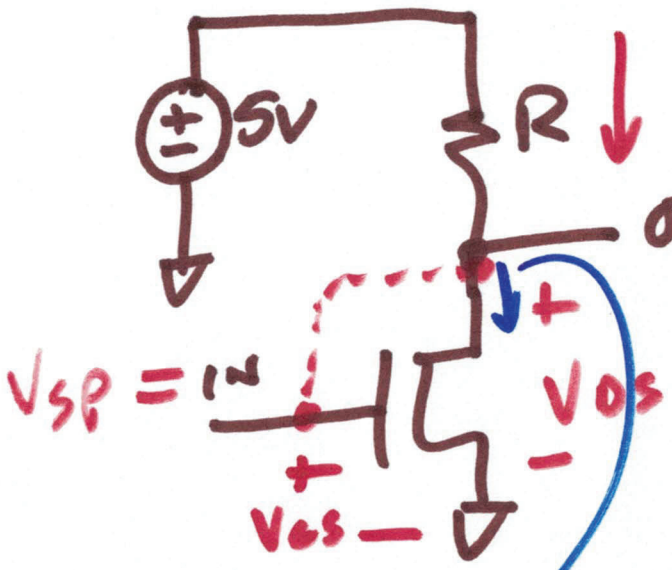
EE 421 / ELG 621
Digital IC Design
Lecture 17
OCT. 25, 2021



$$\frac{5 - V_{SP}}{R} = \frac{K_{PN}}{2}\frac{W_N}{L_N}(V_{SP} - V_{THN})^2$$

$$V_{DS} \geq V_{GS} - V_{THN} \quad (\text{for saturation})$$

$$0 \geq -V_{THN}$$

$\frac{K_{PN}}{2}\cdot\frac{W_N}{L_N}\cdot(V_{SP}-V_{THN})^2$ — Always in saturation

$I_D \neq 0, V_{DS} > V_{THN}$

$$\frac{V_{DD} - V_{SP}}{R} = \frac{K_{PN}}{2}\frac{W_N}{L_N}(V_{SP} - V_{THN})^2$$

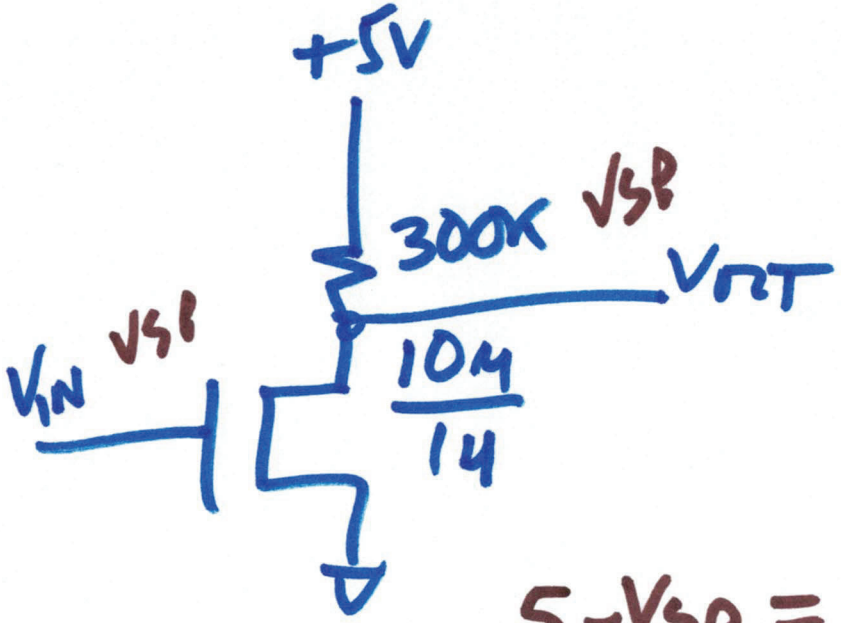
$$(V_{SP} - V_{THN})^2 = \frac{(V_{DD} - V_{SP}) \cdot 2L_N}{R K_{PN} W_N}$$

