EE421/EGG621 Digital IC Design

Oct. 9, 2023

Lecture 12

SAT:

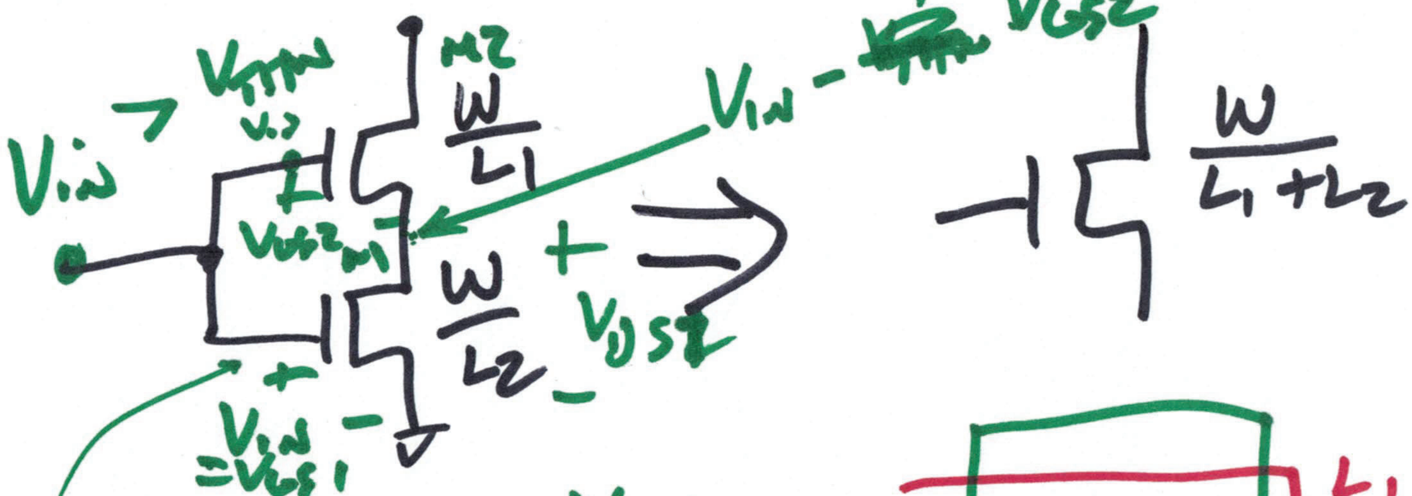
$V_{DS} \geq V_{GS} - V_{THN}$

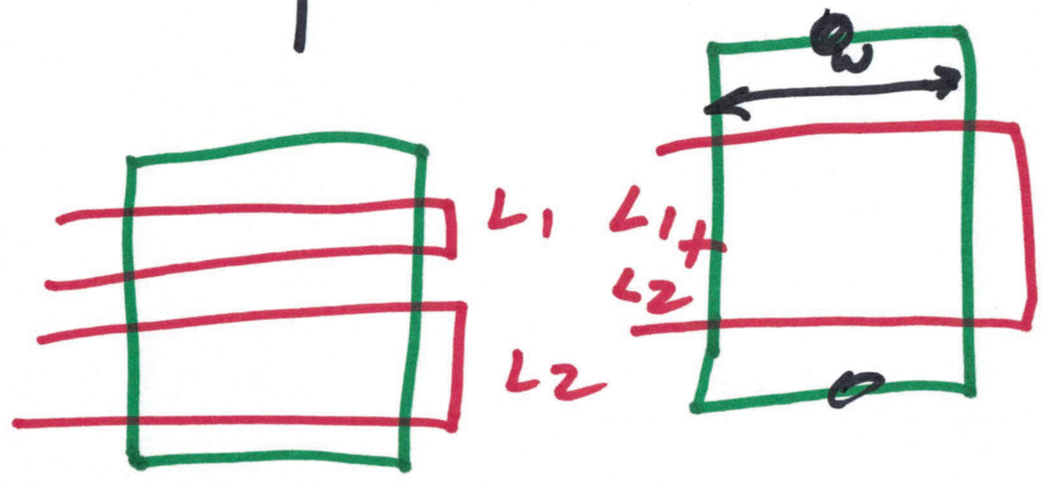
