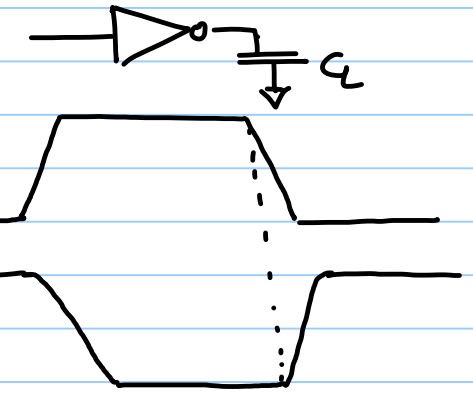
09/09/2019

EE5311

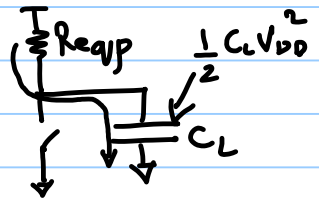
MODULE - 3 - THE INVERTER

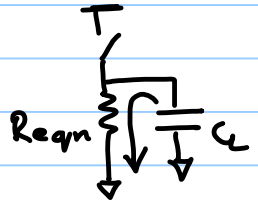
POWER:

1) Dynamic power
2) Short circuit power
3) Leakage power

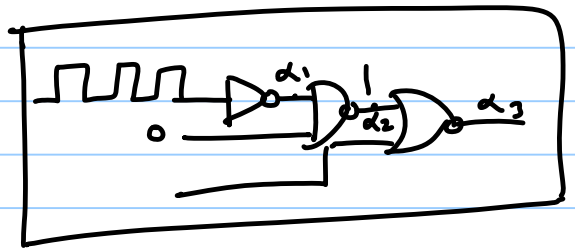


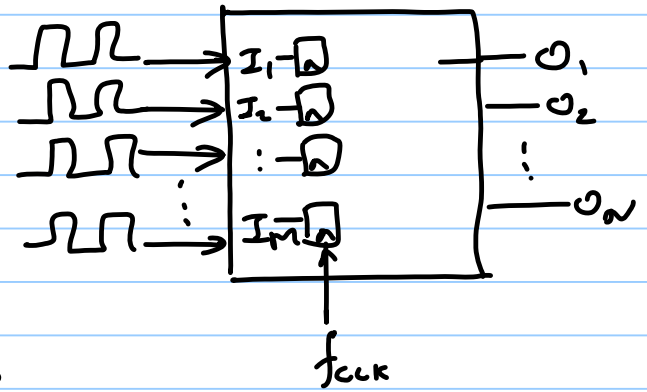
1) Dynamic Power:





FOR EVERY CHARGE/DISCHARGE CYCLE Energy $= C_L V_{DD}^2$ (J)



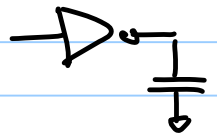


$\alpha \rightarrow$ ACTIVITY FACTOR

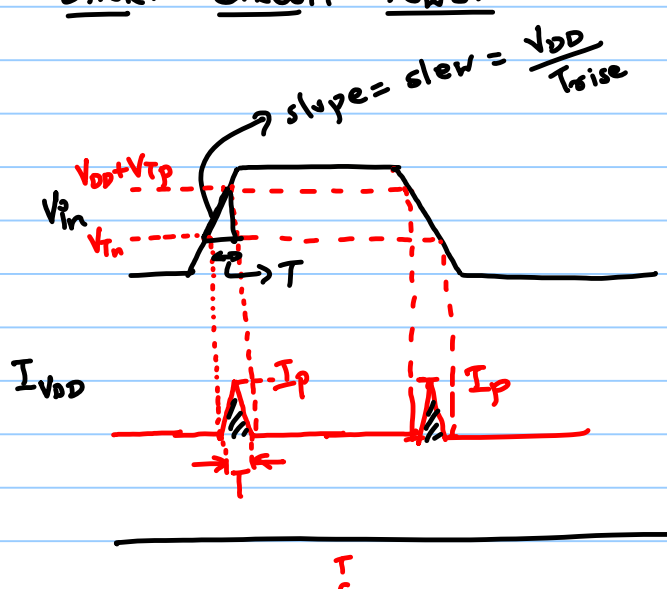
AVERAGE ENERGY PER NODE = $\alpha C_L V_{DD}^2$

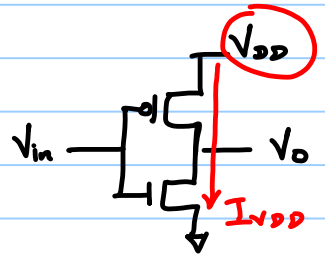
$$P_{DYN} = \alpha C_L V_{DD}^2 \cdot f_{CLK}$$

