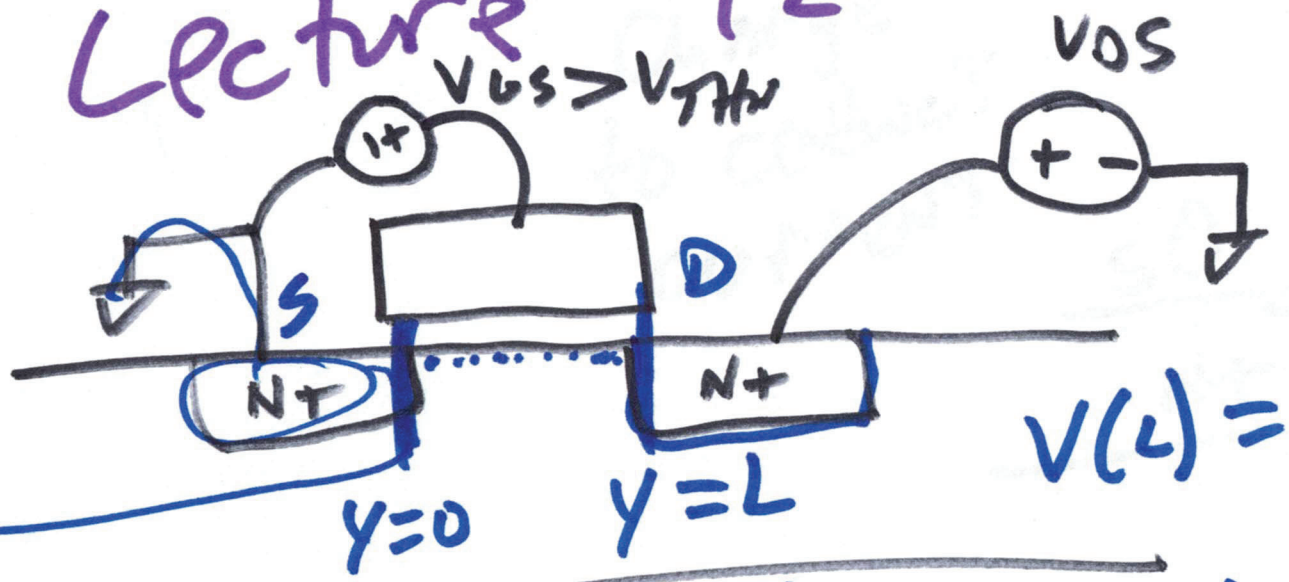
EE 421/621 Digital IC Design

OCT. 4, 2021

Lecture 12

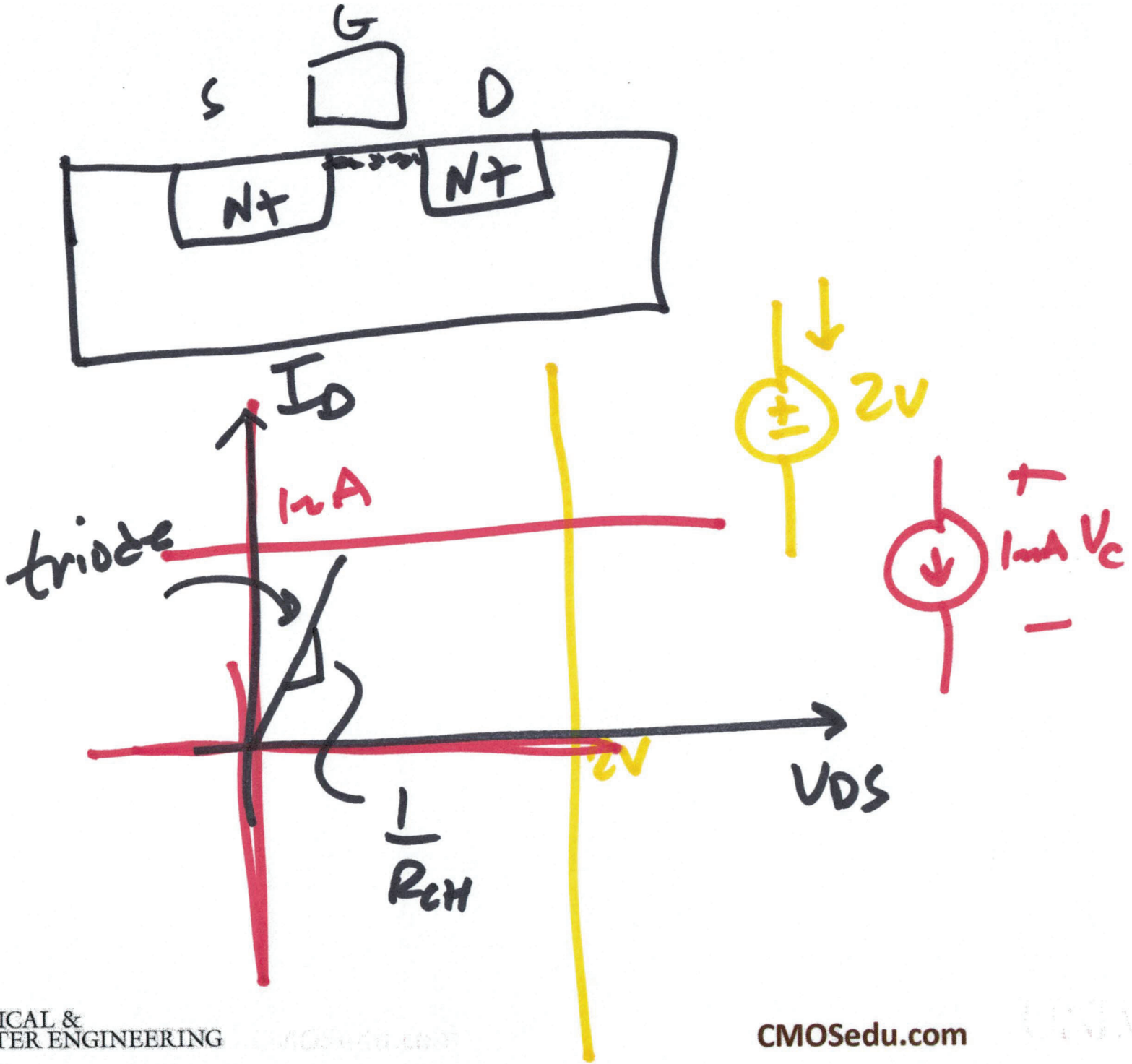
$$C_{ox}' = \frac{\epsilon_{ox}}{t_{ox}}$$



