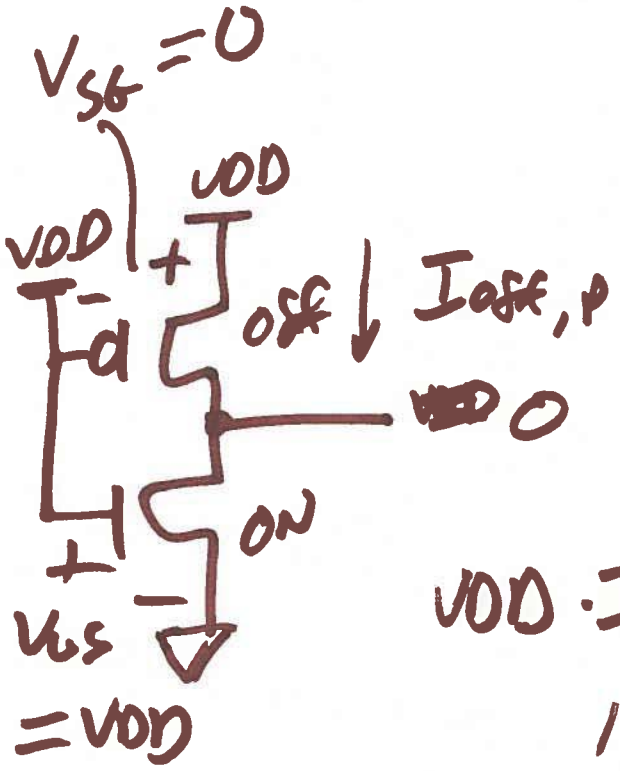
EE 421 / ECE 621
Digital IC Design
Lecture 13
OCT. 11. 2017



