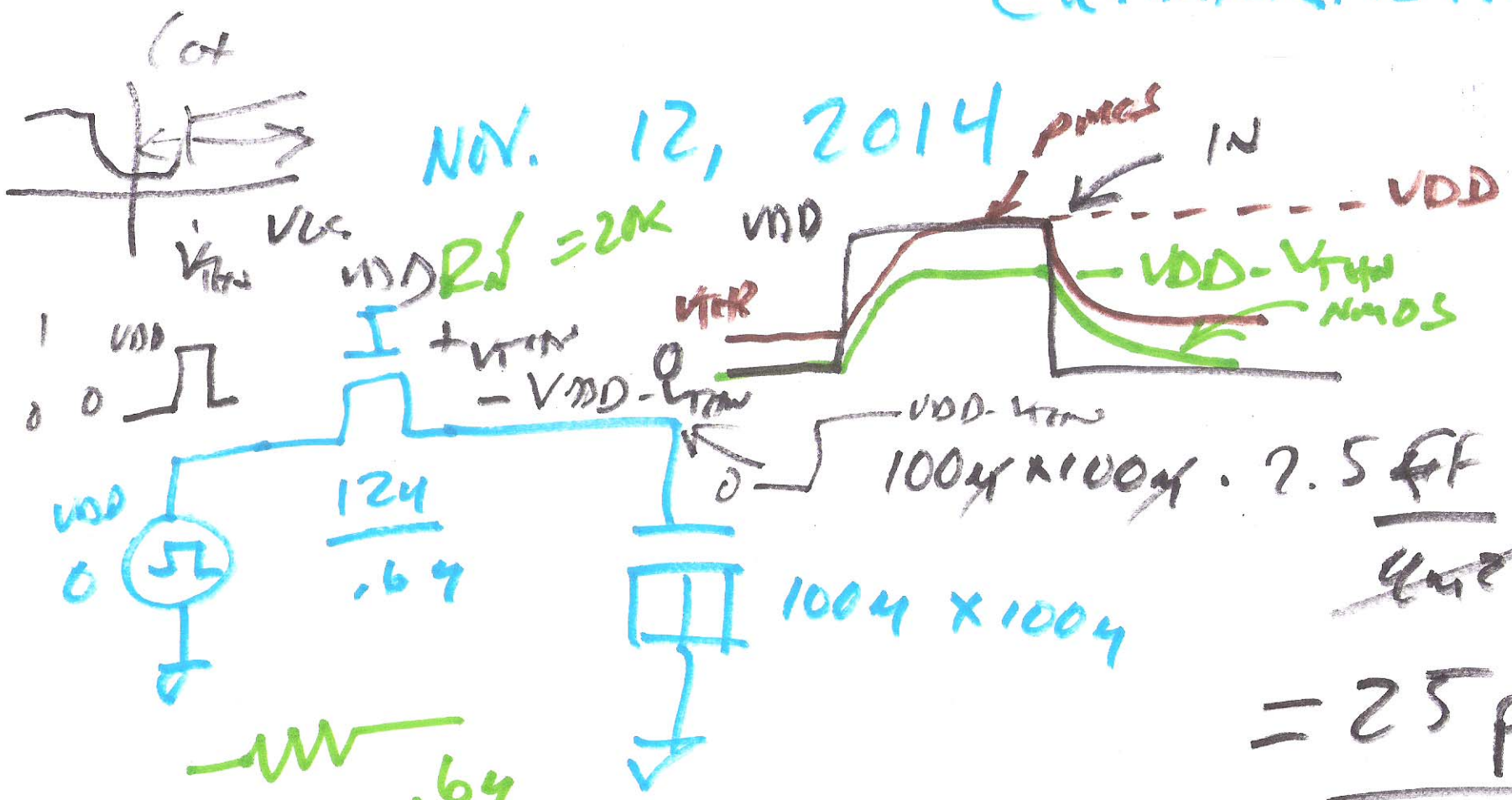
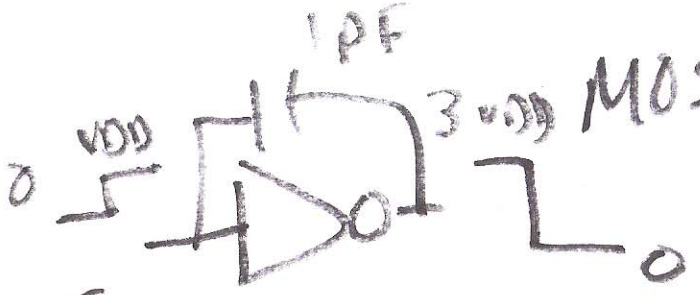
# Inverter Switching Characteristics