$$Q_{ch}' = C_{ox}'\left(V_{GS} - V(y)\right)$$

$$Q_b' = C_{ox}' \cdot V_{THN}$$

$$Q_I' = Q_{ch}' - Q_b'$$

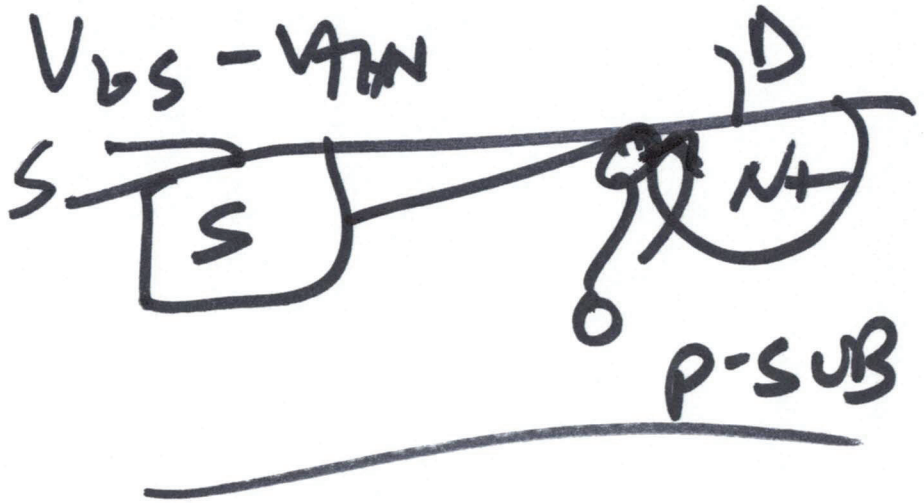

G
S
D
N+
N+
I_D
1mA
triode
2V
$\frac{1}{R_{CH}}$
2V
V_{DS}
+
1mA V_C
−

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