1 Giga transistors

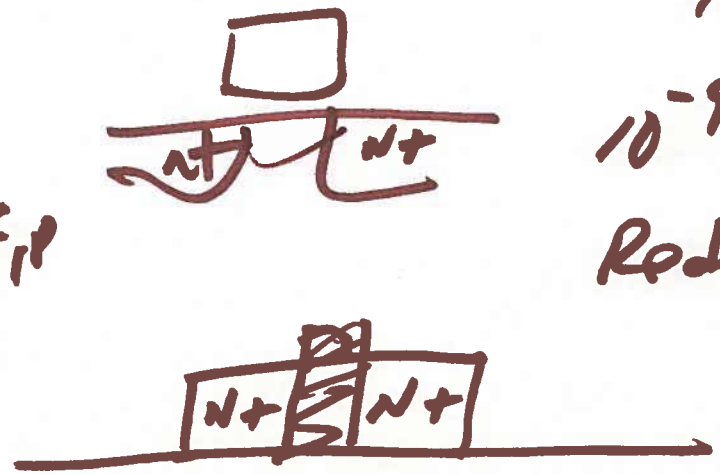
10^9 transistors

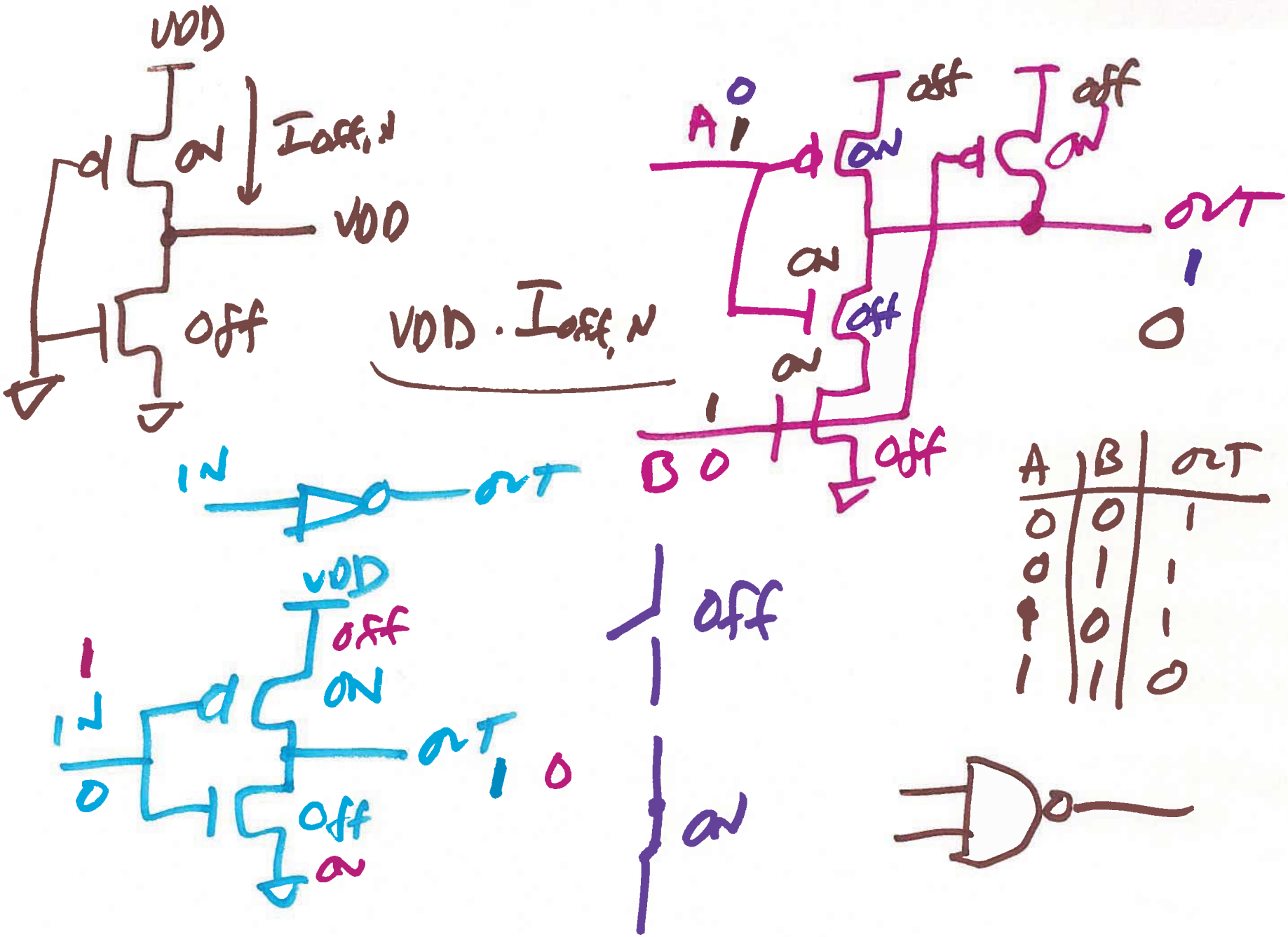
$10^{-9} \cdot 10^9 = 1A$

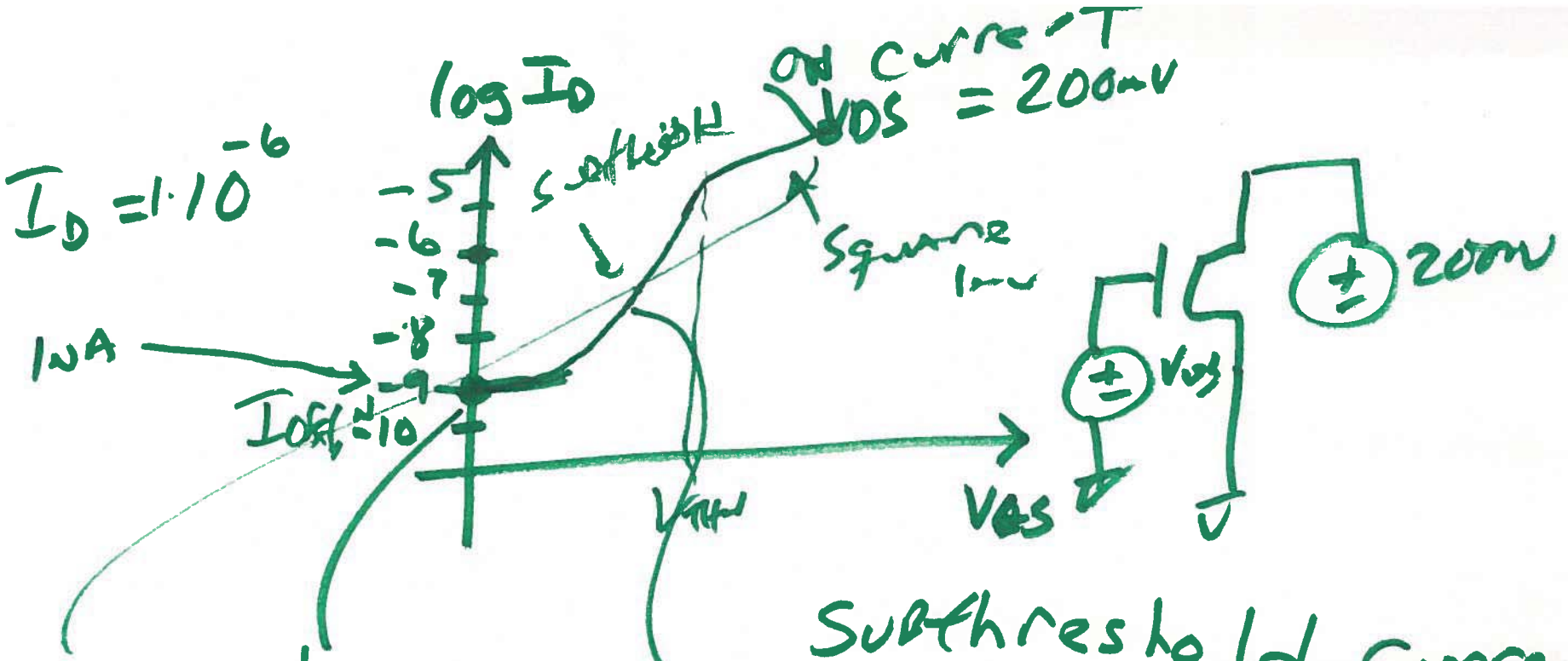
$V_{DD} \cdot I_{OFF,P}$

1 nA

Reduce




VDD
ON
$I_{off,N}$
VDD
off
$V_{DD} \cdot I_{off,N}$
A
B
off
ON
OUT
IN
VDD
off
ON
OUT
off
ON
A | B | OUT
0 | 0 | 1
0 | 1 | 1
1 | 0 | 1
1 | 1 | 0