$$V_{SP}^2 - 2V_{SP}V_{THN} + V_{THN}^2 = X(V_{DD} - V_{SP})$$

$$X = \frac{2L_N}{R K_{PN} W_N}$$

$$V_{SP}^2 - V_{SP}(2V_{THN} + X) + V_{THN}^2 - XV_{DD} = 0$$

$KP_N = 120\mu \frac{A}{V^2}$ $\quad V_{TN} = 0.8$



$$\frac{5-V_{SP}}{300K} = \frac{120\mu}{2}\cdot\frac{10}{1}\cdot(V_{SP}-.8)^2$$

$$5-V_{SP} = 300K\cdot 600\mu\,(V_{SP}^2 - 1.6V_{SP} + .64)$$

$$5-V_{SP} = 180\cdot V_{SP}^2 - 288V_{SP} + 115.2$$

$$0 = 180\cdot V_{SP}^2 - 287V_{SP} + 110.2$$

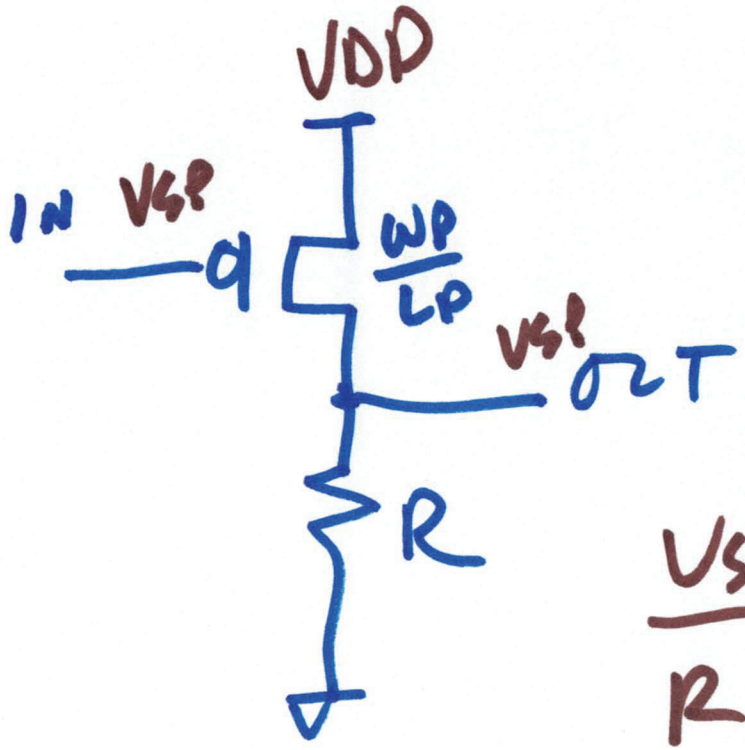
$$V_{SP}^2 - 1.594 + .612 = 0$$

$$V_{SP} = \frac{1.594 \pm \sqrt{(1.594)^2 - 4(.612)}}{2}$$

$$= \frac{1.594 \pm \sqrt{.304^2}}{2}$$

$$V_{SP} = \frac{1.594 \pm .304}{2} =$$

