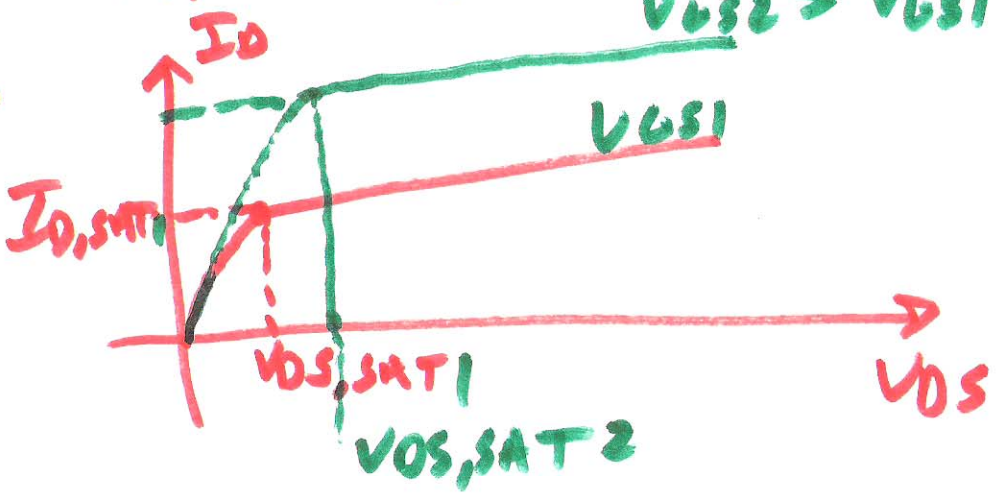
Long-channel devices

$$V_{DS,SAT} = V_{GS} - V_{THN}$$

doesn't work for short-channel MOSFETS

$$V_{DS,SAT} \neq V_{GS} - V_{THN}$$

For either



$$f_T\Big|_{\text{long-channel}} = \frac{3\mu_n}{4\pi} \cdot \frac{V_{OS,SAT}}{L^2} = \frac{3\mu_n}{4\pi L^2}(V_{GS} - V_{THN}) \quad (9.36)$$

for long or short-channel devices

$$V_{OVN} = V_{GS} - V_{THN}$$

How do we select V_{OV}?

for general design

$V_{OV} \Rightarrow 5\%$ of VDD

in book (short channel)

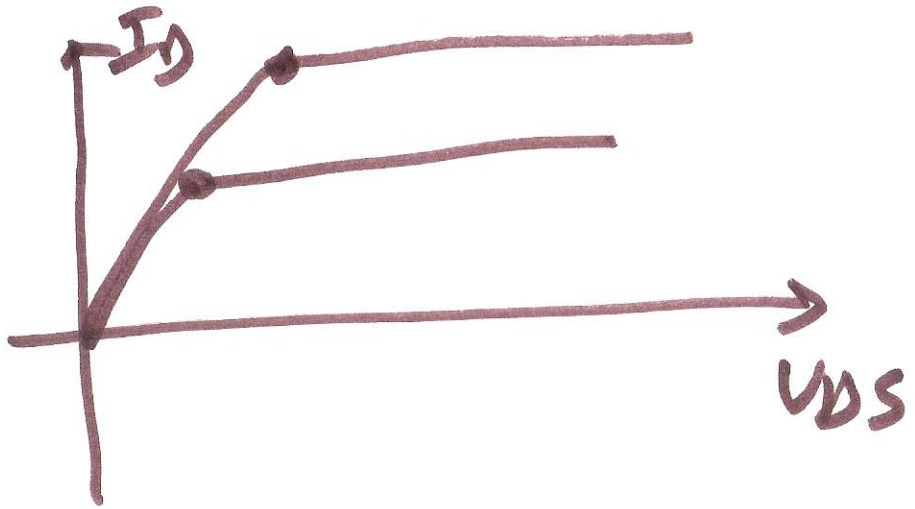
$V_{OV} = 70mV$

$V_{THN} = 280mV$

$V_{GS} = 350mV$

For High-speed Design

$V_{OV} \rightarrow$ 10% or more of V_{DD}



for short channel

$$f_T \simeq \frac{g_m}{2\pi C_{gs}} \propto \frac{V_{OV}}{L}$$

for high-speed use small L!

For short-channel devices

$$I_D \neq \frac{\beta}{2}(V_{GS} - V_{THN})^2, \quad g_m = \sqrt{2\beta I_D} = \beta(V_{GS} - V_{THN})$$

↑ long channel

Square-law equations don't work!

