

# CMOS Delay-9 (H.0) Interconnect Delay

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# References

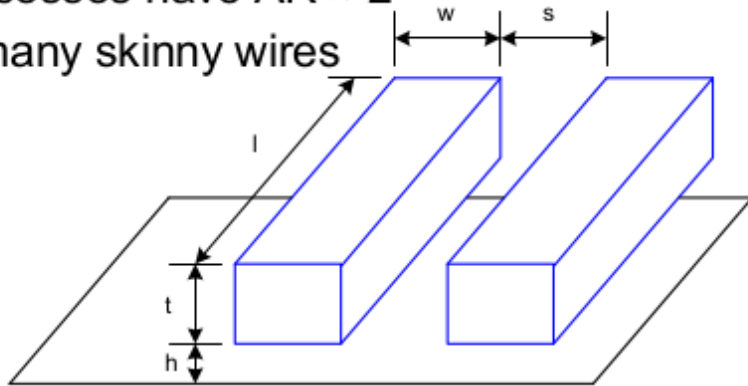
Some Figures from the following sites

[1] <http://pages.hmc.edu/harris/cmosvlsi/4e/index.html>  
Weste & Harris Book Site

[2] [en.wikipedia.org](http://en.wikipedia.org)

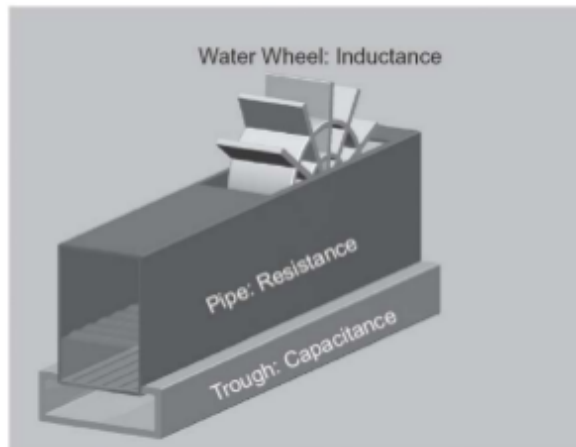
# Wire Geometry

- ❑ Pitch =  $w + s$
- ❑ Aspect ratio:  $AR = t/w$ 
  - Old processes had  $AR \ll 1$
  - Modern processes have  $AR \approx 2$ 
    - Pack in many skinny wires



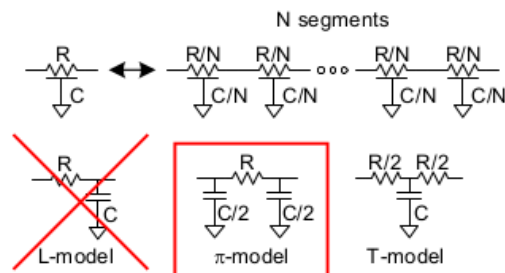
# Interconnect Modeling

- Current in a wire is analogous to current in a pipe
  - Resistance: narrow size impedes flow
  - Capacitance: trough under the leaky pipe must fill first
  - Inductance: paddle wheel inertia opposes changes in flow rate
    - Negligible for most wires



# Lumped Element Models

- ❑ Wires are a distributed system
  - Approximate with lumped element models



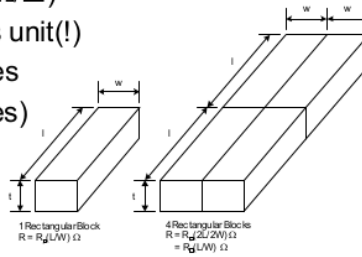
- ❑ 3-segment  $\pi$ -model is accurate to 3% in simulation
- ❑ L-model needs 100 segments for same accuracy!
- ❑ Use single segment  $\pi$ -model for Elmore delay

# Wire Resistance

□  $\rho = \text{resistivity } (\Omega \cdot \text{m})$

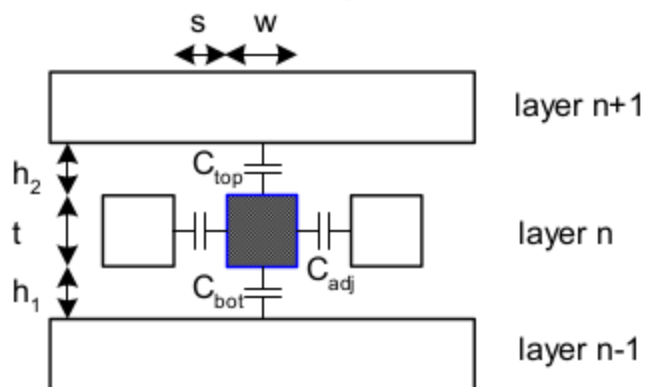
$R =$

- $R_{\square} = \text{sheet resistance } (\Omega/\square)$ 
  - $\square$  is a dimensionless unit(!)
- Count number of squares
  - $R = R_{\square} * (\# \text{ of squares})$



# Wire Capacitance

- ❑ Wire has capacitance per unit length
  - To neighbors
  - To layers above and below
- ❑  $C_{\text{total}} = C_{\text{top}} + C_{\text{bot}} + 2C_{\text{adj}}$



# Diffusion & Polysilicon

- ❑ Diffusion capacitance is very high (1-2 fF/ $\mu\text{m}$ )
  - Comparable to gate capacitance
  - Diffusion also has high resistance
  - Avoid using diffusion *runners* for wires!
- ❑ Polysilicon has lower C but high R
  - Use for transistor gates
  - Occasionally for very short wires between gates



# Wire RC Delay

- Estimate the delay of a 10x inverter driving a 2x inverter at the end of the 1 mm wire. Assume wire capacitance is  $0.2 \text{ fF}/\mu\text{m}$  and that a unit-sized inverter has  $R = 10 \text{ K}\Omega$  and  $C = 0.1 \text{ fF}$ .

-  $t_{\text{od}} =$