$$\boxed{V_{SP} = .949} \text{ or } .645$$

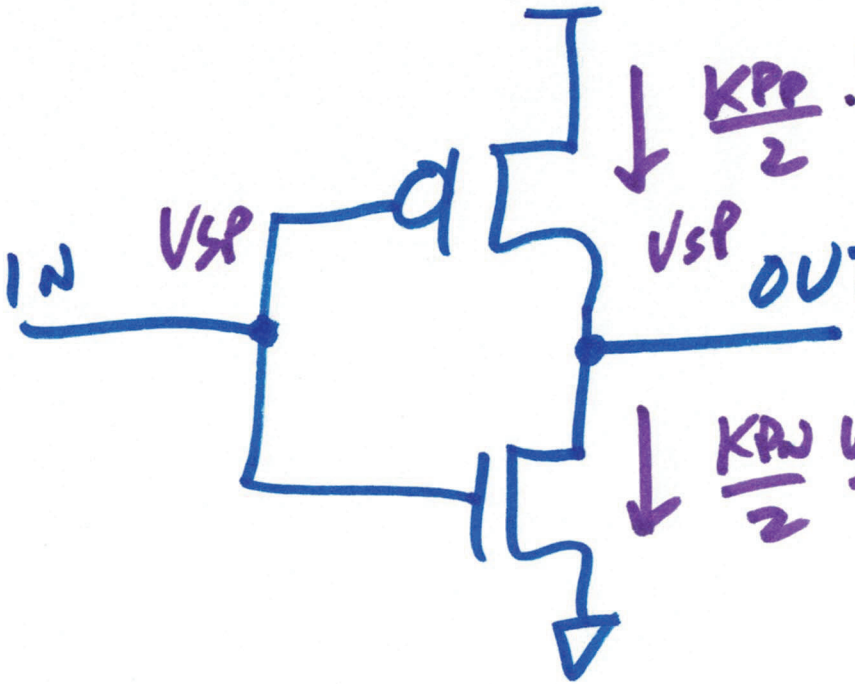


$$\frac{V_{SP}}{R} = \frac{KP_P}{2}\frac{W_P}{L_P}\left(V_{SG}-V_{THP}\right)^2$$

$$\frac{V_{SP}}{R} = \frac{KP_P}{2}\frac{W_P}{L_P}\left(V_{DD}-V_{SP}-V_{THP}\right)^2$$

CMOS Inverter

switching point



$$\frac{KP_p}{2}\cdot\frac{W_p}{L_p}\cdot(V_{DD}-V_{sp}-V_{THp})^2$$

$$\frac{KP_n}{2}\frac{W_n}{L_n}(V_{sp}-V_{THn})^2$$

$$\sqrt{\frac{KP_p}{2}\cdot\frac{W_p}{L_p}\cdot(V_{DD}-V_{sp}-V_{THp})^2}=\sqrt{\frac{KP_n}{2}\cdot\frac{W_n}{L_n}(V_{sp}-V_{Tn})^2}$$

$$X = \sqrt{\frac{\frac{K_P}{2}\frac{W_P}{L_P}}{\frac{K_N}{2}\frac{W_N}{L_N}}} = \sqrt{\frac{\beta_P}{\beta_N}}, \quad \beta_N = K_{PN}\cdot\frac{W_N}{L_N}$$