Subthreshold current

$V_{GS} = 0$

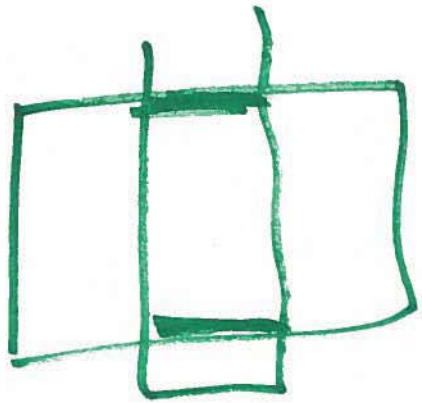
$V_{DS} = V_{DD}$

$I_{off,N}$

$I_{ON,N}$

$I_D = I_{00} e^{\frac{V_{GS}}{nV_T}}$

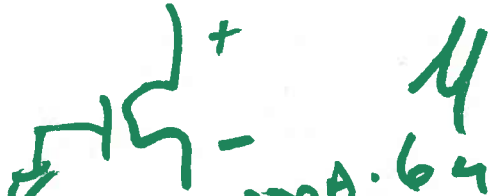
$I_C = I_S e^{\frac{V_{BE}}{nV_T}}$



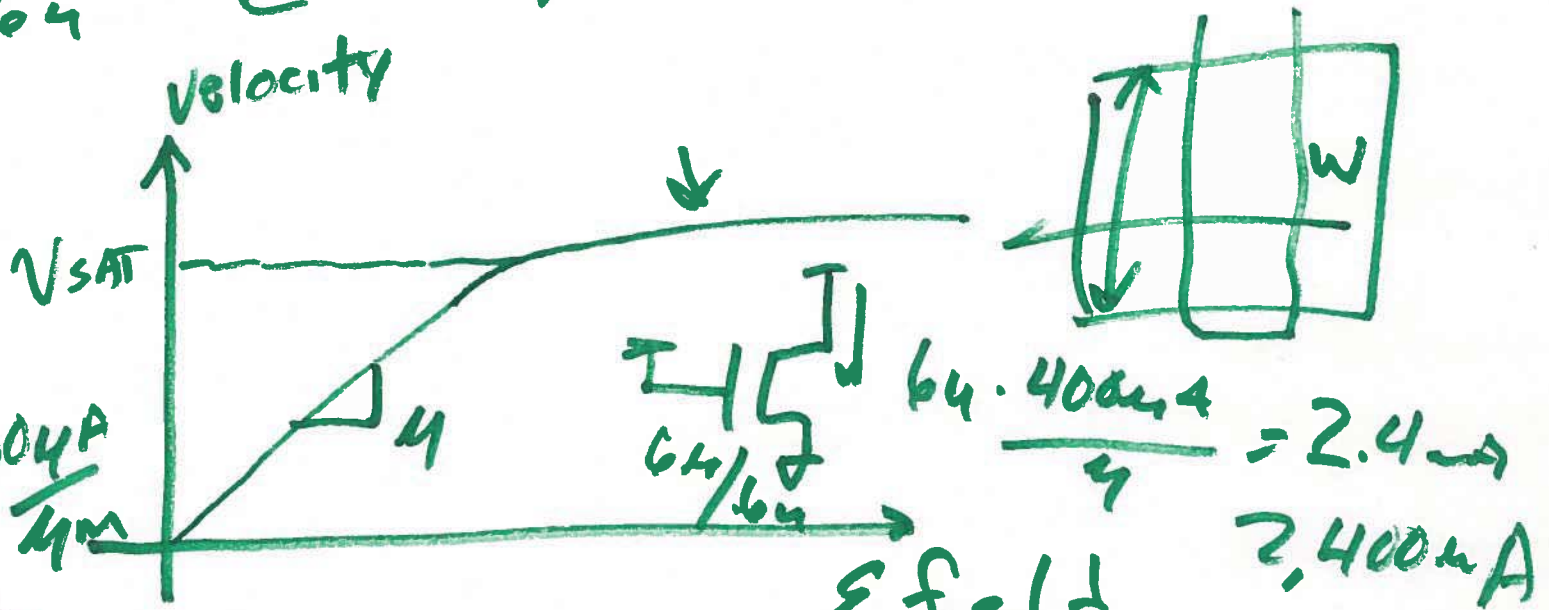
$I_D = \frac{k'}{2} \frac{W}{L} (V_{GS} - V_{THN})^2$

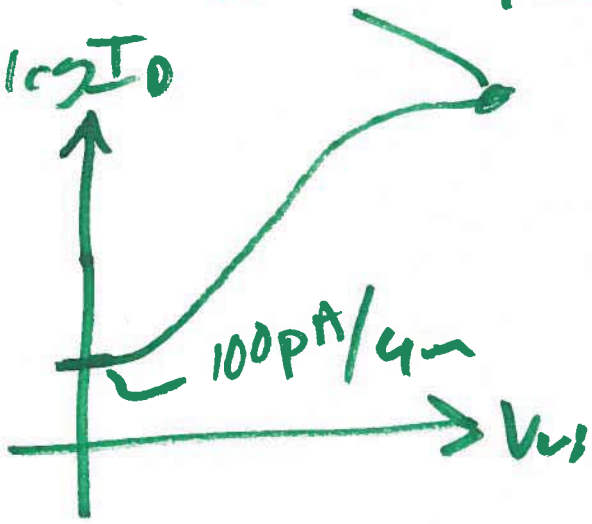
$g_m = \frac{I_D}{nV_T}$

$$\mu = \frac{\text{Velocity, cm/s}}{\text{E-field, V/cm}}, \quad \frac{cm^2}{V \cdot s}$$