Saturation

$V_{GS} > V_{THN}$

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

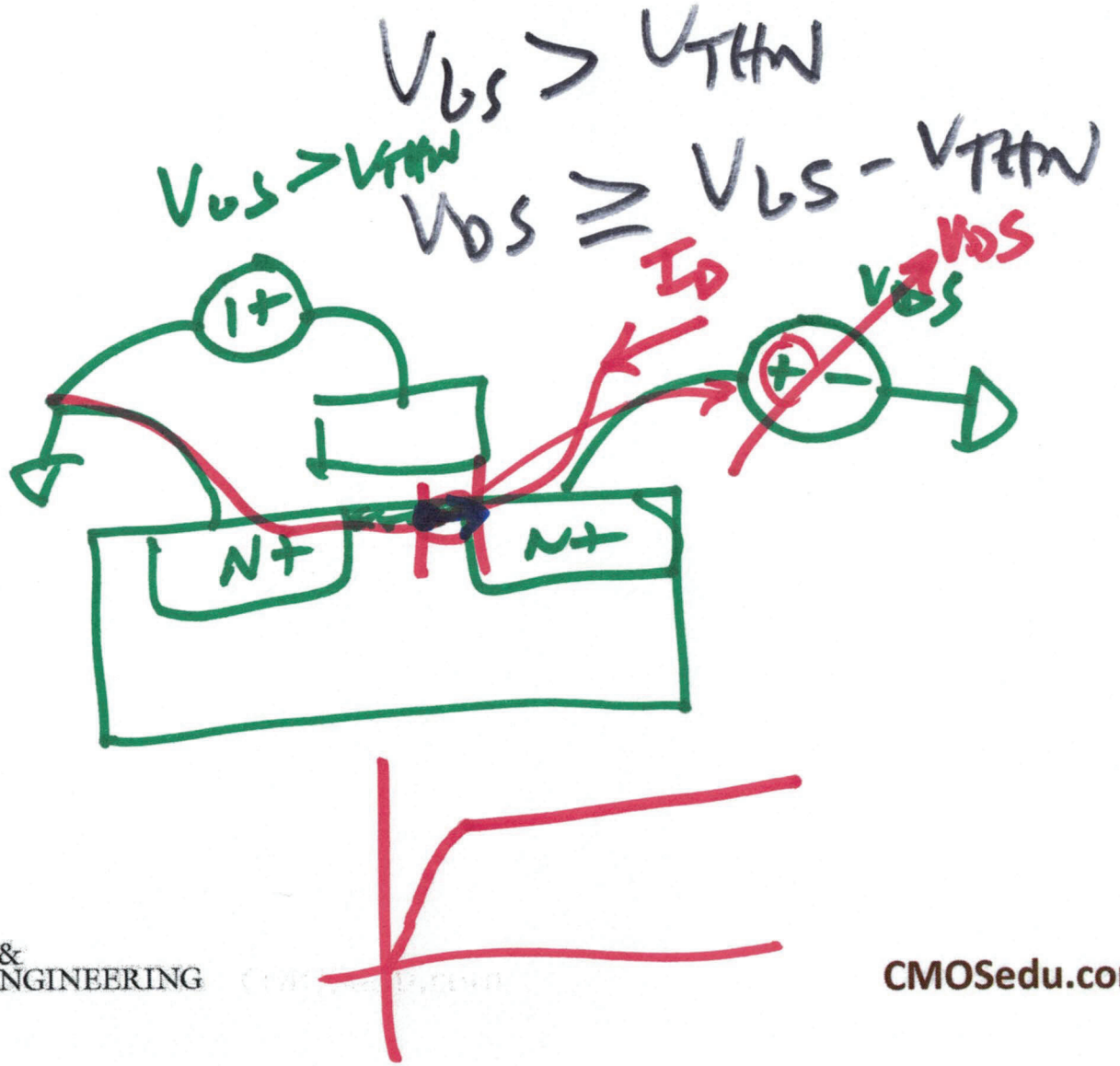


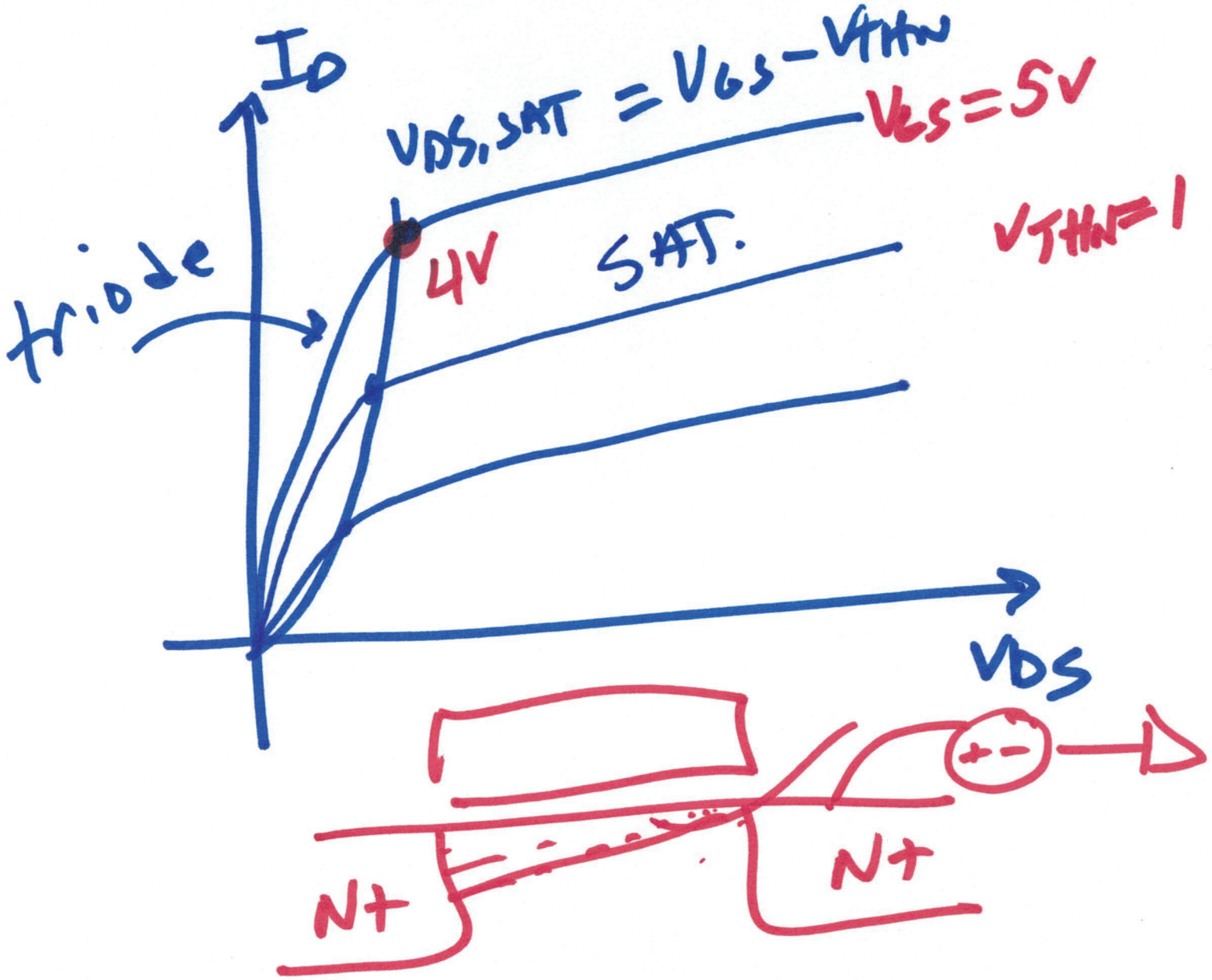
$$I_D = \mu_N C_{ox}' \frac{W}{L}\left((V_{GS}-V_{THN})(V_{GS}-V_{THN}) - \frac{1}{2}(V_{GS}-V_{THN})^2\right)$$