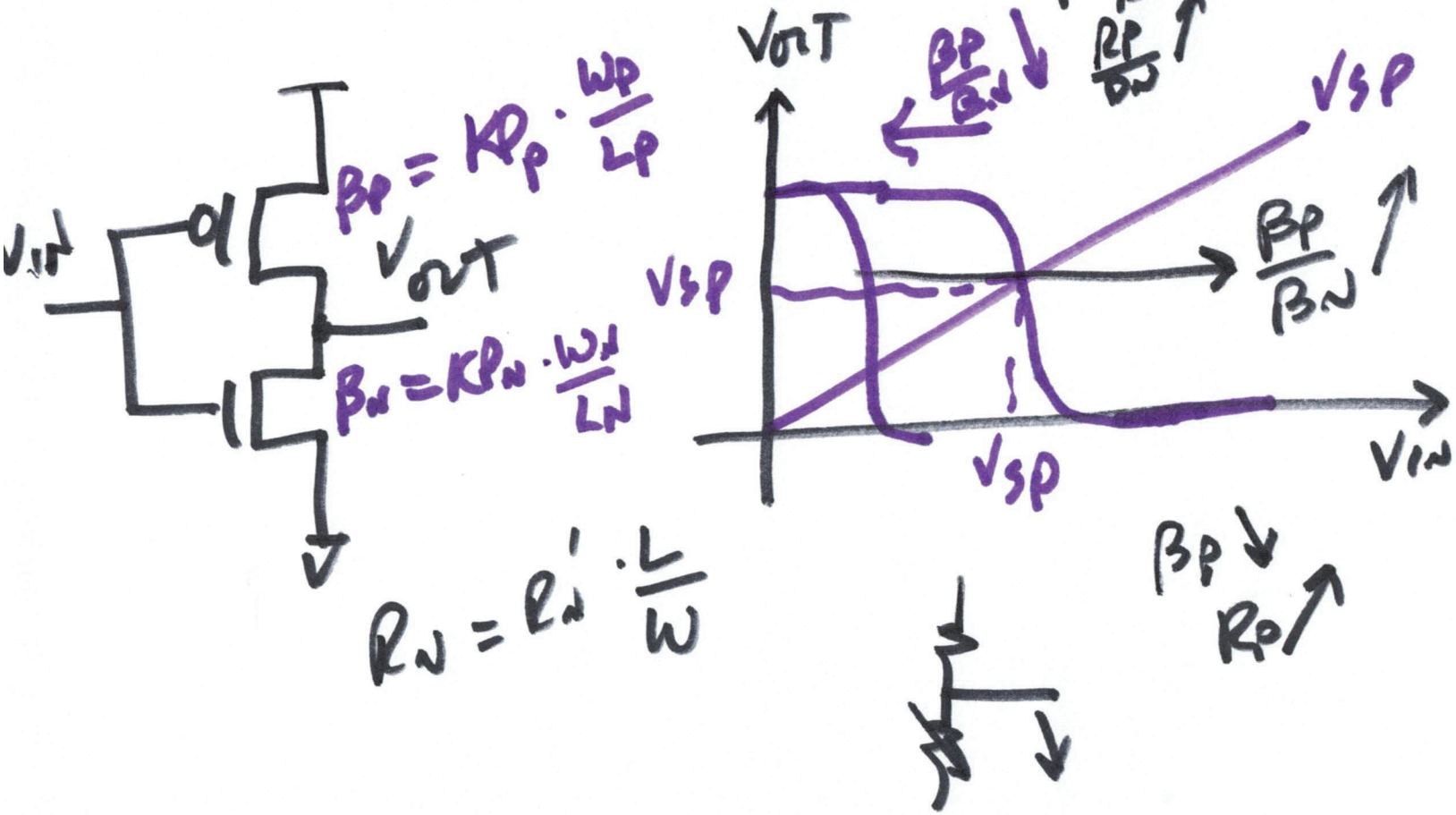
$$X(V_{DD} - V_{SP} - V_{THP}) = V_{SP} - V_{THN}$$