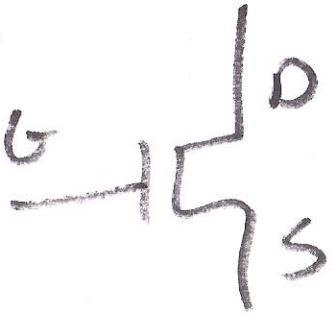
NOV. 12, 2014



# MOSFET Models




Q estimate

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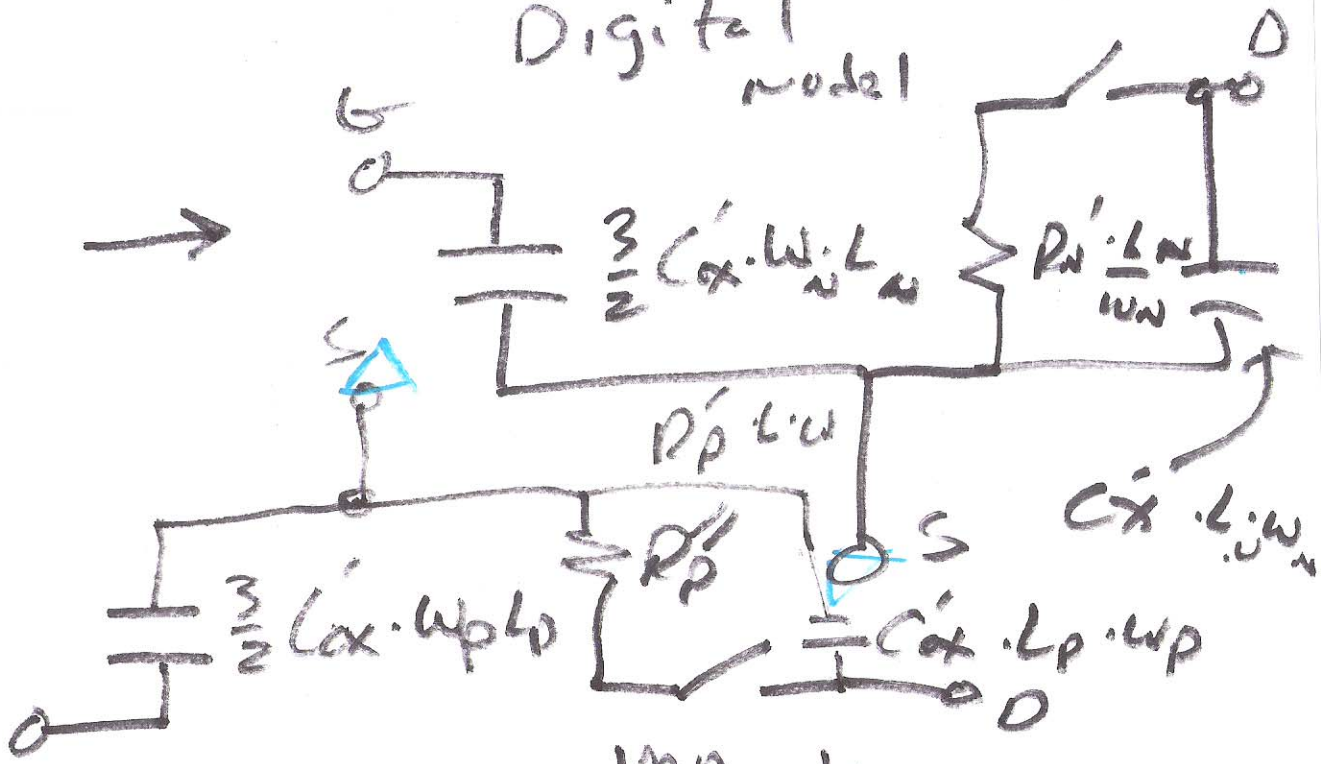
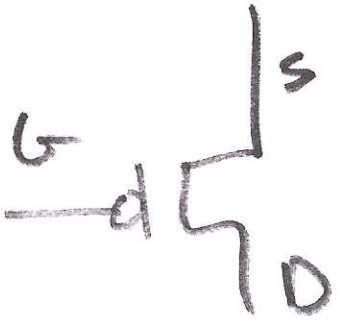
Digital model