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

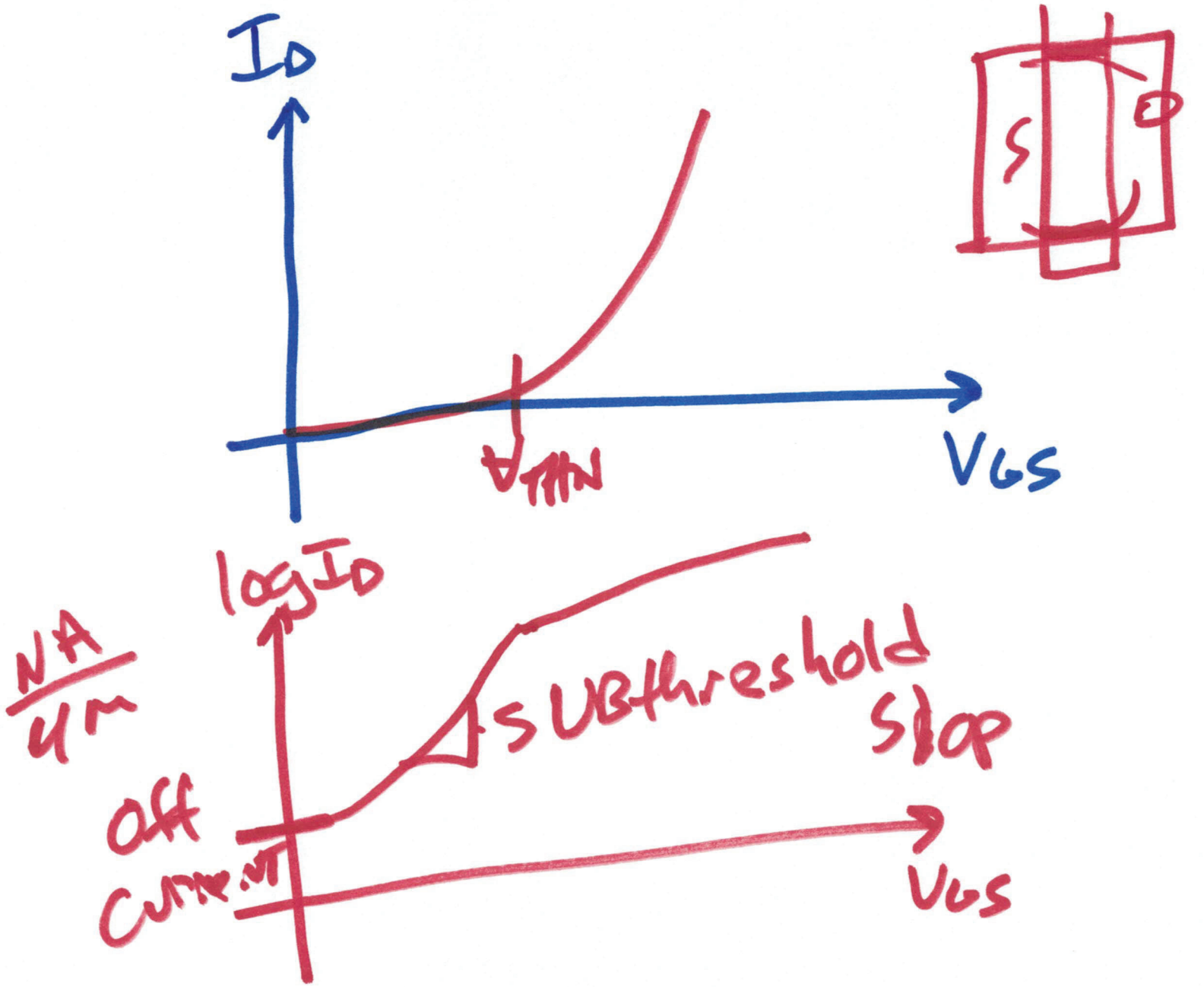