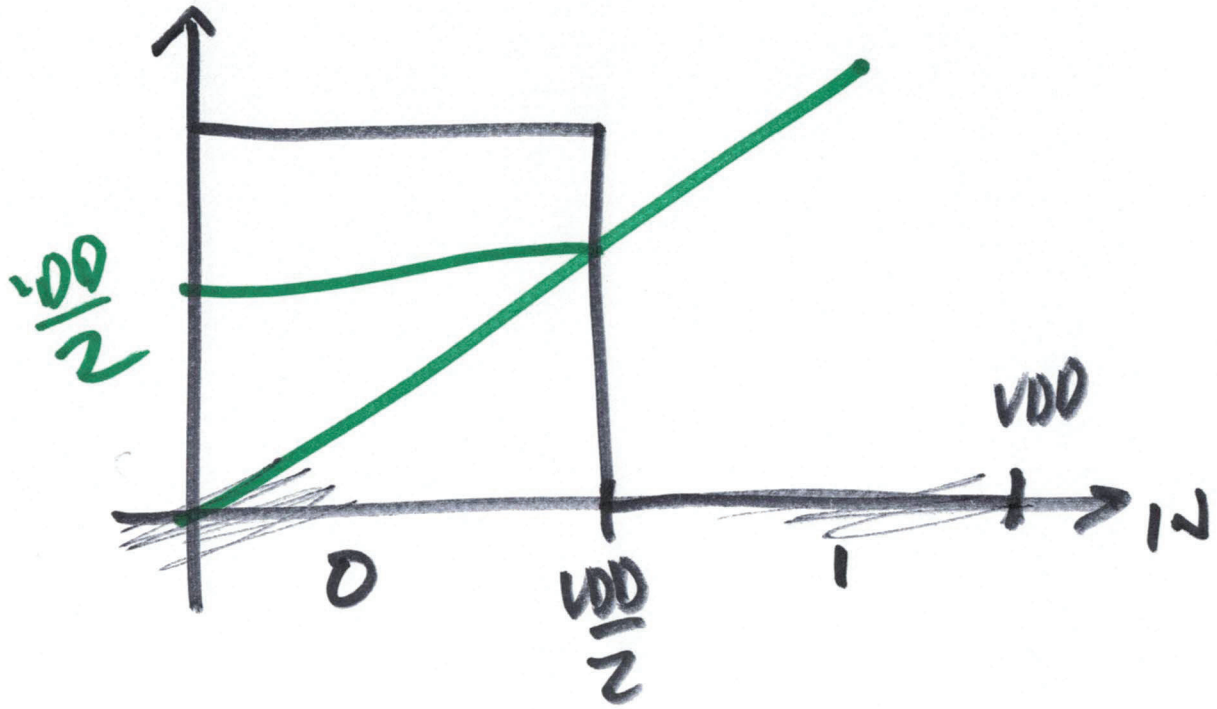
$$V_{THN} + X(V_{DD} - V_{THP}) = V_{SP}(1 + X)$$

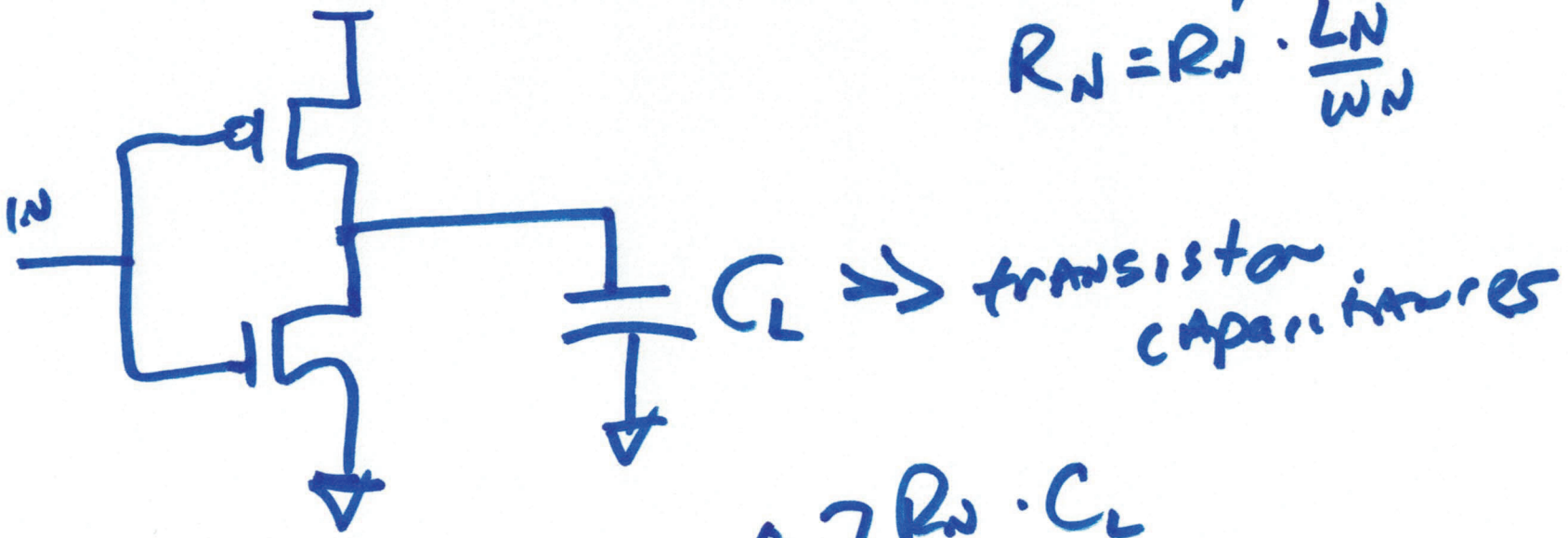
$$V_{SP} = \frac{V_{THN} + \sqrt{\frac{\beta_P}{\beta_N}}\,(V_{DD} - V_{THP})}{1 + X}$$

