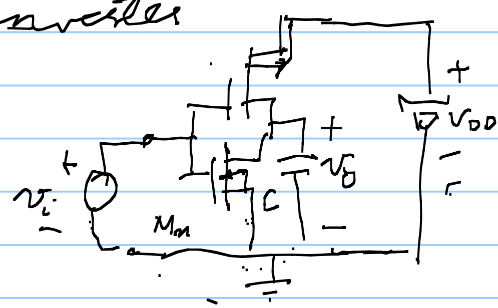
Note Title 11/5/2013

EE 303H
11/05/13

Examon Th

Power in an inverter

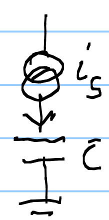


$v_o(0) = 0$ @ $t = 0_-$, $v_i = V_{DD}$

@ $t = 0_+$ let $v_i = 0$, turns on top

M_n = off

@ $t > 0$



$p(t)$ from $V_{DD} = V_{DD} \cdot i_S(t)$

$$\mathcal{E}(t) = \text{energy from } V_{DD} = \int_0^{t_s} p(t)\,dt = \int_0^{t_s} V_{DD} \cdot i_S(t)\,dt = V_{DD} \cdot \int_0^{t_s} i_S\,dt$$

$$= V_{DD} \cdot Q(t_s) = V_{DD} \cdot C\, v_c(t_s)$$

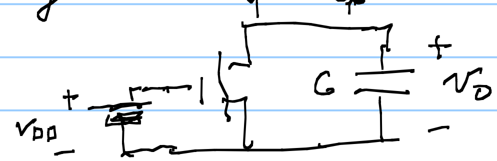
$$= V_{DD} C V_{DD} = C V_{DD}^2 = \text{energy from source}$$

Energy into C is $\int_0^t v(\tau)\, i(\tau)\, d\tau = \int_0^t v(\tau)\, C \frac{dv(\tau)}{d\tau}\, d\tau = C \int_{v(0)}^{v(t)} v(\tau)\, dv(\tau) = C \frac{1}{2} v^2(\tau) \Big|_{v(0)}^{v(t)}$

$\Rightarrow \frac{1}{2} C v^2(t_s) - \frac{1}{2} C v^2(0) = \frac{1}{2} C V_{DD}^2$

$\therefore$ energy into CMOS to charge $C = C V_{DD}^2 - \frac{1}{2} C V_{DD}^2 = \frac{1}{2} C V_{DD}^2$ into heat

to discharge C $\quad v_O = i_{S}$

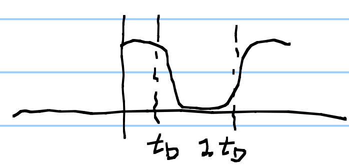


$\Rightarrow$ into heat $\frac{1}{2} C V_{DD}^2$ = energy from C into M_n

for one cycle we dissipate $C V_{DD}^2$ of energy
power on the average is $f C V_{DD}^2 = \frac{1}{T} C V_{DD}^2 =$
T = period

for f_{max}, T is minimum;

PDP = power delay product
$= f C V_{DD} \cdot t_D$, t_D = time delay through the inverter



$T_{min} = 2 t_D$

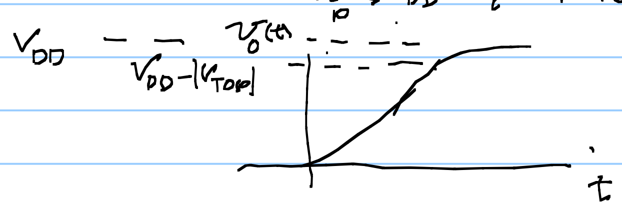
$\Rightarrow$ best $PDP = \frac{1}{2 t_{D_{min}}} \cdot C V_{DD}^2 \cdot t_{D_{min}} = \frac{1}{2} C V_{DD}^2$ (fixed & a measure of the C loaded inverter) to look at i_S in this circuit: to determine the state of M_p

@ $t=0$ apply $v_i = 0$ then with $v_O(0) = 0$

M_p has $v_{SG} = V_{DD} - v_i = V_{DD}$, $v_{SG} - |V_{TOp}|$ compare with $v_{SD} = V_{DD} - v_O = V_{DD}$

$\therefore$ M_p is in saturation if $V_{TOp} < 0$ as $v_{SG} - |V_{TOp}| < v_{SD}$

$$k_p (V_{DD} - v_i - |V_{TOp}|)^2 = C \frac{d v_O}{dt} \Rightarrow v_O(t) = \frac{k_p}{C}(V_{DD} - |V_{TOp}|)^2 t$$



when $v_{SG} - |V_{TOp}|$ becomes $\leq v_{SD}$ switches to ohmic

switches to ohmic at $v_O = V_{DD} - |V_{TOp}|$

Then $i_S = k_p\left(2(V_{DD} - |V_{TOp}|)(V_{DD} - v_O) - (V_{DD} - v_O)^2\right) = C \frac{d v_O}{dt} \Rightarrow$ a Riccati eq.

$$\int_0^t d\tau = \frac{C}{k_p} \int_{v_O(0)}^{v_O(t)} \frac{d v_O}{(V_{DD} - v_O)\left[2(V_{DD} - |V_{TOp}|) - (V_{DD} - v_O)\right]}$$ use partial fraction gives ln terms

allows analytic solution which is approximate