$V_{GS} > V_{THN}$

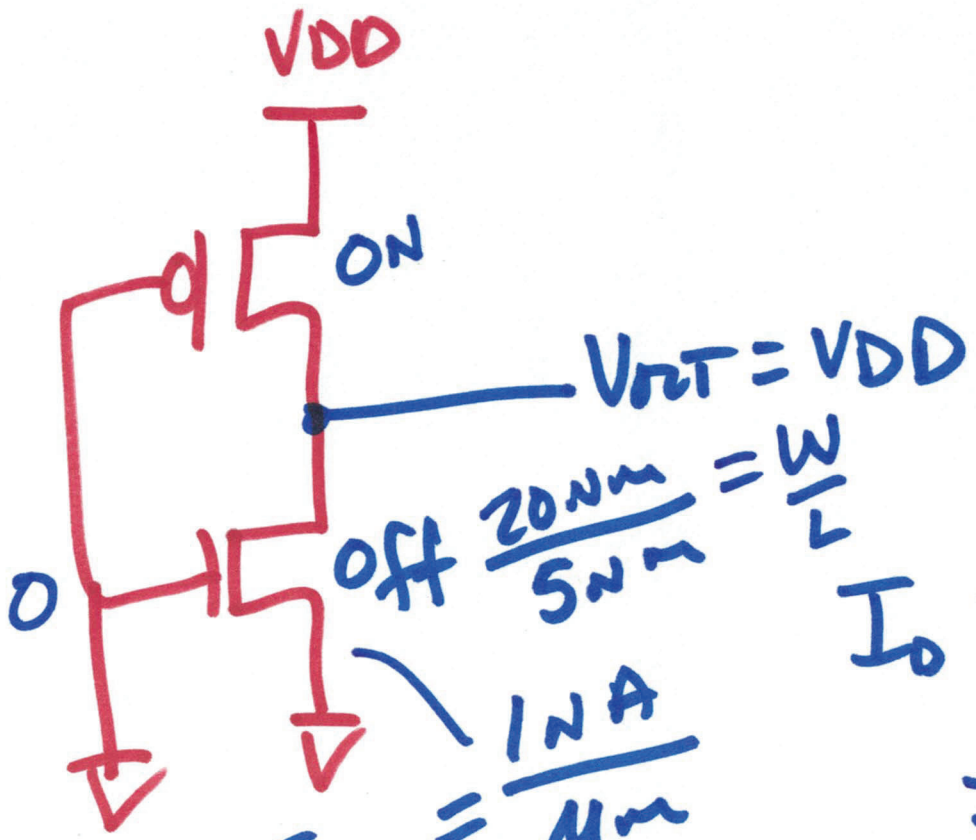
$V_{DS} \geq V_{GS} - V_{THN}$





a)


