Quality Metrics (pow, delay)

Power-delay-product (PDP)

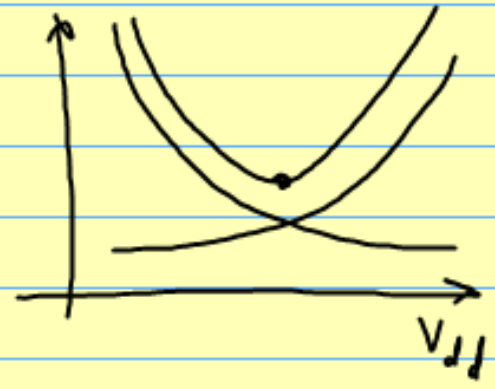
$PDP = C_{eff} \cdot V_{dd}^2 \cdot f \qquad t_p = \frac{1}{2} C_L V_{dd}^2$

$= \frac{1}{2 t_p}$

Energy-delay Product (EDP)

$EDP = PDP \times t_p = \frac{1}{2} C_L V_{dd} \cdot t_p$

$= C_L \frac{V_{dd}^2}{2} \cdot \frac{\propto V_{dd}}{V_{dd} - V_t - \frac{V_{dsat}}{2}}$



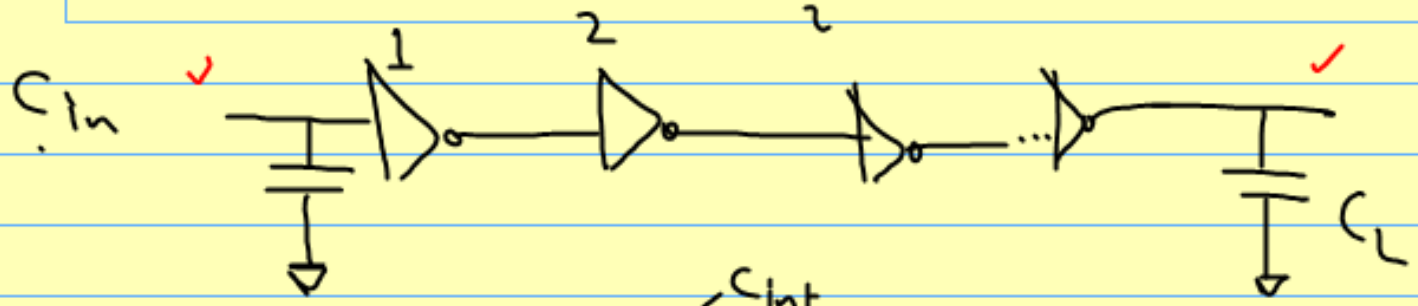
EDP: opt V_{dd}?

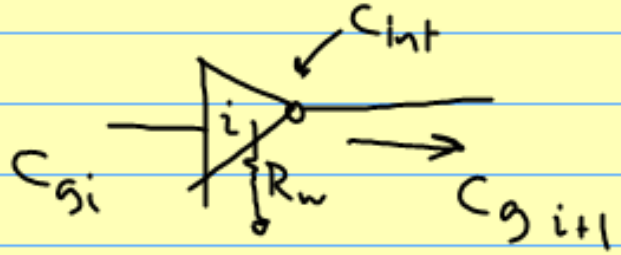
$$\frac{d\,EDP}{d\,V_{dd}} = 0 \Longrightarrow V_{dd\,opt} = \frac{3}{2}\left(V_t + \frac{V_{dsat}}{2}\right)$$

eg $V_t = 0.4$ $V_{dsat} = 0.6$ $V_{dd\,opt} = \left(\frac{3}{2} \times \left(0.4 + \frac{0.6}{2}\right)\right)$

$= 1.05\ V$

Sizing Inverter Chain





$$t_p = k R_w (C_{int} + C_{g\,i+1}) = k R_w C_{int} \left(1 + \frac{C_{g\,i+1}}{C_{int}}\right)$$

$k R_w C_{int}$: $\propto \frac{1}{w}$ $\propto w$

t_{p0} intrinsic delay (tech dep)

$$C_{int} = \gamma C_{gi} \qquad (\gamma \text{ tech dep})$$

$$t_p = t_{p0}\left(1 + \frac{1}{\gamma}\frac{C_{g\,i+1}}{C_{gi}}\right)$$

$\frac{C_{g\,i+1}}{C_{gi}} \rightarrow f_i$ eff fan out

Inverter Chain Sizing (fixed N)

$$t_{phld} = \sum_{i=1}^{N} t_{p0}\left(1 + \frac{1}{\gamma}\frac{C_{gi+1}}{C_{gi}}\right)$$

Goal: opt C_{gi}'s

$$\frac{\partial t_{phld}}{\partial C_{gi}} = 0 \Longrightarrow -\frac{1}{\gamma}\frac{C_{gi+1}}{C_{gi}^2} + \frac{1}{\gamma}\frac{1}{C_{gi-1}} = 0$$

$i \rightarrow 1, 2, \ldots, N$

$$\frac{C_{gi-1}}{C_{gi}} = \frac{C_{gi}}{C_{gi+1}} = f$$

∴ Equal amount sizing all stages

Inverter Chain Sizing (f, N)

$$C_{gin},\ f C_{gin},\ f^2 C_{gin},\ \ldots,\ f^{N-1} C_{gin}$$

$$f = \sqrt[N]{\frac{C_L}{C_{gin}}} = \sqrt[N]{F} \quad \text{overall eff fanout} \qquad \rightarrow f^N C_{gin} = C_L$$

Optimal N ?

$$t_{total} = N\, t_{p0}\left(1 + \frac{f}{\gamma}\right) = t_{p0}\frac{\ln F}{\ln f}\left(1 + \frac{1}{\gamma} f\right)$$

$$\frac{d\, t_{total}}{df} = t_{p0} \cdot \ln F \quad \Rightarrow \quad \ln f - \frac{\gamma}{f} - 1 = 0$$