# Introduction to VLSI Design
## Lecture 16 - 13/09/22

$$t_p = t_{p0}\left(1 + \frac{gf}{\gamma}\right) \qquad t_p = t_{p0}\left(1 + \frac{f}{\gamma}\right)$$

$$f = \frac{C_{g,j+1}}{C_{g,j}}$$

$$t_p = 0.69\, R_{eq}\left(C_{int} + C_L\right)$$

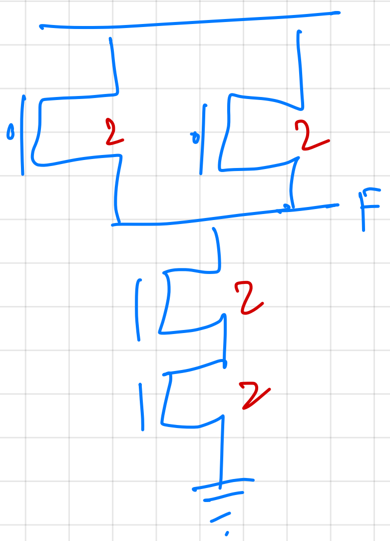
$C_{int}$ ↳ drain cap

$$C_{d,H} = \gamma C_g$$

$$= 0.69\, R_{eq} C_{int}\left(1 + \frac{C_L}{\gamma C_g}\right)$$

$$t_p = t_{p0}\left(\gamma + f\right)$$

Alternative $t_{p0} = 0.69\, R_{eq} C_g$



| | NMOS | PMOS | |
|---|---|---|---|
| $C_{dnand} =$ | $2C_d$ | $+ 4C_d$ | $= 6C_d$ |
| $C_{dinv} =$ | $C_d$ | $+ 2C_d$ | $= 3C_d$ |

$$C_{gnand} = 4C_g \qquad \gamma = \frac{C_d}{C_g}$$

$$C_{ginv} = 3C_g$$

$$t_p = 0.69\, R_{eq}\left(C_{int} + C_L\right)$$

$$= 0.69\, R_{eq} C_{gnand}\left(\frac{C_{dnand}}{C_{gnand}} + \frac{C_L}{C_{gnand}}\right)$$

$$t_p = 0.69\, R_{eq} \left( C_{int} + C_L \right) \qquad t_p = t_{p0}(\gamma + f)$$

$$= 0.69\, R_{eq}\, C_{gnand} \left( \frac{C_{dnand}}{C_{gnand}} + \frac{C_L}{C_{gnand}} \right)$$

$C_{gnand} = 4C_g$

$C_{ginv} = 3C_g$

$$0.69\, R_{eq} \left( \frac{4}{3} C_{ginv} \right) \left( \frac{6C_d}{4C_g} + f \right)$$

$g$

$$\underbrace{0.69\, R_{eq}\, C_{ginv}}_{t_{p0}} \left( \cancel{\frac{4}{3}} \times \frac{\overset{2}{\cancel{6}}}{\cancel{4}} \gamma + \frac{4f}{3} \right)$$

$$t_p = t_{p0} \left( 2\gamma + gf \right)$$

$$= t_{p0} \left( 2 + \frac{gf}{\gamma} \right)$$

$t_{p0} = 0.69\, R_{eq}\, C_{ginv}$

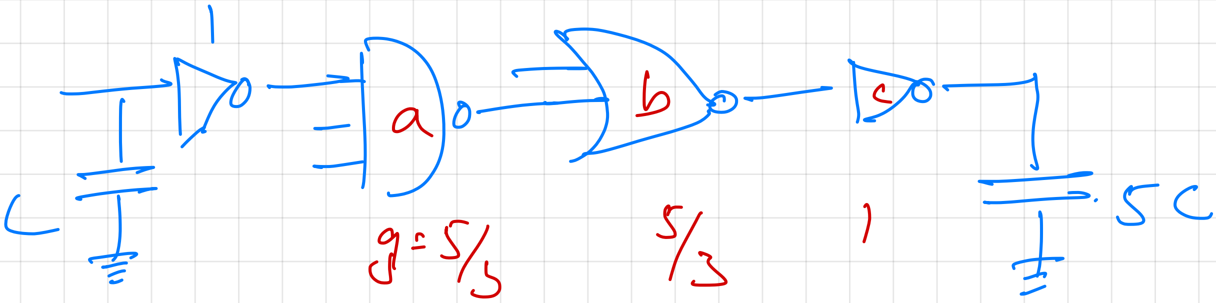
$$t_p = 0.69\, R_{eq}\, C_{gnand} \left( 1 + \frac{C_L}{C_{gnand}} \right)$$

$$t_p = t_{p0} \left( p + \frac{gf}{\gamma} \right)$$

$g$ → Logical effort

$p$ → No. of inputs

$t_{p0}$ ← Intrinsic delay of inverter




$F = 5 \qquad G = 1 \times \frac{5}{3} \times \frac{5}{3} \times 1 = \frac{25}{9}$

$H = \frac{125}{9} \qquad h_{opt} = \left(\frac{125}{9}\right)^{1/4} = 1.93$

$h_1 = 1 \times a \qquad a = 1.93 \qquad t_{p1} = t_{p0}(1 + 1.93)$

$h_2 = \frac{5}{3} \times \frac{b}{a} \qquad b = 2.26 \qquad t_{p2} = t_{p0}(3 + 1.93)$