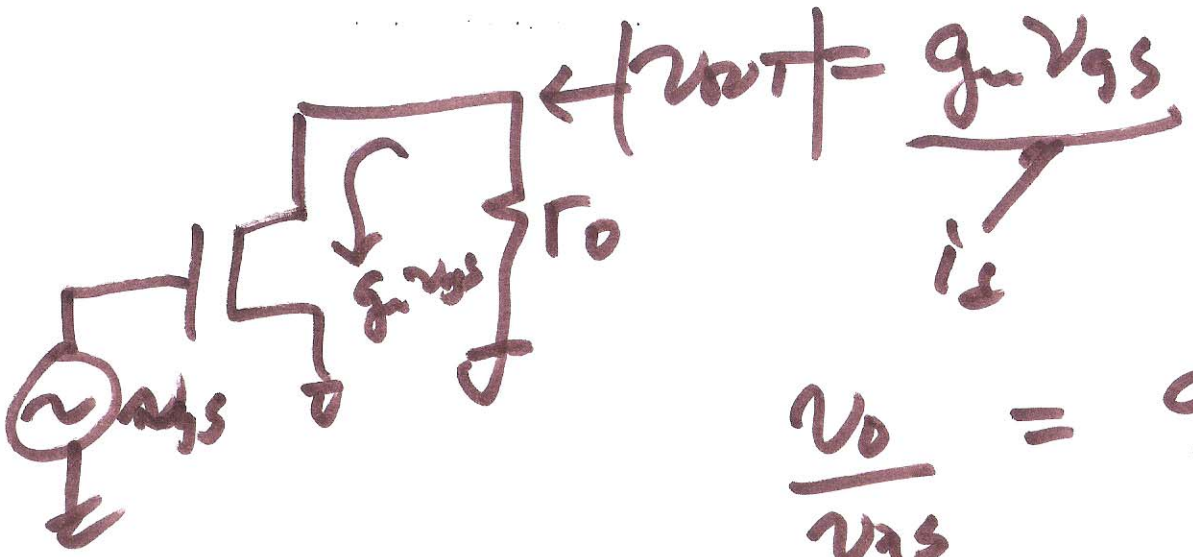
$$i_D = v_{SAT} \cdot C_{ox}' \cdot W (V_{GS} - V_{THN} - V_{DSSAT})$$

short channel

$$g_m = v_{SAT} \cdot C_{ox}' \cdot W$$

independent of L

g_m is dependent on L because v_{SAT}, is dep on L!

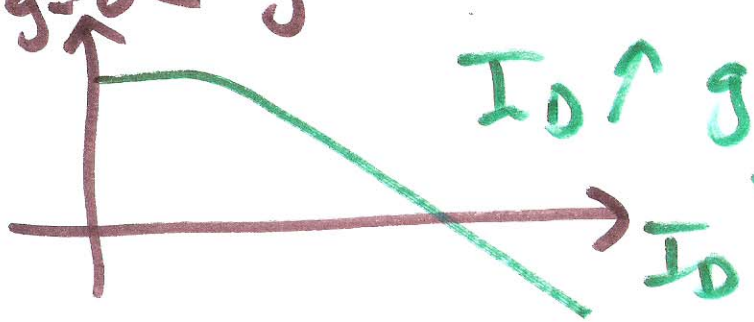


$$\frac{v_o}{v_{gs}} = g_m r_o$$ ← open-ckt gain!

Long-channel devices

$$g_m r_o = \sqrt{2K_{PN} \cdot \frac{W}{L} \cdot I_D} \cdot \frac{1}{\lambda I_D} = \frac{\sqrt{2K_P \cdot \frac{W}{L}}}{\lambda} \cdot \frac{1}{\sqrt{I_D}}$$

$g_m r_o$ ← gain



$I_D \uparrow$ gain down ↓

$f_T \propto I_D \propto V_{OV}$

$V_{OV} \uparrow I_D \uparrow f_T \uparrow$

$$g_m r_o = \frac{K_{P_n} \cdot \frac{W}{L}(V_{OS} - V_{THN})}{\lambda \underbrace{\frac{K_P \cdot W}{2} \frac{W}{L}(V_{OS} - V_{THN})^2}_{I_D}} = \frac{2}{\lambda \underbrace{(V_{OS} - V_{THN})}_{V_{OVN}}}$$

$$= \frac{2}{\lambda \cdot V_{OVN}}$$

$GAIN \cdot f_T = GFT$ $\quad V_{OVN} \uparrow \; I_D \uparrow \; f_T \uparrow \; g_m r_o \downarrow$

$g_m r_o \cdot f_T \quad \frac{3\mu_n}{4\pi L^2} \cdot \frac{2}{\lambda V_{OVN}} \cdot V_{OVN}$ $\quad$ gain $\uparrow$

$= GFT = \frac{3\mu_n}{2\pi L^2 \lambda}$

$\propto \frac{\mu_n}{L^2} \nearrow$

6)

TO increase both speed
And GAin the only "tweak"
is Length!

$$GFT \propto \frac{\mu_N}{L^2}$$

In book

$$GFT\Big|_{\text{for Long-channel}} = \overset{g_m r_o}{750} \cdot 900\,MHz \approx 700\,GHz$$

Best for slow designs use old CMOS

Short channel GFT

$$= 25 \cdot 6\,GHz = 150\,GHz$$

for high-speed use small/new CMOS Technology

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