$$V_{SP} = \frac{V_{THN} + \sqrt{\frac{\beta_P}{\beta_N}}\,(V_{DD} - V_{THP})}{1 + \sqrt{\frac{\beta_P}{\beta_N}}}$$

$$V_{SP} = \frac{V_{THN} + \sqrt{\frac{\beta_P}{\beta_N}}\,(V_{DD} - V_{THP})}{1 + \sqrt{\frac{\beta_P}{\beta_N}}}$$

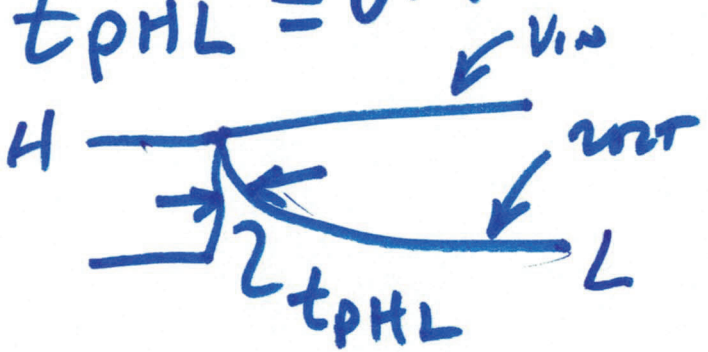



VDD/2
VDD
IN
0
VDD/2
1

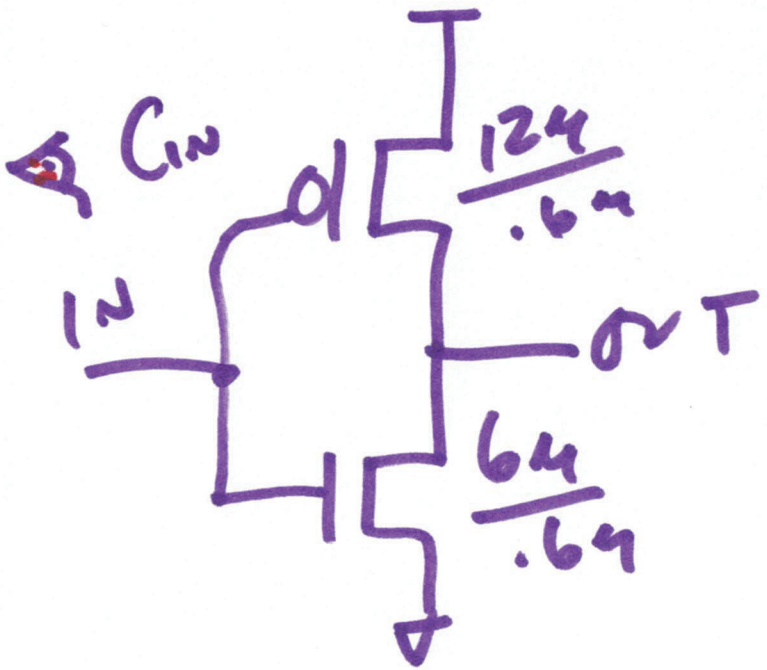