I_D
V_{TH}
V_{GS}
S
D
log I_D
NA/μm
Subthreshold Slop
Off Current
V_{GS}



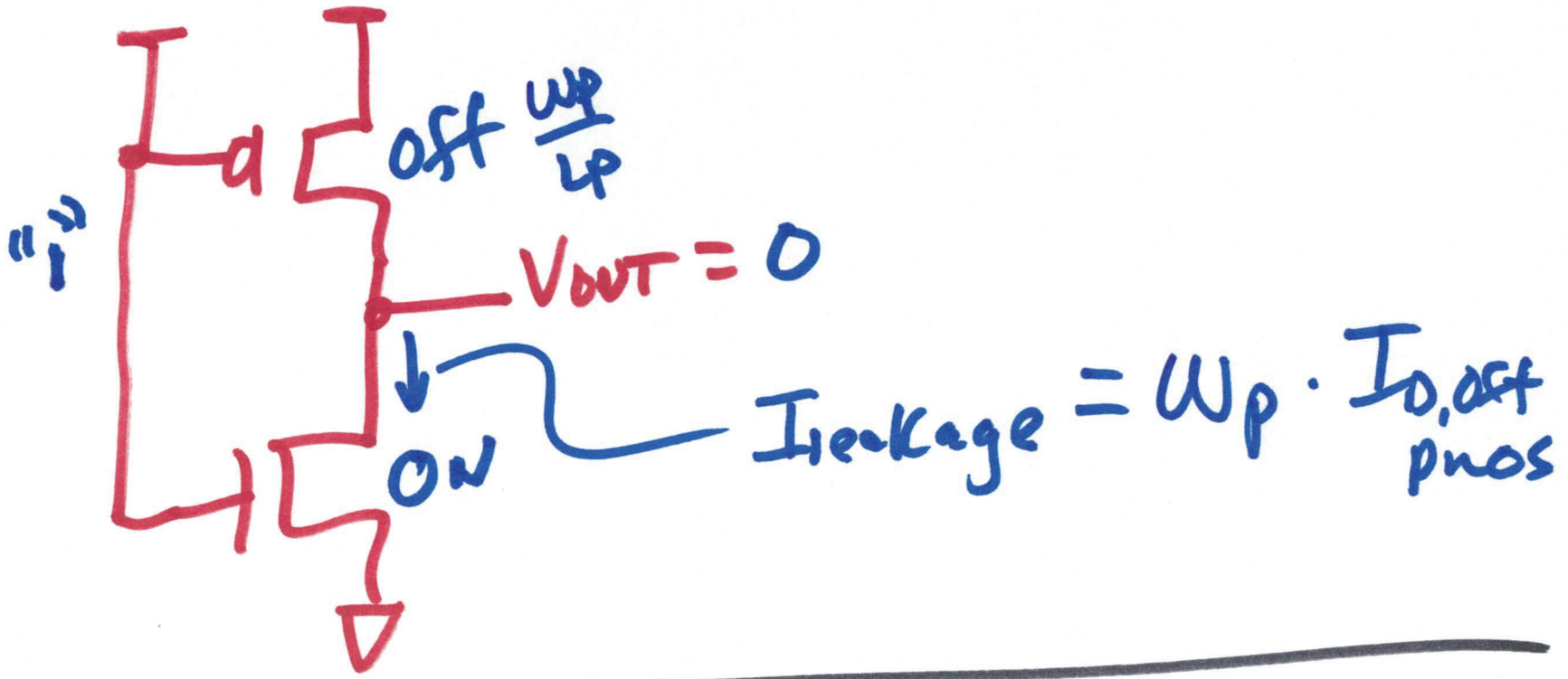
$I_D = I_{off} \cdot W$

$= \frac{1nA}{4m} \cdot 0.0024$