triode

$V_{DS} \leq V_{GS} - V_{THN}$

.8

1V





$V_{DS1} \geq V_{GS1} - V_{THN}$

$V_{in} - V_{GS2} \geq V_{GS1} - V_{THN}$

$1V - .8$

$V_{IN} - V_{GS2} = V_{DS1}$

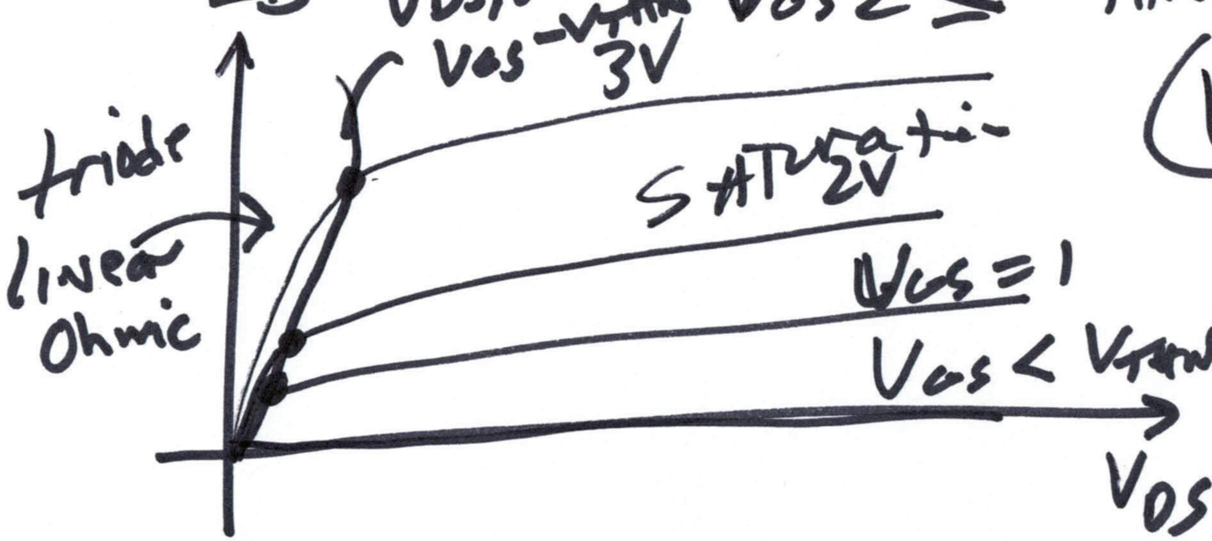
I_{off}

I_{on}

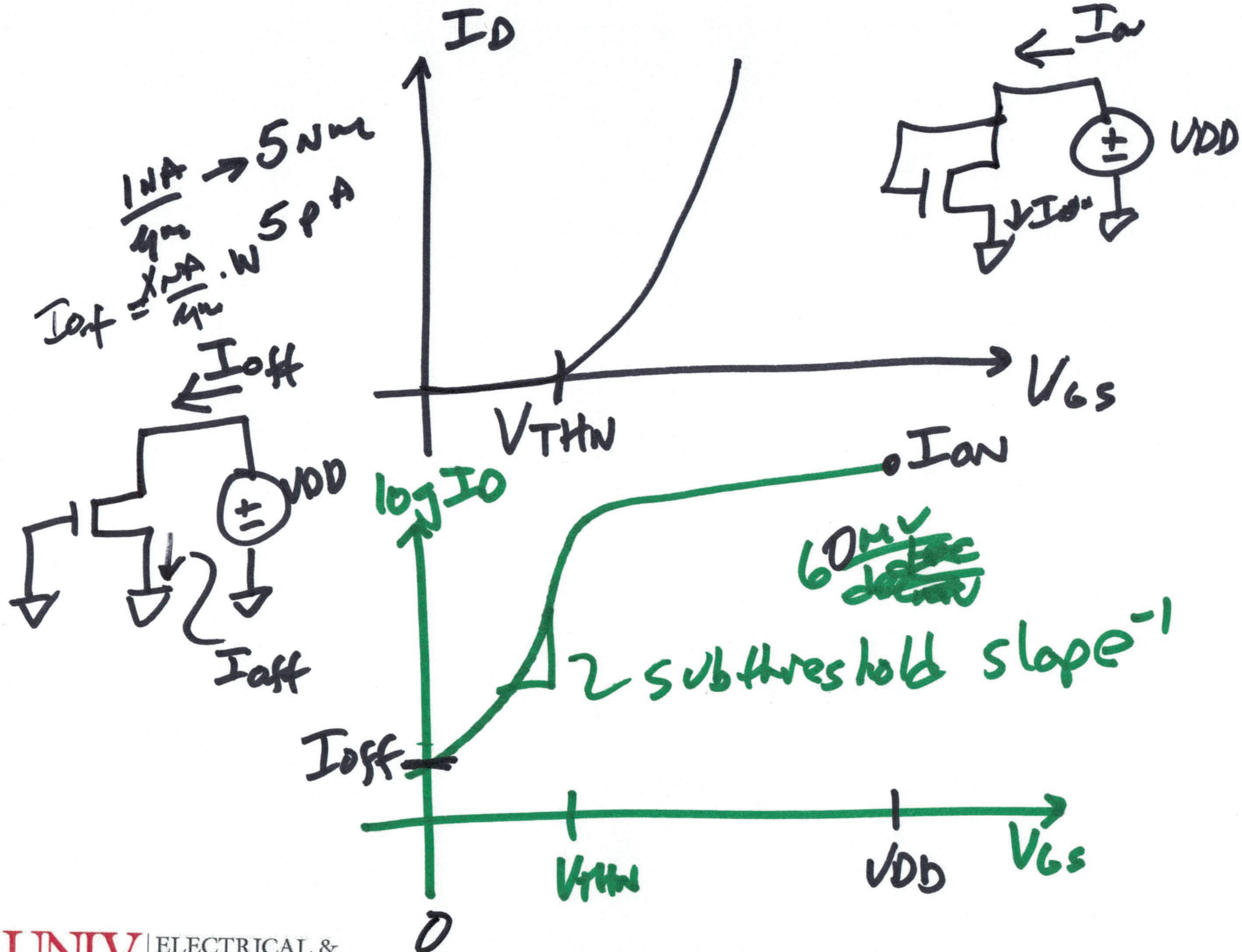
$V_{DS1} \overset{?}{\geq} V_{GS1} - V_{THN}$