$$R_N = R_N' \cdot \frac{L_N}{W_N}$$

$$t_{pHL} = 0.7 R_N \cdot C_L$$



$$t_{pLH} = 0.7 R_P \cdot C_L$$



$$C_{IN} = C_{INN} + C_{INP}$$

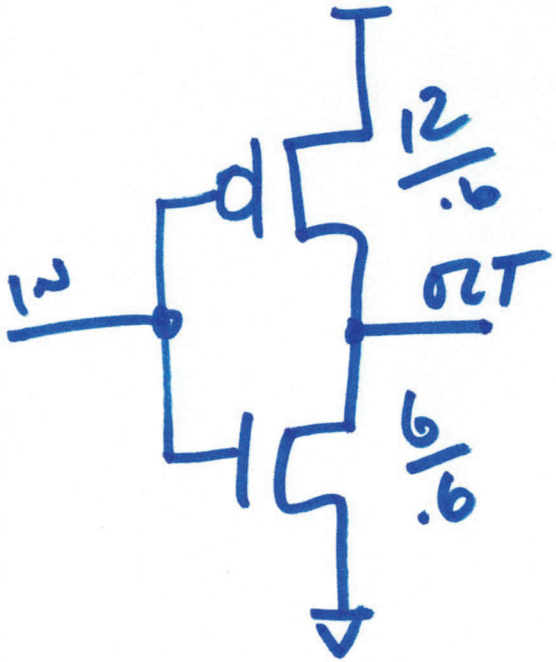
$$\frac{3}{2}C_{OXN} + \frac{3}{2}C_{OXP}$$

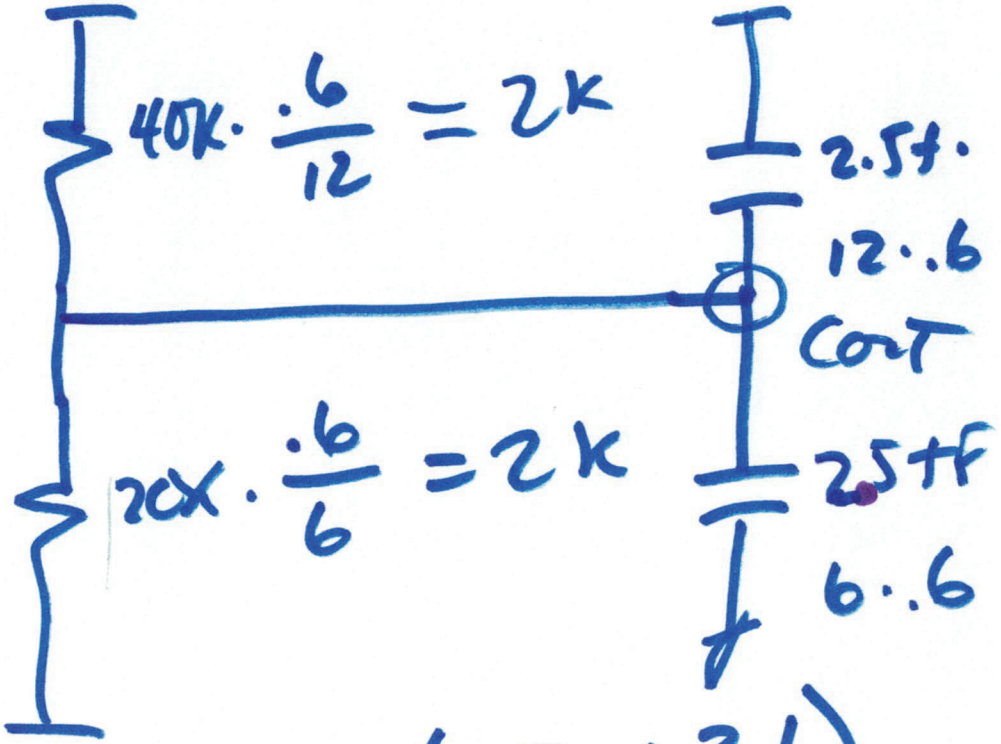
$$= \frac{3}{2} \cdot 2.5\frac{fF}{\mu m^2} \cdot .6\mu \cdot .6\mu +$$

