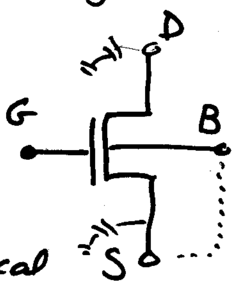
TA Office Hours:	Download for 1/28/04
3-4:30pm Tuesday Room E292 Van Leer	• Latch-up in CMOS technology

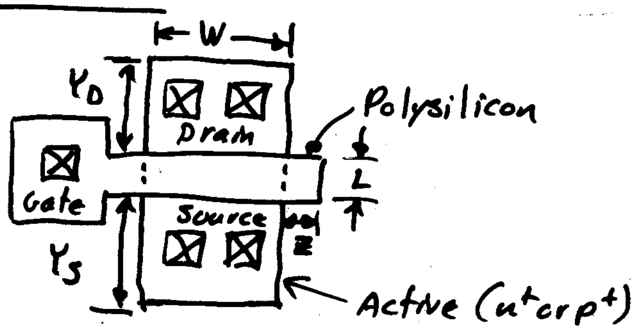
Shengyuan Li

Models-

- Thinking → Level 1 (Sah model modified for DSM)
- Simulation → BSIM 3.?

Specifying MOS Transistors





Design:

1.) Electrical
2.) Layout
3.) Fabrication
4.) Testing

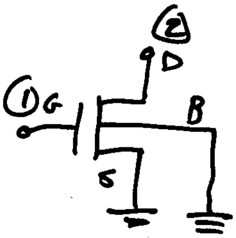
MOSFET:

MXXX D G S B Modelname L W AD AS PD PS

D = drain node
G = gate node
S = source node
B = bulk node
Modelname - The name of model NXXX or PXXX
L = the drawn length of the MOSFET
W = " " width " " "
AD (AS) = area of the drain (source)
PD (PS) = perimeter (edge) of drain (source)

Example

Write a SPICE description of a NMOS transistor with $L = 0.2\mu m$, $W = 0.4\mu m$ & $Y_D = Y_S = 0.5\mu m$.




```
M1 2 1 0 0 NMOS1 L=0.2U W=0.4U
+ AD=0.2P PD=0.4U AS=0.2P PS=0.4U
```

Use a scaling option -

```
.opt scale = 0.1U
```

```
M1 2 1 0 0 NMOS1 L=2 W=4 AD=20 PD=4
+ AS=20 PS=4
```

SPICE MOS LEVEL 1 Model

Parameters: VTO, KP, LAMBDA, PHI and GAMMA
(V_{TO}) K' λ ϕ γ

Indirect calculation of these parameters -

Given NSUB, TOX and UO, then

$$PHI = \frac{2kT}{q} \ln\left(\frac{NSUB}{n_i}\right)$$

$$C_{ox} = \frac{\epsilon_{ox}}{TOX} \qquad GAMMA = \frac{\sqrt{2\epsilon_{si} q \, NSUB}}{C_{ox}}$$

$$V_T = VTO + GAMMA\left(\sqrt{PHI - V_{BS}} - \sqrt{PHI}\right)$$

$$KP = UO \cdot C_{ox} \qquad W_{eff} = W - LD$$

Model:

$$i_{DS} = \frac{W_{eff}}{L_{eff}} \frac{KP}{2}\left[2(v_{GS} - V_T)v_{DS} - v_{DS}^2\right](1 + LAMBDA \cdot v_{DS})$$

for $v_{GS} \geq V_T$ and $v_{DS} \leq v_{GS} - V_T$

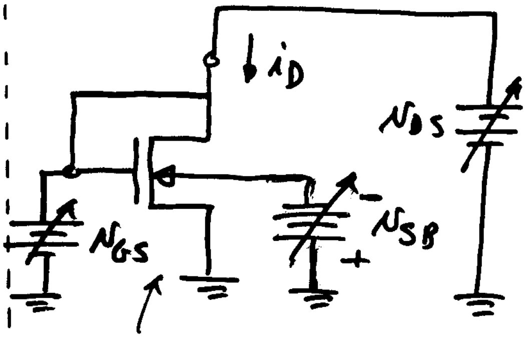
$$i_D = \frac{W_{eff}}{L_{eff}} \frac{KP}{2}(v_{GS} - V_T)^2(1 + LAMBDA \cdot v_{DS})$$