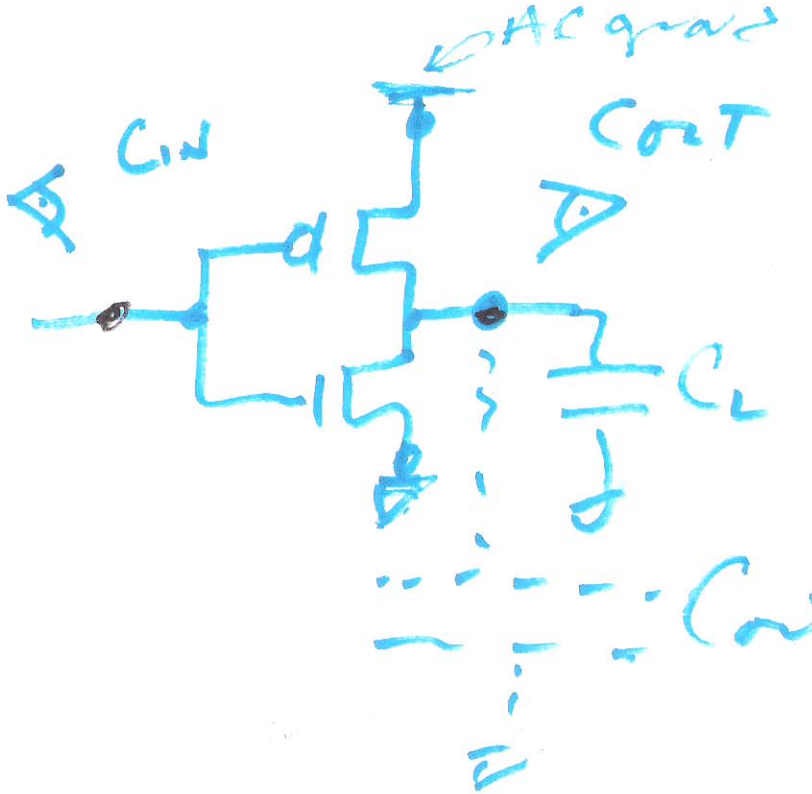
open $V_{GS} < \frac{V_{DD}}{2}$

closed $V_{GS} > \frac{V_{DD}}{2}$




$\frac{V_{DD}}{2} > V_{SG}$ closed






$$t_{pHL} = 0.7 R_N (C_L + C_{OUT})$$

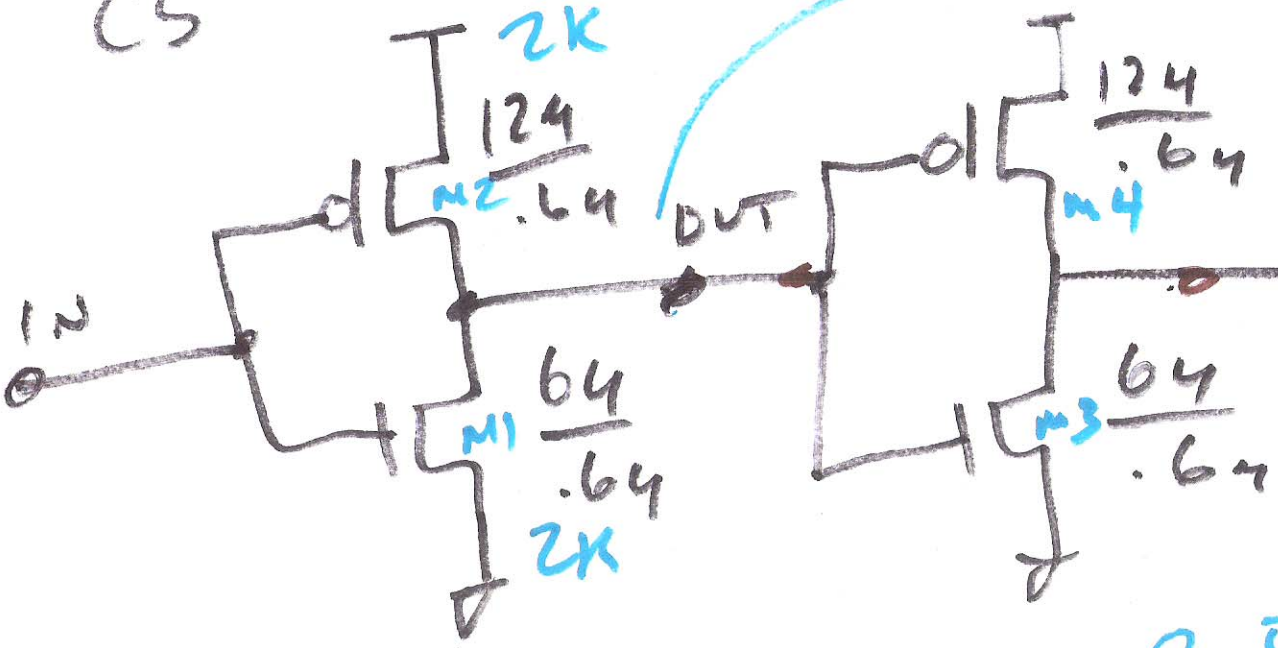
$$t_{pLH} = 0.7 R_P (C_L + C_{OUT})$$

$$C_{OUT} = C_{ox}' \cdot W_N L_N + C_{ox}' \cdot W_P L_P$$

$$= C_{ox}' (W_N L_N + W_P L_P)$$

$$C_{IN} = \frac{3}{2} C_{OUT} = \frac{3}{2} C_{ox}' \cdot W_N L_N + \frac{3}{2} C_{ox}' \cdot L_P W_P$$

