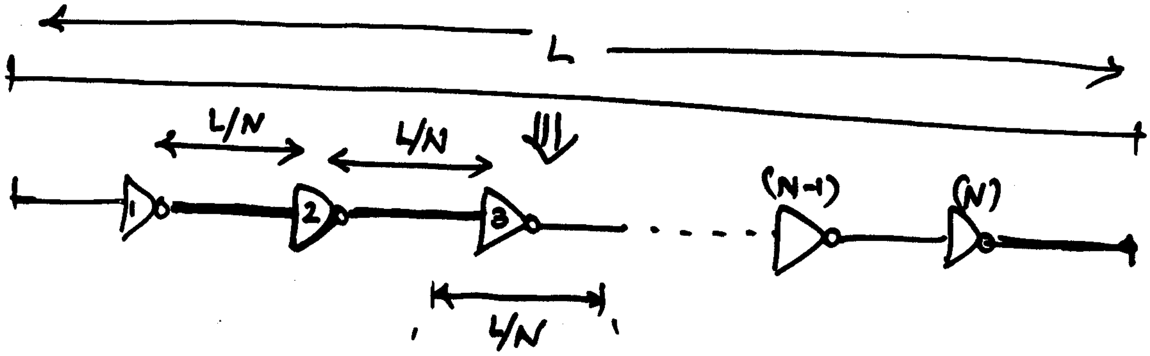
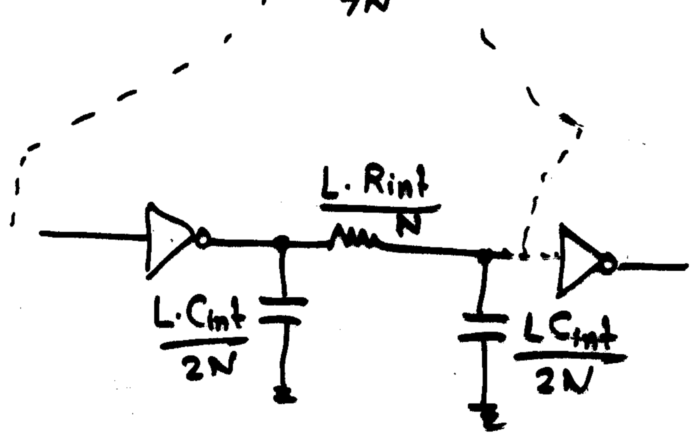
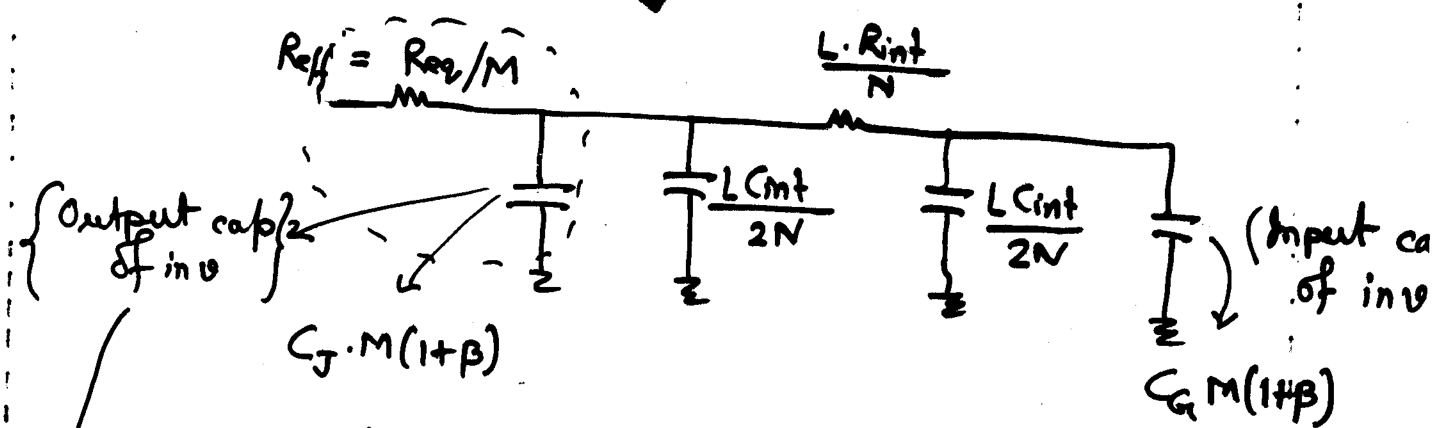
How do you reduce the delay of long wires?

Buffer insertion







1X inverter

$$C_{out} = C_{eff} \cdot W_n (1+\beta) \quad ; \quad \beta = \frac{W_P}{W_N}$$

$$C_{in} = C_g (W_n + W_p) = C_g (W_n)(1+\beta).$$

Elmore delay for 1 segment

$$t_{seg} = \frac{R_{eqn}}{M}\left(C_J(1+\beta)M + \frac{C_{int}\cdot L}{2N}\right) +$$

$$\left\{\frac{R_{eqn}}{M} + \frac{R_{int}\cdot L}{N}\right\}\left[\frac{C_{int}\cdot L}{2N} + C_G(1+\beta)M\right]$$

Total delay for N segments

$$t_{total} = N\cdot(t_{seg})$$

$$= \{N(C_G + C_J)R_{eqn}(1+\beta)$$ → Buffer only

$$+ \left\{C_G(1+\beta)\cdot R_{int}M + \frac{C_{int}\cdot R_{eqn}}{M}\right\}L$$ → Buffer & Interconnect

$$+ \left\{\frac{C_{int}R_{int}}{2N^2}\right\}L^2$$ → Interconnect only

($2N^2$) → error in the book.