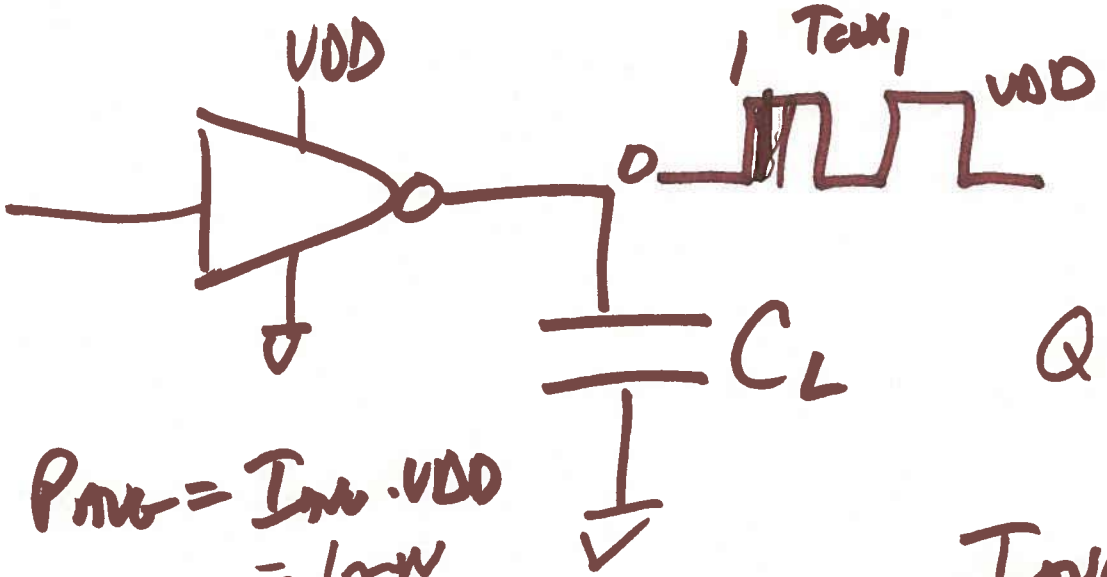
$\frac{64}{0.6\mu}$ $\frac{100pA \cdot 64}{\mu m \Omega}$





$$I_D = \frac{(\mu_n) C_{ox}'}{2} \frac{W}{L} \left(V_{GS} - V_{TH}\right)^2 \quad \text{Long channel}$$