10^9 transistor

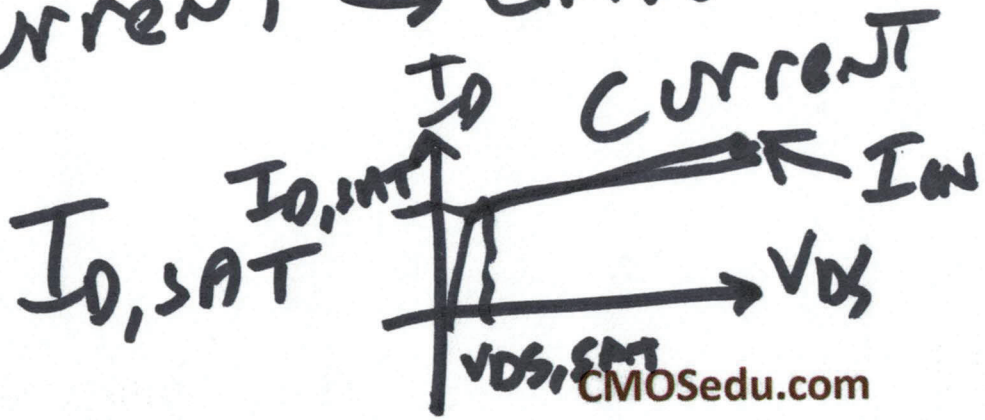
$\boxed{I_D = 20pA}$

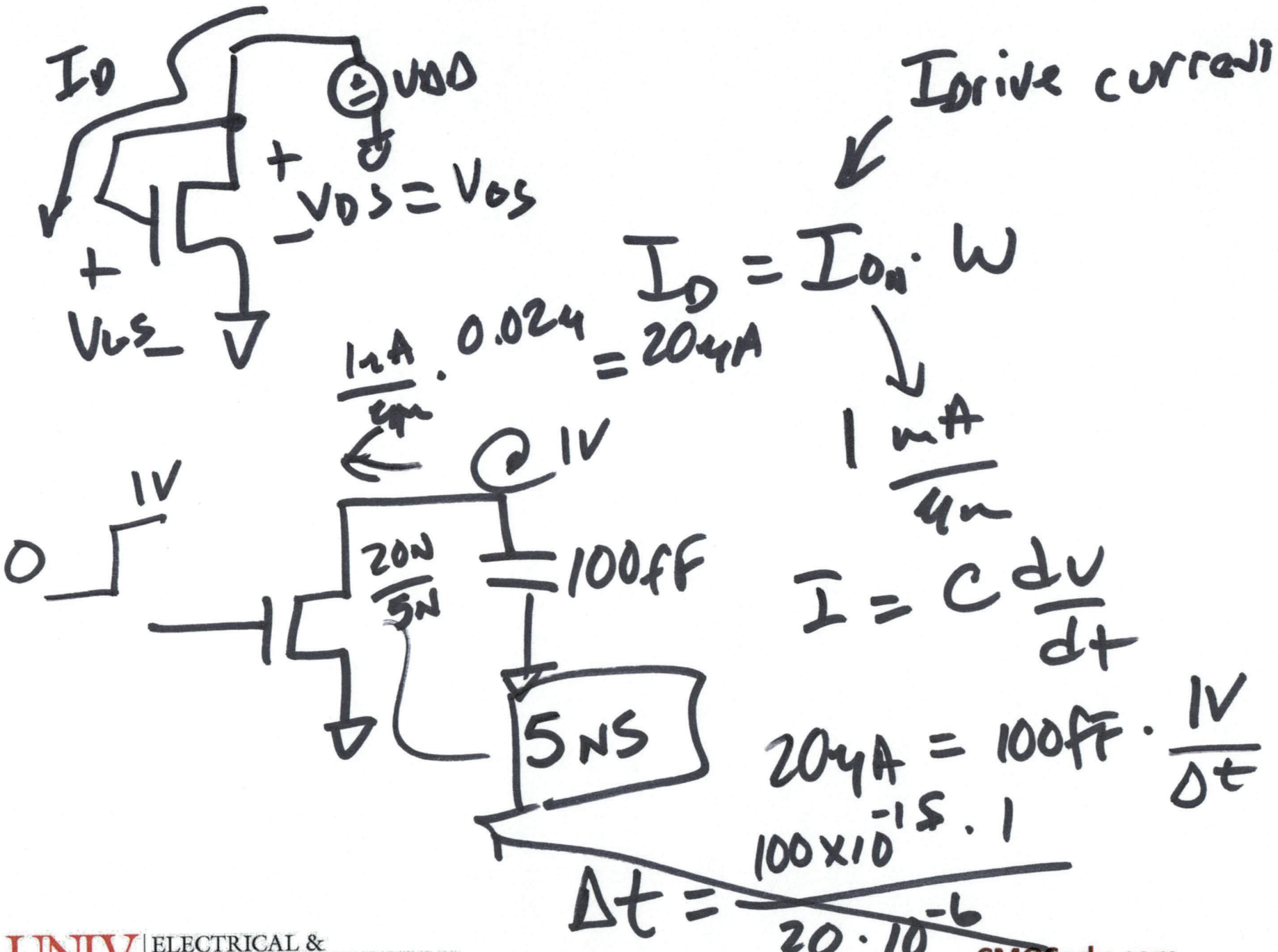
$I_{Leakage} = 10^9 \cdot 20 \times 10^{-12} = 20mA!$

