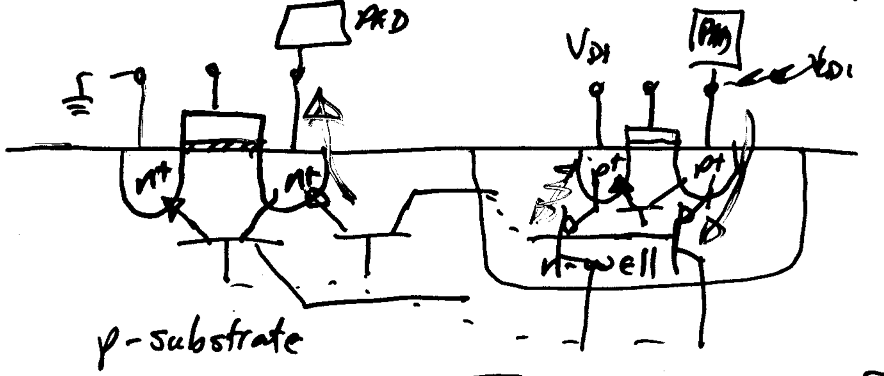
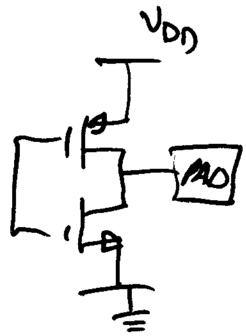
3rd Exam is 4/22

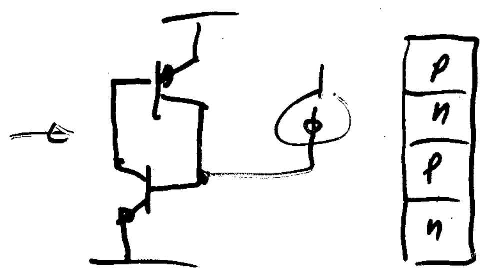
Prob. session scheduled for 4/21 at 7pm.

## Industrial Perspective of CMOS Technology

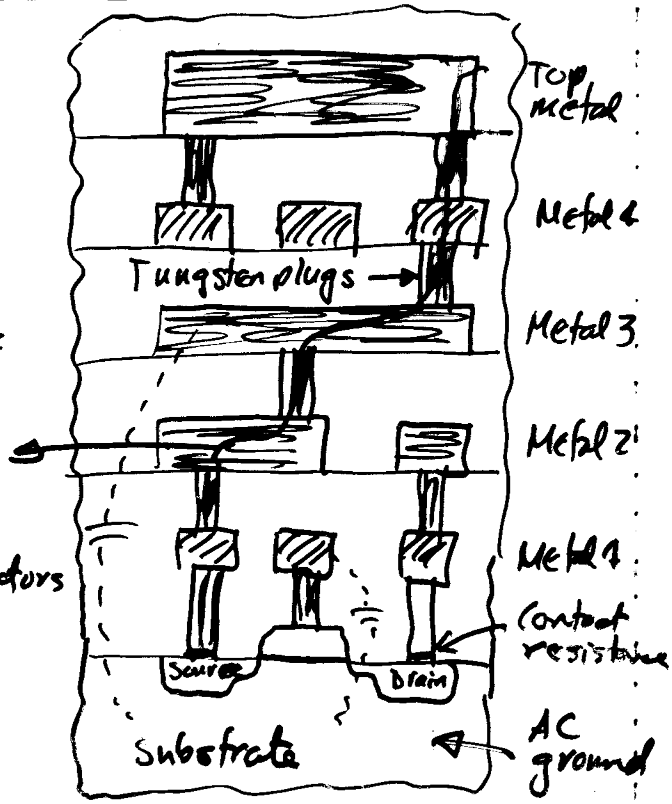



SCR




## CHAPTER 10 - INTERCONNECT DESIGN




Interconnects dominate the physical aspects of modern digital integrated circuits.

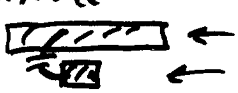
Parasitics:

1.) Series (bulk) resistance

Al: $\rho = 2.7\,\mu\Omega\text{-cm}$

Cu: $\rho = 1.7\,\mu\Omega\text{-cm}$

2.) Capacitance

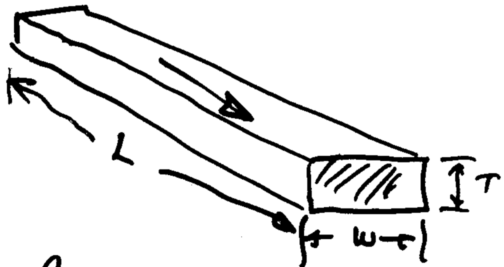



$C \approx 0.1 - 0.2\,fF/\mu m$

3.) Inductance

$L \approx 0.45\,pH/\mu m$

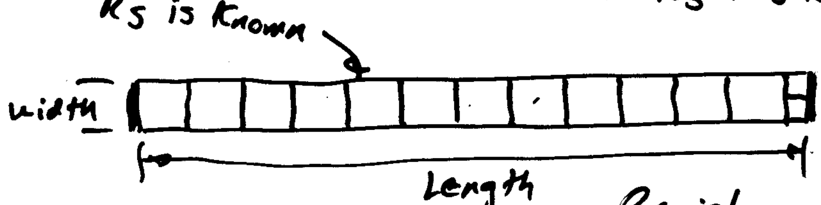
## Wire Resistance




$$R = \frac{\rho L}{A} = \frac{\rho L}{WT} = \left(\frac{\rho}{T}\right)\frac{L}{W}$$

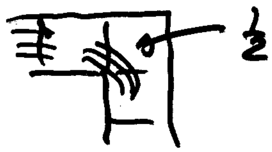
$$= R_S \frac{L}{W}$$

$R_S$ = sheet resistance ($\Omega$/sq.)