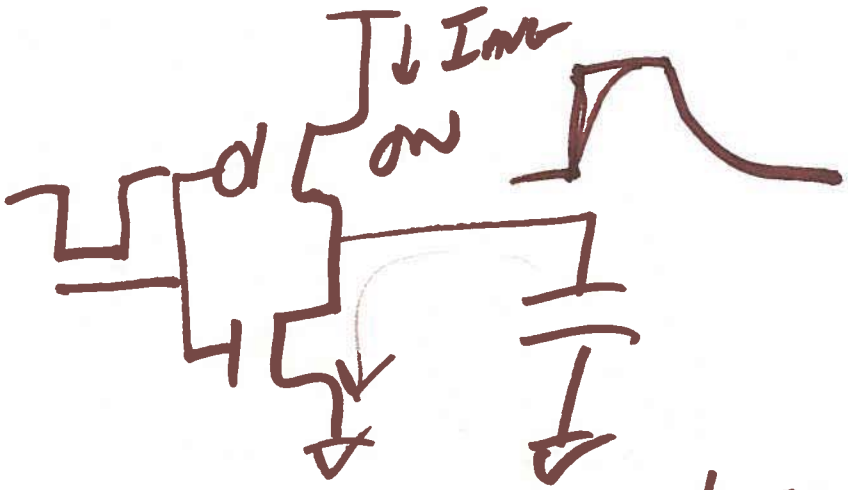
$$I_D \propto V_{GS}$$



$$P_{PMOS} = I_{PMOS} \cdot VDD = 1mW$$

$$Q = C_L \cdot VDD$$

$$I_{PMOS} = \frac{C_L \cdot VDD}{T_{CLK}}$$



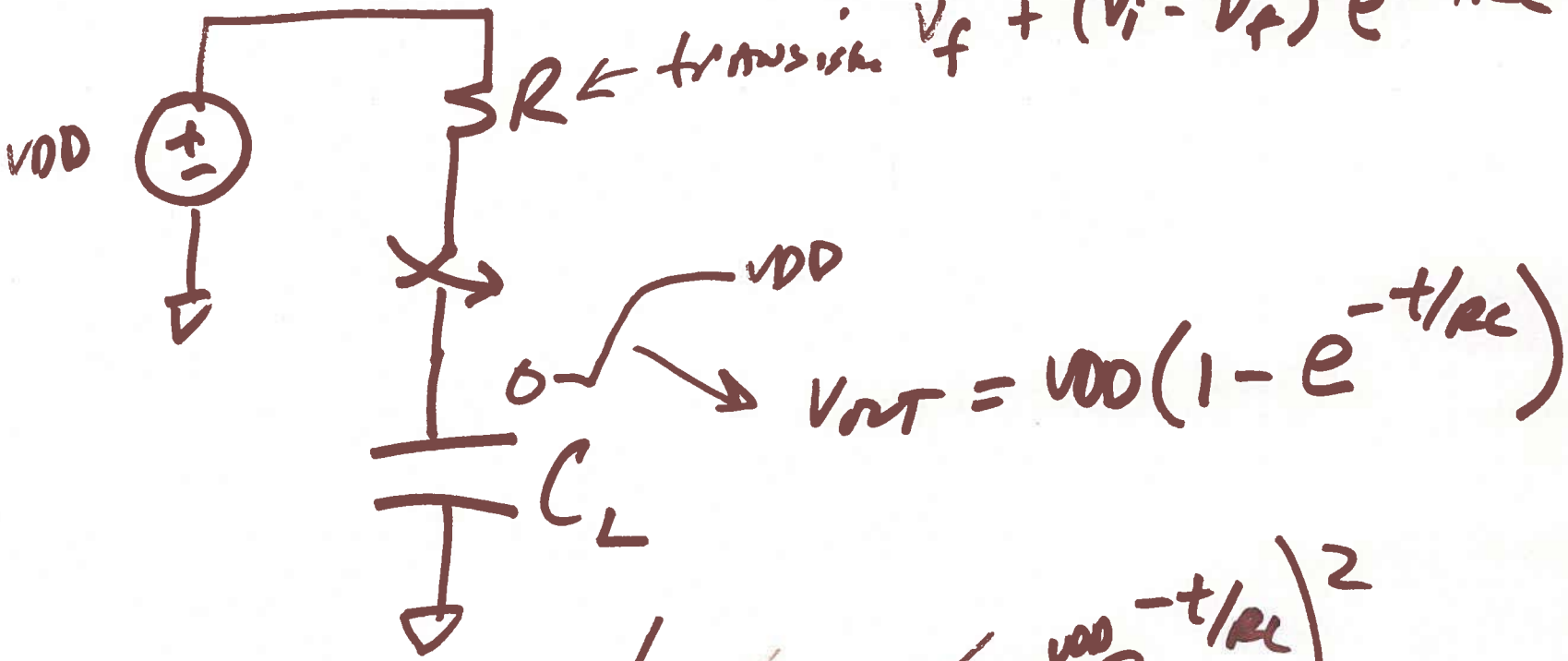
$$I_{PMOS} = C_L \cdot VDD \cdot f_{CLK}$$

$$P_{PMOS} = C_L \cdot VDD^2 \cdot f_{CLK}$$

$$P_{PMOS} = \frac{\frac{1}{2} C_L VDD^2}{T_{CLK}}$$

$$\mathcal{E} = \frac{1}{2} C_L VDD^2$$

$$= \frac{1}{2} C_L VDD^2 f_{CLK}$$



$V_f + (V_i - V_f)\, e^{-t/RC}$ ← transition

$V_{OUT} = VDD(1 - e^{-t/RC})$

$$P = \frac{v^2}{R} = \frac{\left(VDD - VDD + VDD\, e^{-t/RC}\right)^2}{R}$$

$$P_{AVG} = \int P(t) = \frac{1}{T_{CLK}} \int_0^{T_{CLK}} \frac{VDD^2}{R} e^{-2t/RC} \cdot dt$$

$$\frac{1}{T_{CLK}} \frac{VDD^2}{R} \int_0^{T_{CLK}} e^{-2t/RC} \cdot dt$$

$$P_{NMOS} = \frac{1}{T_{CLK}} \frac{V_{DD}^2}{R} \int_0^{T_{CLK}} e^{-\frac{2}{RC} \cdot t} \cdot dt$$

$$let \quad u = -\frac{2t}{RC} \qquad du = -\frac{2}{RC} dt$$

$$dt = \frac{RC}{-2} du$$

$$= \frac{1}{T_{CLK}} \frac{V_{DD}^2}{R} \frac{RC}{-2} \int_0^{-\frac{2}{RC} T_{CLK}} e^u du$$

$$= \frac{1}{T_{CLK}} \frac{V_{DD}^2 RC}{R} \frac{}{-2} \left[e^{-\frac{2}{RC} T_{CLK}} - 1 \right]$$

$$= \frac{1}{2} V_{DD}^2 C_L \cdot f_{CLK}$$

7)

Decoupling cap