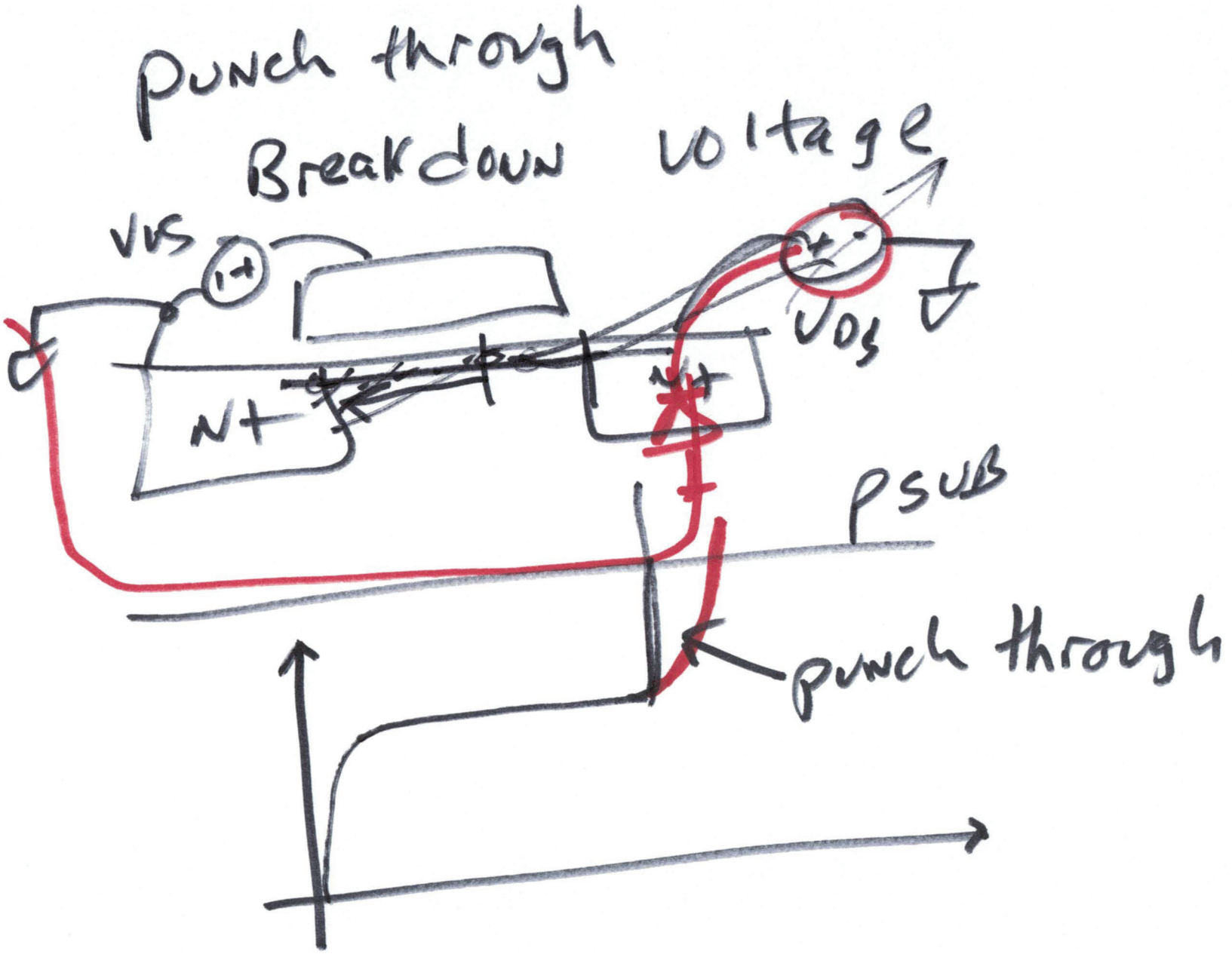


ON currents

ON-current → drive current




I_D
V_{DD}
$+ V_{DS} = V_{OS}$
$+ V_{GS} -$
Idrive current
$I_D = I_{ON} \cdot W$
$\frac{1nA}{4n} \cdot 0.024 = 20\mu A$
$\frac{1mA}{4m}$
1V
1V
0
20N / 5N
100fF
5NS
$I = C \frac{dV}{dt}$
$20\mu A = 100fF \cdot \frac{1V}{\Delta t}$
$\Delta t = \frac{100 \times 10^{-15} \cdot 1}{20 \cdot 10^{-6}}$


punch through
Breakdown voltage
VBS
N+
N+
VDS
PSUB
punch through