$V_{IN} - V_{GS2} \overset{?}{\geq} V_{IN} - V_{THN}$

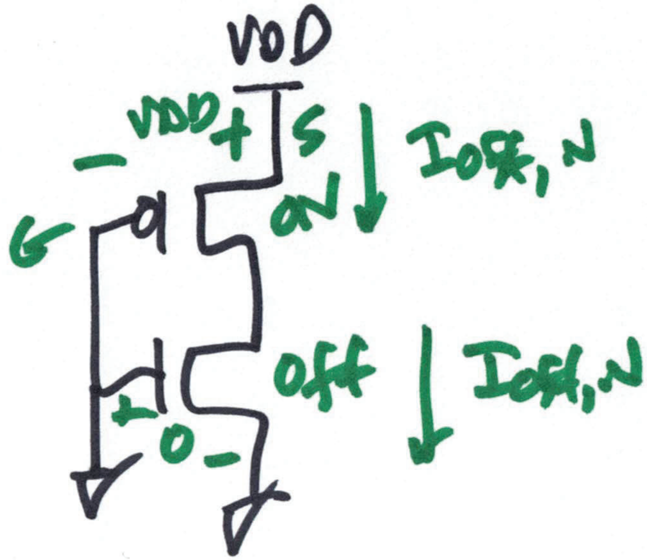
$V_{GS2} \overset{?}{\geq} V_{THN}$

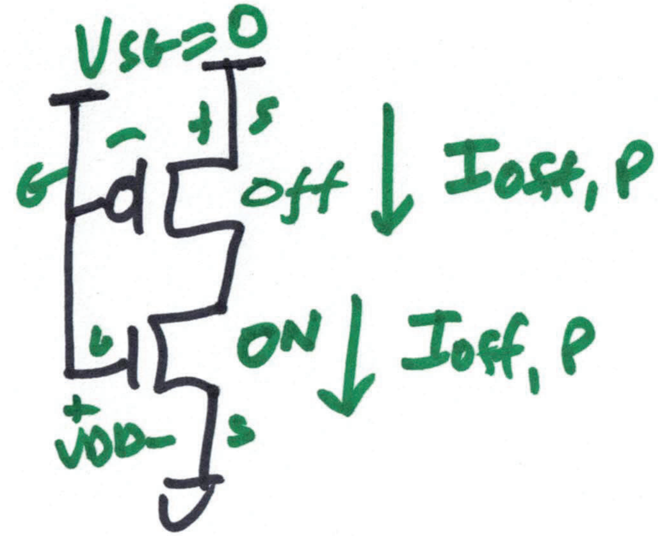


$(V_{DS} \geq V_{GS} - V_{THN})$



ID
VGS
VTHN
Ion
VDD
Ioff
log ID
60
2 subthreshold slope⁻¹
Ioff
VTHN
VDD
VGS
0





$VDD \cdot I_{off,N}$

$VDD \cdot I_{off,P}$

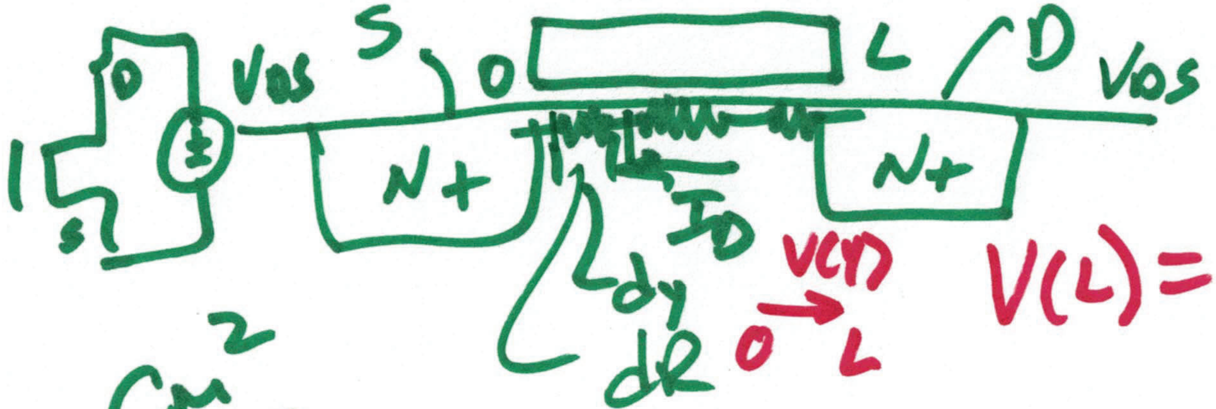
Example: $100{,}000{,}000 = 10^8$ transistors