$$\frac{3}{2} \cdot 2.5\frac{fF}{\mu m^2} \cdot 12\mu \cdot .6\mu$$

$$= \frac{3}{2} \cdot 2.5 fF (3.6 + 7.2)$$

$$\boxed{C_{IN} = 40.5\,fF}$$



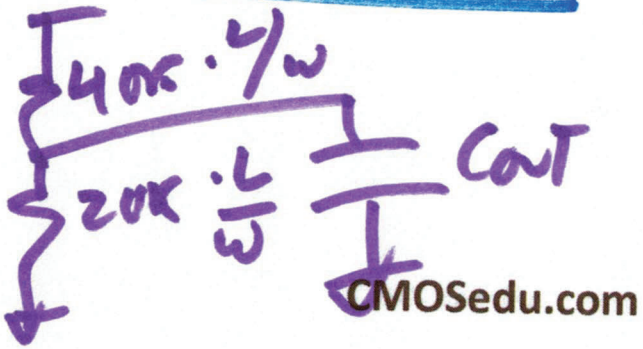


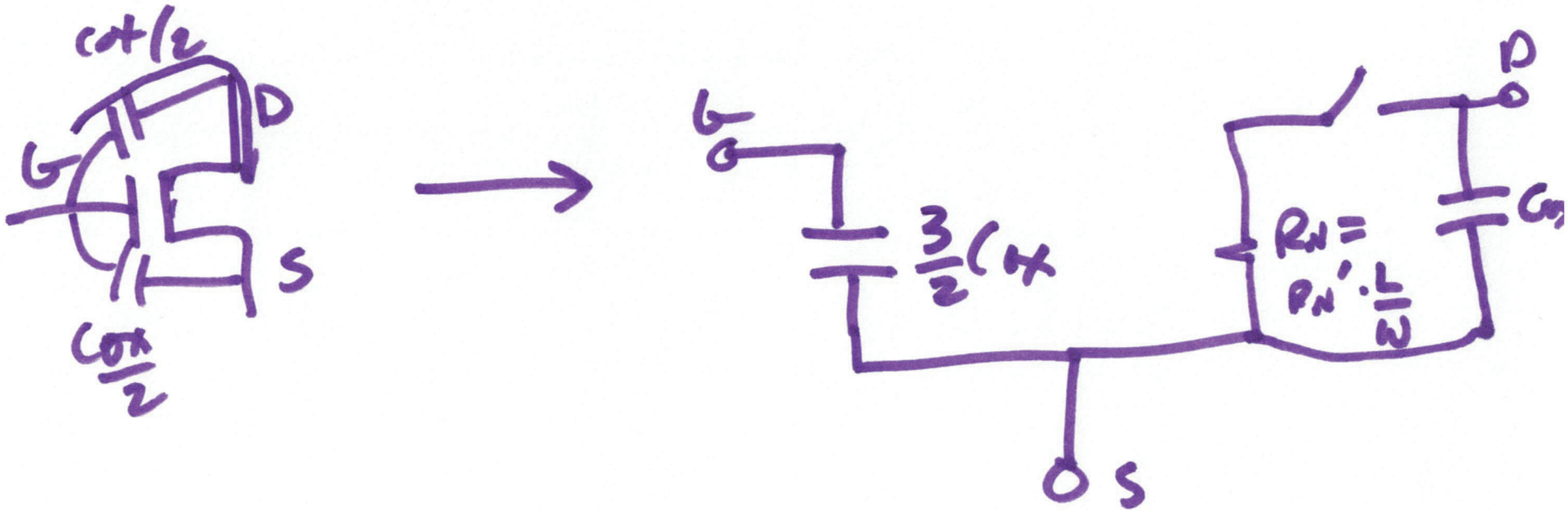
$$C_{oxT} = 2.5ff(7.2 + 3.6)$$

$$= 27ff$$

$$t_{PLH} = 0.7 R_p \cdot C_{oxT}$$

$$t_{pHL} = 0.7 R_N C_{oxT}$$




Cox/2
D
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