for $v_{GS} \geq V_T$ and $v_{DS} \geq (v_{GS} - V_T)$

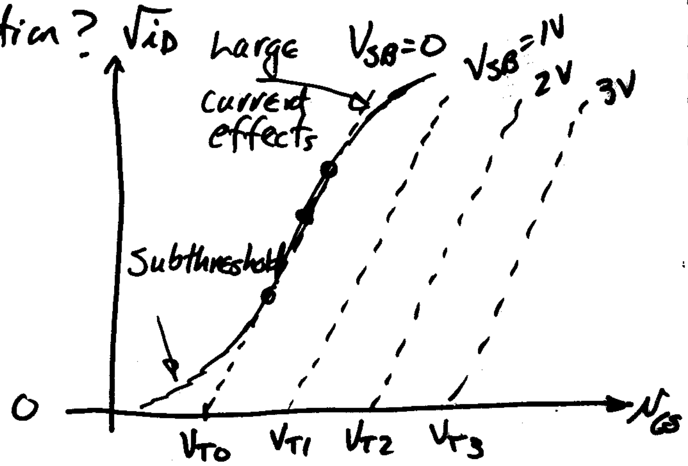
How can one find the "thinking" model parameters if you only have the transistor in your hand or a "fancy" BSIM model?

Extraction is the means by which we "get" these parameters.

How does one do extraction?

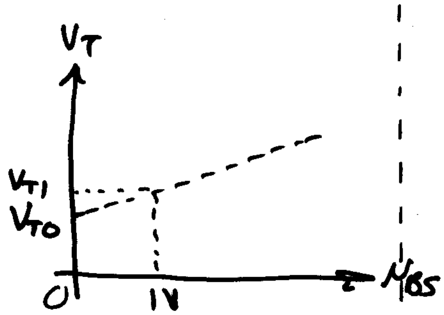


Make $L \geq 2L_{min}$



From the data:

$$\text{slope} = \sqrt{\frac{k'W}{L}} = \frac{\sqrt{2 i_D}}{V_{GS}-V_T}$$



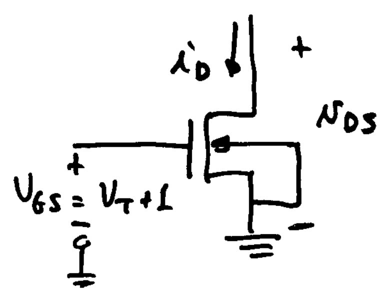
Appendix B of Allen and Holberg ECE6412

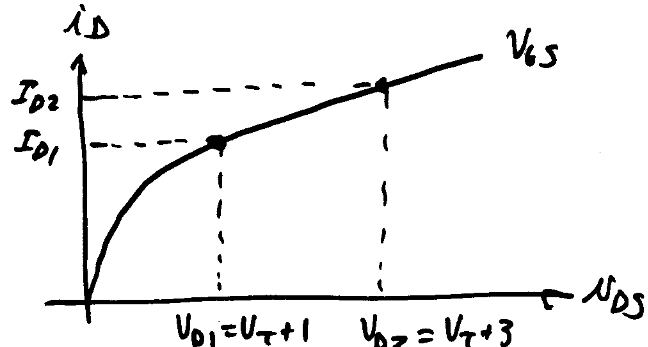
Also, one can plot $v_T = f(v_{SB})$

$$\gamma = \frac{V_T(V_{SB}) - V_{T0}}{\sqrt{2\phi_F + V_{SB}} - \sqrt{2\phi_F}}$$ guess $\phi_F \approx 0.6V$

www.aicdesign.org Chapter 2 of 2003 short course notes

Lamda:





$$\frac{I_{D2}}{I_{D1}} = \frac{1+\lambda V_{D2}}{1+\lambda V_{D1}} \rightarrow \lambda$$

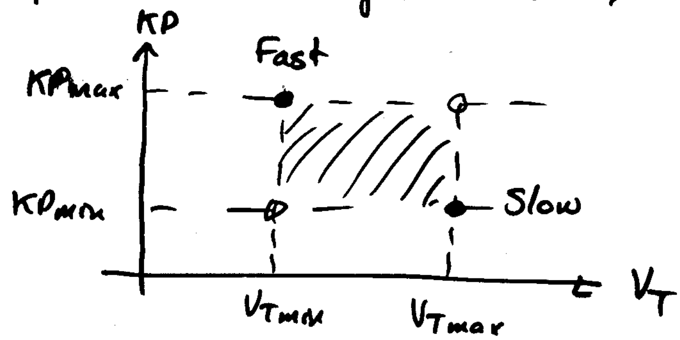
$v_{DS} \geq V_{GS} - V_T$

ADDITIONAL EFFECT IN MOSFETS

Parameter Variations

"Fast" parameters — g_m large ⇒ KP↑ VT↓

"Slow" parameters — g_m small ⇒ KP↓ VT↑



Temperature