C5




TOTAL C on this NODE

$= 9 + 13.5 + 18 + 27$

$= \underline{67.5ff}$

$R_N' = 20K$

$R_P' = 40K$

$C_{ox}' = 2.5 \frac{ff}{\mu m^2}$

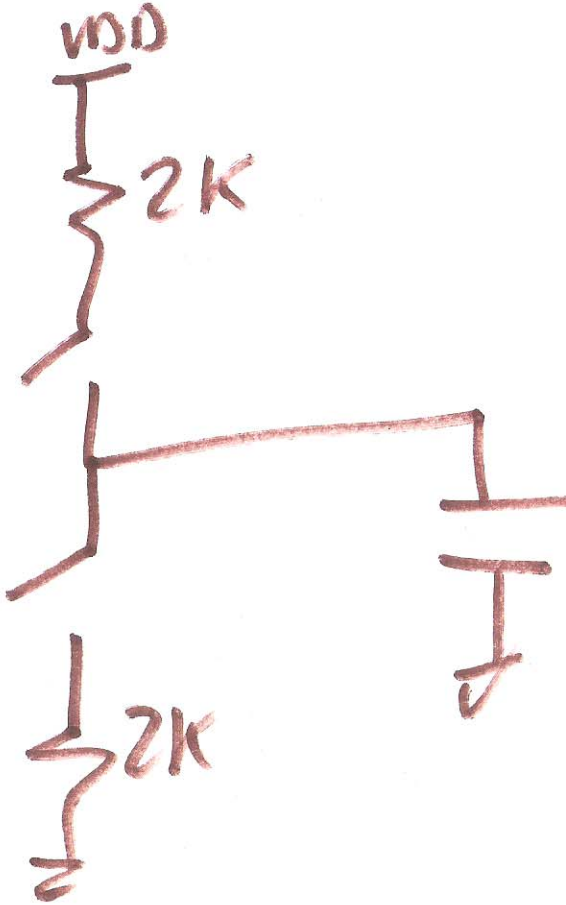
$C_{OT1} = 2.\frac{5ff}{\mu m^2} \cdot \underset{W_N}{.64} \cdot \underset{L_N}{.64} = 9ff$

$C_{IN3} = \frac{3}{2} \cdot \frac{2.5ff}{\mu m^2} \cdot .64 \cdot .64$

$= 13.5ff$

$C_{OT2} = 18ff$

$C_{IN4} = 27ff$




$t_{pLH} = 0.7 \cdot 2K \cdot 67.5fF$

$t_{pHL} = 0.7 \cdot 2K \cdot 67.5fF$

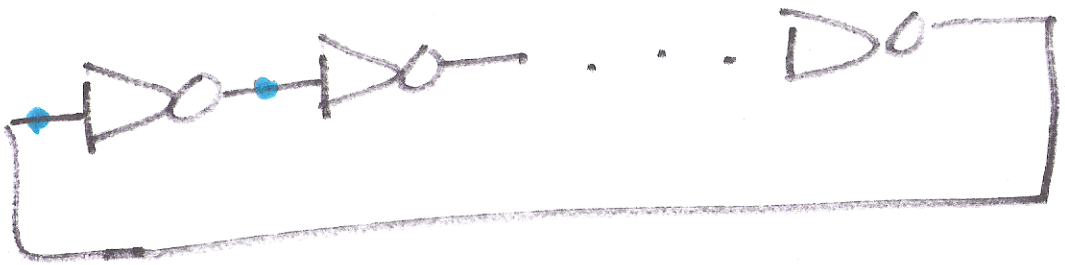
$\simeq$ 100 ps

OTPUT $= t_{pHL} = t_{pLH} = 0.7 \cdot 2K \cdot (9 +$ 15 ~~13.5f~~)

$\simeq$ 40 ps

5)

Odd number, N



Estimate oscillation frequency of ring oscillator

$$t_{PHL} + t_{PLH} = 0.7(R_N + R_P)\cdot(C_{out} + C_{in})$$

$$= 0.7(R_N + R_P)\cdot\left(\frac{3}{2}C'_{ox}\cdot W_N L_N + \frac{3}{2}C'_{ox}\cdot W_P L_P + C'_{ox}\cdot W_N L_N + C'_{ox}\cdot W_P L_P\right)$$

$$= 0.7(R_N + R_P)C'_{ox}\cdot\left(\frac{5}{2}W_N L_N + \frac{5}{2}W_P L_P\right)$$

$$t_{pHL} + t_{pLH} =$$

$$0.7(R_N + R_P)C_{ox}' \cdot \frac{S}{2}(W_N L_N + W_P L_P)$$

$$f_{osc} = \frac{1}{N \cdot 0.7(R_N + R_P)C_{ox}' \cdot \frac{S}{2}(W_N L_N + W_P L_P)}$$

delay of one inverter

31-stage ring osc

100ps

$$f_{osc} = \frac{1}{31 \cdot 100ps}$$

$$= 333\ MHz$$