5nm $\rightarrow$ $\frac{1nA}{\mu m}$

$I_{offP} = I_{offN} = 5nm \cdot \frac{1nA}{1000nm} = 5pA$

$10^8 \cdot 5 \times 10^{-12}\,A$

$5 \times 10^{-4} = \frac{1}{2}\,mA$



$$V(L) = V_{DS}$$

$$\int_0^L dR = R_{CH}$$

$$\int_0^L dy = L$$

$$\mu_N = \frac{cm^2}{V \cdot s} = \frac{\text{speed}}{\text{Electric field}} = \frac{cm/s}{V/cm}$$

$$dR = \frac{dy}{W} \cdot \frac{1}{\mu_N \cdot Q_I'(y)}$$

$$I_D \cdot dR = dV(y)$$

$$= \frac{I_D \cdot dy}{\mu_N Q_I'(y) \cdot W} = dV(y)$$

UNLV | ELECTRICAL & COMPUTER ENGINEERING

CMOSedu.com

$$\frac{I_D \cdot dy}{\mu_N Q_I'(y) \cdot W} = dV(y)$$

$$Q_I'(y) = C_{ox}'(V_{GS} - V(y) - V_{THN})$$

$\int x\,dx$

$\frac{1}{2}x^2$

$$\int_0^L \frac{I_D}{\cancel{\mu_N}} \cdot \frac{dy}{W} = \int_0^{V_{DS}} \mu_N C_{ox}' (V_{GS} - V(y) - V_{THN}) \cdot dV(y)$$

$$I_D \cdot \frac{L}{W} = \mu_N C_{ox}' \left(\int_0^{V_{DS}} V_{GS} \cdot dV(y) + \int_0^{V_{DS}} (-V(y))\,dV(y) + \int_0^{V_{DS}} (-V_{THN})\,dV(y) \right)$$

$V_{GS}V_{DS}$

$-\frac{1}{2}V_{DS}^2$

$-V_{THN}V_{DS}$

$$I_D = \frac{W}{L} \cdot \mu_n C'_{ox} \left(V_{GS} V_{DS} - \frac{1}{2} V_{DS}^2 - V_{THN} V_{DS} \right)$$

$$KP_n = \mu_n C'_{ox}$$

$$I_D = \frac{W}{L} KP \left((V_{GS} - V_{THN}) V_{DS} - \frac{1}{2} V_{DS}^2 \right)$$

$$V_{DS,SAT} = V_{GS} - V_{THN} \qquad V_{DS} \le V_{GS} - V_{THN}$$

triode

saturation

$$I_D = \frac{W}{L} KP \left((V_{GS} - V_{THN})(V_{GS} - V_{THN}) - \frac{1}{2} (V_{GS} - V_{THN})^2 \right)$$

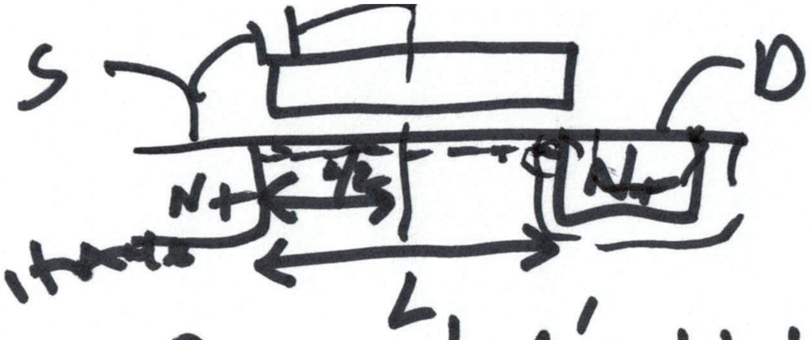
$V_{DS,SAT}$

$$= \frac{W}{L} \frac{KP}{2} (V_{GS} - V_{THN})^2$$

$$V_{DS} \ge V_{GS} - V_{THN}$$

UNLV | ELECTRICAL & COMPUTER ENGINEERING

CMOSedu.com



capacitance between gate & source → $C_{gs} = \frac{1}{2} C'_{ox} \cdot W \cdot L$

triode

channel goes from S → D

$C_{gd} = \frac{1}{2} C'_{ox} \cdot W \cdot L$

Saturation

$C_{gs} = \frac{2}{3} C'_{ox} \cdot W \cdot L$

C_{gd} = just drain to bulk depletion c