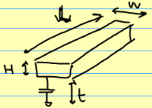
Wire Delay Scaling



$$(W', H', t') = \frac{1}{S}(W, H, t)$$

(i) local wire $L' = \frac{1}{S}L$

$$C' = \frac{\varepsilon L' W'}{t'} = \frac{1}{S}C$$

$$\tau' = R'C' = RC = \tau$$

$$R' = \frac{\rho L'}{W'H'} = S R$$

(ii) Const Length wires $L' = L$

$C' = C$ $R' = S^2 R$ $\tau' = S^2 \tau$

Wire Scaling

Global wires $L' = \frac{1}{S_c} L \quad S_c < 1$

$$C' = \frac{1}{S_c} C \qquad R' = \frac{S^2}{S_c} R$$

$$\tau' = R'C' = \frac{S^2}{S_c^2} \tau$$

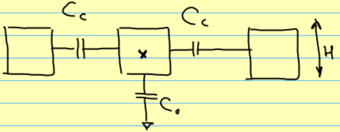
Scaling BAD for wires

Solutions:

$\underline{C}$ $\begin{cases} \varepsilon \quad \text{low } k \quad \varepsilon_r \\ \text{don't scale } t \\ \text{scale } W \times L \end{cases}$

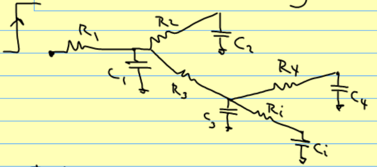
$\underline{R}$ $\begin{cases} \rho_{Al} \rightarrow \rho_{Cu} \\ \text{Don't scale } W \times H \\ \text{Scale } L \end{cases}$

Coupling Cap



↓	↓	↓	C_0
–	↓	↓	$C_0 + C_c$
–	↓	–	$C_0 + 2C_c$
–	↓	↑	$C_0 + 3C_c$
↑	↓	↑	$C_0 + 4C_c$

Elmore Delay



Path $R_{44} = R_1 + R_3 + R_4$

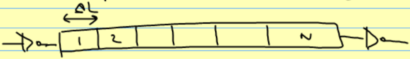
$t_{pi} = 0.69\,T_i$

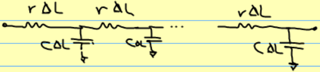
Shared path $R_{i4} = R_1 + R_3$

$$\boxed{T_i = \sum_{k=1}^{n} C_k R_{ik}}$$

$$T_i = C_1 R_1 + C_2 R_1 + C_3 (R_1 + R_3) + C_4 (R_1 + R_3) + C_i (R_1 + R_3 + R_i)$$

Example Elmore Delay





$$T = C\Delta L \left(r\Delta L + 2r\Delta L + 3r\Delta L + \cdots + nr\Delta L \right)$$

$$= rC\,\Delta L^2 \,(1+2+3+\cdots+n)$$

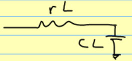
$$= rC\,\Delta L^2 \,\frac{N(N+1)}{2} \qquad \left(\Delta L = \frac{1}{N} L\right)$$

$$= rc\,\frac{L^2}{N^2}\,\frac{N(N+1)}{2} \qquad (N \to \infty)$$

$$= \frac{1}{2} rcL^2$$

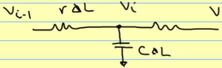
Lumped vs Elmore

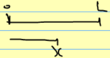
Lumped:



rcL^2

Elmore $\frac{1}{2} rcL^2$ (first-order approx)





$$C\Delta L \frac{dv_i}{dt} = \frac{V_{i+1} - V_i}{r\Delta L} + \frac{V_{i-1} - V_i}{r\Delta L}$$

$$cr \frac{dv_i}{dt} = \frac{(V_{i+1} - V_i) - (V_i - V_{i-1})}{\Delta L^2}$$

$$\Rightarrow rc \frac{\partial V}{\partial t} = \frac{\partial^2 V}{\partial x^2} \quad \text{(diffusion Eq.)}$$