$h_3 = \frac{5}{3} \times \frac{c}{b} \qquad c = 2.5 \qquad t_{p3} = t_{p0}(2 + 1.93)$

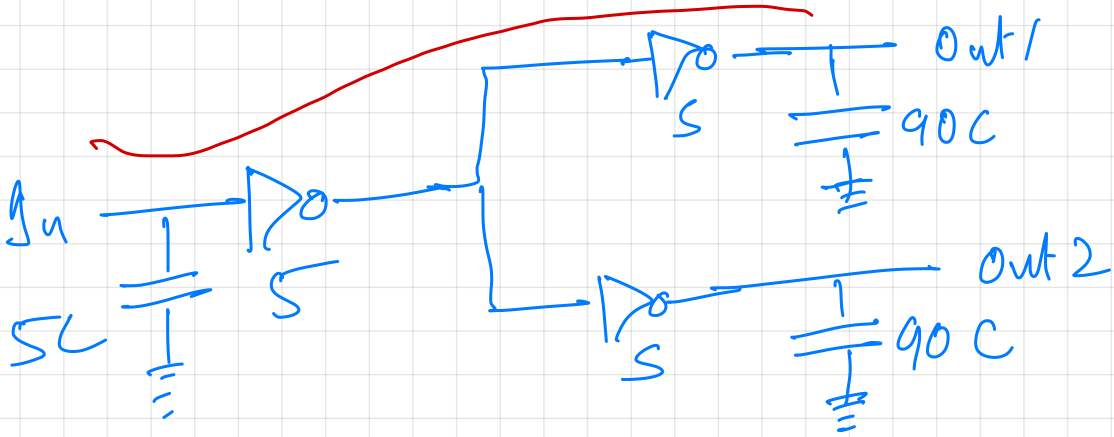
$t_{p4} = t_{p0}\left(1 + \frac{5}{2.5}\right)$

$h_4 = 1.93 = 1 \times \frac{5}{c} \qquad c = \frac{5}{1.93} = 2.59$

$h_3 = 1.93 = \frac{5}{3} \times \frac{c}{b} \qquad b = \frac{5 \times 2.59}{3 \times 1.93}$

$= 2.23$

$h_2 = 1.93 = \frac{5}{3} \times \frac{b}{a} \qquad a = 1.93$




$F = \frac{90}{5} = 18 \qquad f_{opt} = \sqrt{18} \; - ?$

Branching Effort $b = \frac{C_{on\text{-}path} + C_{off\text{-}path}}{C_{on\text{-}path}}$

$b_1 = \frac{25}{5} = 2 \qquad b_2 = 1$

Path branch effort : $B = \prod b_i$

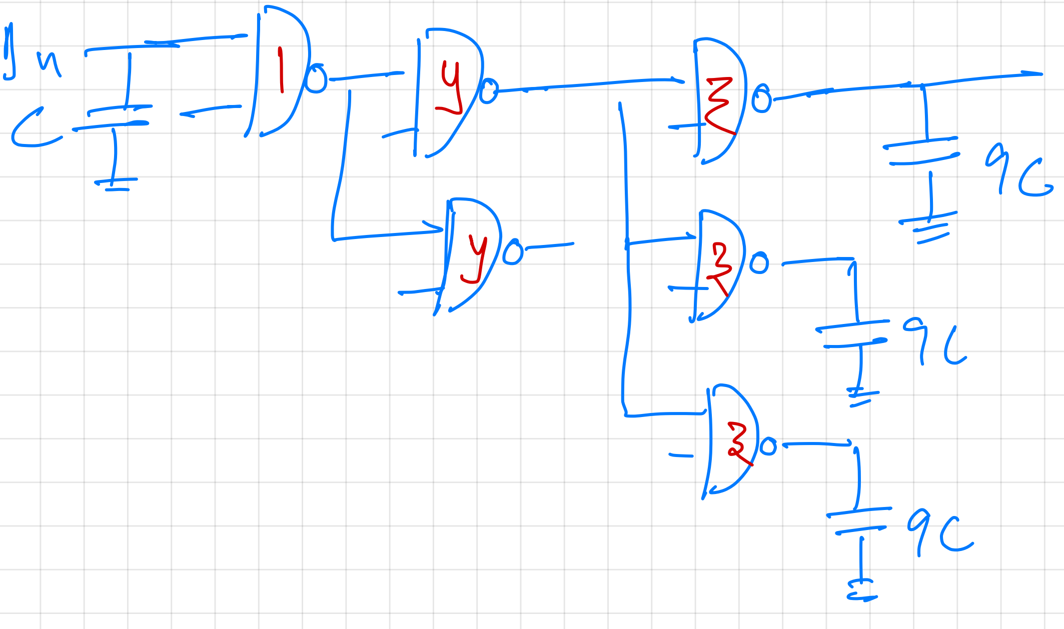
Path effort $H = GFB = 1 \times \frac{90}{5} \times 2$

$= 36$

$h_{opt} = 6$

$h_1 = 6 = 2 \times \frac{s}{5} \Rightarrow s = 15$

$h_2 = 6 = 1 \times \frac{90}{s} \Rightarrow s = 15$




$y = 1.875$

$z = 2.34$

$z = 2.4$

$y = 1.92$