↑ STRONGEST CONTROL



SHORT CIRCUIT POWER





$$E_{SC} = \int_0^T V_{DD} \cdot I_{VDD}(t)\,dt = \frac{1}{2} V_{DD} \cdot I_p(T) \leftarrow$$

$$\frac{V_{DD}}{t_{rise}} = \frac{V_{DD}+V_{Tp}-V_{Tn}}{(T)} \Rightarrow T = \frac{(V_{DD}-2V_{Tn})}{V_{DD}} t_{rise} \quad (\text{if } V_{Tn} = -V_{Tp})$$

$$E_{SC} = V_{DD} \cdot I_p \left(\frac{(V_{DD} - 2V_{Tn})}{V_{DD}} \right) \cdot t_{rise}$$

$$= I_p \left((V_{DD} - 2V_{Tn}) \right) t_{rise}$$

$$P_{SC} = \alpha E_{SC} \cdot f_{CLK}$$

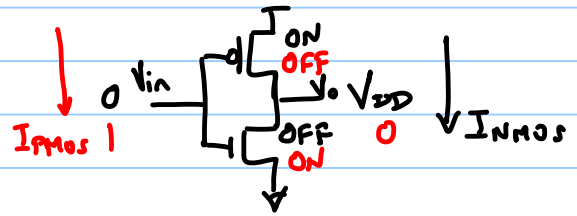
$$= \alpha \cdot I_p (V_{DD} - 2V_{Tn}) \cdot t_{rise} \cdot f_{CLK}$$

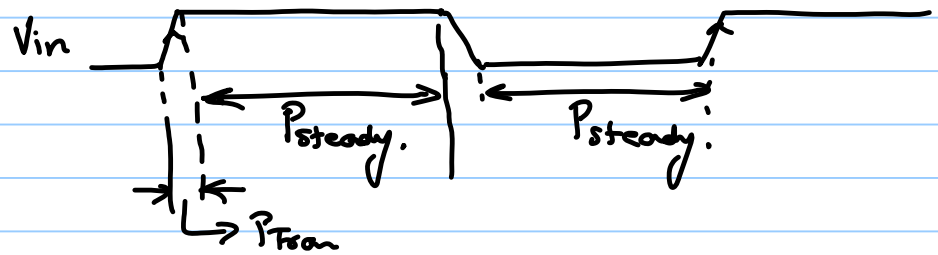
$$\text{Transient Power} = P_{DYN} + P_{SC} = \alpha f_{CLK} \cdot (C_L V_{DD}^2 + I_p (V_{DD} - 2V_{Tn}) t_{rise})$$

αf_{CLK}: Reduce f_{CLK} to reduce P_{Trans}.

$C_L V_{DD}^2$: Dominate

LEAKAGE POWER





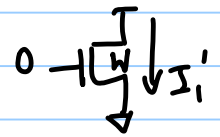
$$\text{POWER FROM } V_{DD} = V_{DD} \cdot I_{NMOS} \,/\, V_{DD} \cdot I_{PMOS}.$$

$$\text{AVG POW} = V_{DD} \left(\frac{I_{NMOS} + I_{PMOS}}{2} \right)$$

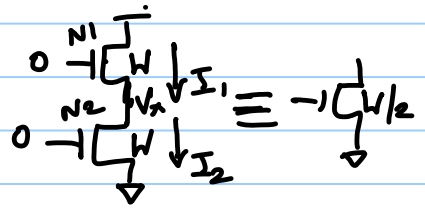
$$I_{NMOS} = \frac{W}{L} I_0 e^{\left(\frac{V_{GS} - V_{Tn}}{n \phi_t}\right)} \left(1 - e^{-V_{ds}/\phi_t}\right)$$

STACKING EFFECT

1-STACK



2-STACK.



(a) (b)

Assume: 1) No Body Effect ($\gamma = 0$)
2) No DIBL ($\eta = 0$)
3) V_{DD} is large
4) Ideality factor = $n = 1$

	V_{GS}	V_{DS}
N1	$-V_x$	$V_{DD}-V_x$
N2	0	V_x

$\boxed{I_1 = I_2}$

$$I_1 = \frac{W}{L} \cdot I_0 e^{\frac{-V_x - V_{Tn}}{\phi_t}}$$

$$I_2 = \frac{W}{L} I_0 e^{\left(\frac{-V_{Tn}}{\phi_t}\right)} \left(1 - e^{\frac{-V_x}{\phi_t}}\right)$$

N2: Large V_{GS} (0) $\Rightarrow$ V_{DS} is small

N1: small V_{GS} ($-V_x$) $\Rightarrow$ V_{DS} is large

$\Rightarrow$ V_x closer to GND

$$I_1 = I_2$$

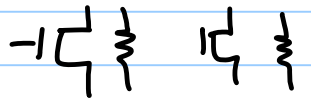
$$\Rightarrow \frac{W}{L} e^{\frac{-V_x - V_{Tn}}{\phi_t}} = \frac{W}{L} e^{\frac{-V_{Tn}}{\phi_t}} \left(1 - e^{-V_x/\phi_t}\right)$$

$$\Rightarrow V_x = \phi_t \ln(2)$$

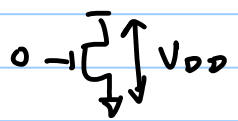
$$I_1 = \frac{W}{L} \cdot I_0 e^{\frac{(-\phi_t \ln(2) - V_{Tn})}{\phi_t}}$$

$$\therefore I_1 = \frac{1}{2}\left(\frac{W}{L}\right) \cdot I_0 e^{-\frac{V_{Tn}}{\phi_t}}$$

$$I_1' = \frac{W}{L} \cdot I_0 e^{-\frac{V_{Tn}}{\phi_t}}$$



WITH DIBL

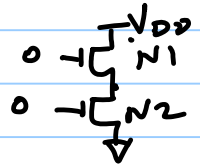


DIBL EFFECT ON

$V_{TH} = \eta V_{DD}$

$\downarrow$

V_{TH}



DIBL EFFECT ON

$N1 = \eta (V_{DD} - V_x)$