Find N and M

To find N → $\left(\frac{\partial t_{total}}{\partial N} = 0\right)$

$$N = \sqrt{\frac{R_{int}\cdot C_{int}\cdot L^2/2}{R_{eqn}(C_J+C_G)(1+\beta)}} = \sqrt{\frac{t_{wire}}{FO1}}.$$

To find M.

$$\frac{\partial t_{total}}{\partial M} = 0 \Rightarrow M = \sqrt{\frac{R_{eqn} \cdot C_{int}}{C_G (1+\beta) R_{int}}}$$

Ex. 10.4

Do Ex. 10.3 but use buffer insertion approach.

$R_{int} = 54 \text{ m}\Omega/\mu m$, $C_{int} = 0.1 \text{ fF}/\mu m$, $L = 20{,}000 \mu m$

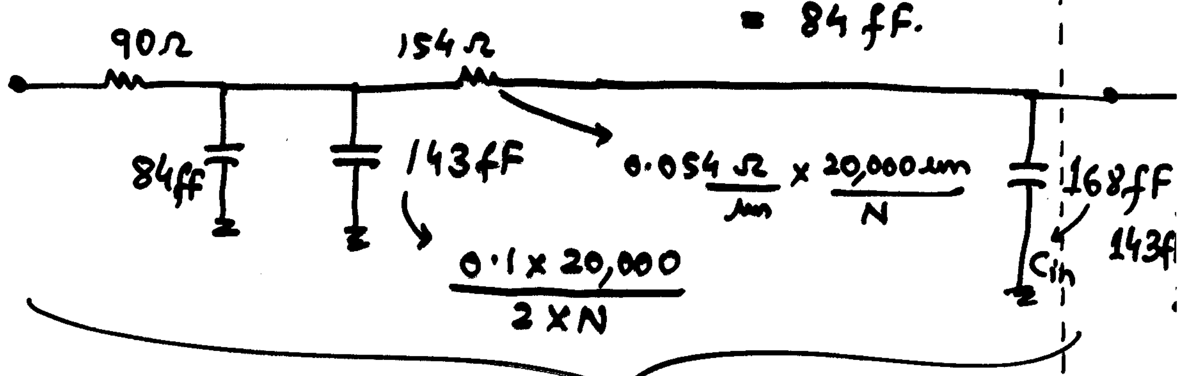
$R_{eqn} = 12.5 \text{ k}\Omega/\square$, $C_G = 2 \text{ fF}/\mu m$, $C_{eff} = 1 \text{ fF}/\mu m$

$W_n = 0.2$ and $\beta = 2 \rightarrow W_p = 0.4 \mu m$.

$$N = \sqrt{\frac{t_{wire}}{F_{01}}} = 6.9 \rightarrow \underline{7}.$$

$$M = 139 \longrightarrow \underline{140}.$$

$$R_{eff} = \frac{12.5 \text{ k}\Omega}{140} = 90\Omega, \quad C_{self} = C_{eff}(2W+W) 140 = 84 \text{ fF}.$$

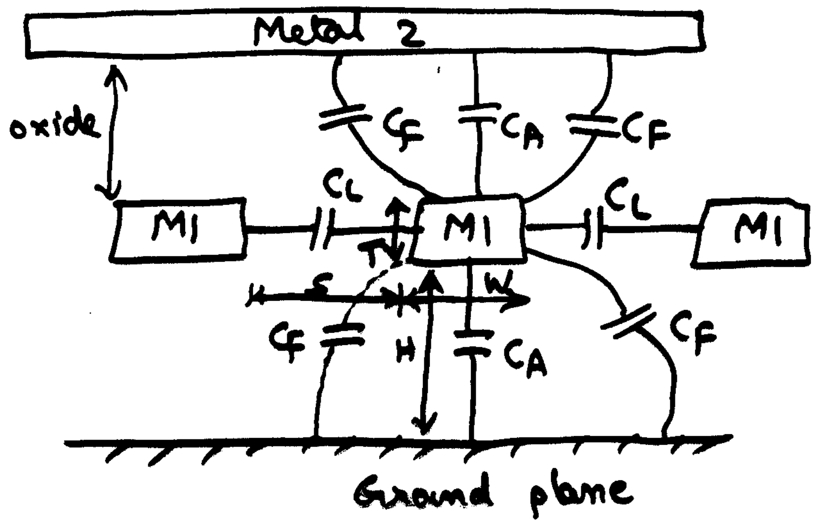


One segment

$$\text{Total delay} = 7 \times \left[90(143\text{fF} + 84\text{fF}) + (90 + 154)(168\text{fF} + 143\text{fF}) \right]$$

$$= \underline{0.67 \text{ ns}} \quad (\text{with no buffers, delay} = 1.3 \text{ ns})$$

Interconnect coupling capacitance



Types.

1) Vertical. (C_A) → $\epsilon_{ox} \frac{W}{H} = 4\epsilon_0 \frac{W}{H} \cong 0.035 \frac{W}{H}$ fF/μm
2) Lateral. (C_L) → $\epsilon_{ox} \cdot \frac{T}{S} = 0.035 \frac{T}{S}$ fF/μm.
3) Fringing. (C_F) → $\epsilon_{ox} \ln\left(1 + \frac{T}{H}\right)$ fF/μm.