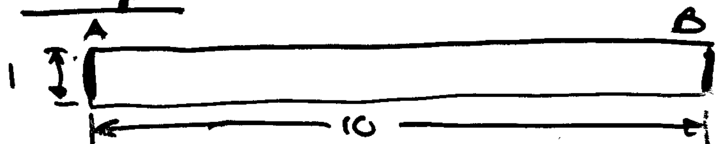

← Squares = 12.5

Resistance = $R_S \times 12.5$



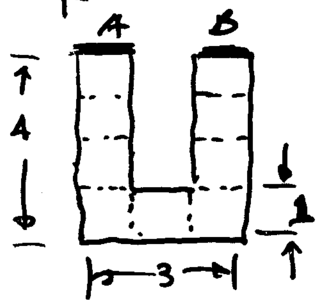

| | Lower metal | Top metal |
|---|---|---|
| Aluminum | $R_S = 54 m\Omega/\square$ | $R_S = 27 m\Omega/\square$ |
| Copper | $R_S = 42 m\Omega/\square$ | $R_S = 21 m\Omega/\square$ |

### Example




If $R_S = 54 m\Omega/\square$ find the resistance

$R_{AB} = 0.54\,\Omega$

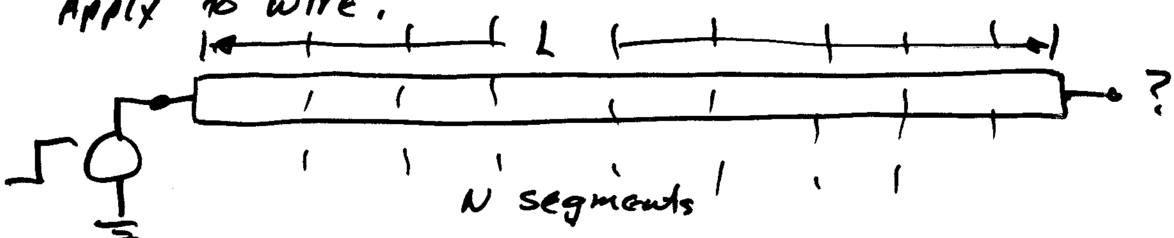



$$R_{AB} = 7 \cdot R_S + 2 \cdot \frac{R_S}{2} = 8 R_S$$

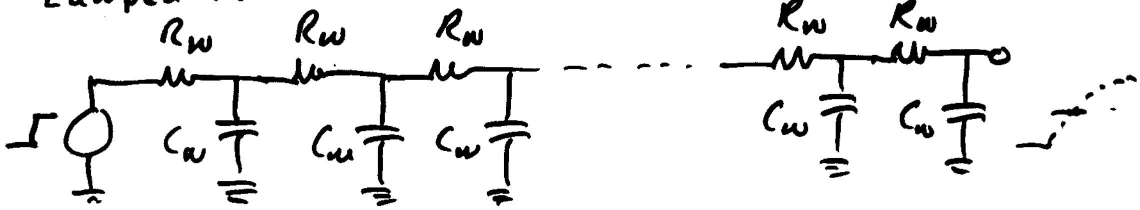
If $R_S = 21 m\Omega/\square$, then $R_{AB} = 0.168\,\Omega$

## Elmore Delay Calculation

Apply to wire:

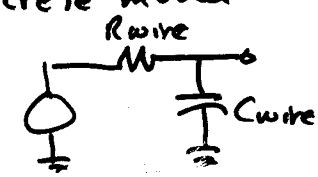



Lumped model:




$R_{wire} = N \cdot R_w$ $C_{wire} = N \cdot C_w$

Discrete model -




Find $R_{wire}$ & $C_{wire}$ for 1mm length of 0.18μm metal that is 0.4μm wide. $R_s = 54\,m\Omega/\square$ and $C_{int} = 0.2\,fF/\mu m$

$C_{wire} = 1000\mu m \times 0.2\,fF/\mu m = 200\,fF$

$R_{wire} = 0.054\,\Omega \times \frac{1000}{0.4} = 135\,\Omega$

$\therefore \tau_{lumped\ discrete} = R_{wire} C_{wire} = 27\,ps$

(Actual delay ≈ 10ps)

Elmore Delay -

$$\tau_i = \sum_k (C_k R_{ik})$$

$i$ = node of interest

$C_k$ = capacitance (to ground) at node $k$

$R_{ik}$ = sum of all resistors in common from node $i$ to node $k$.