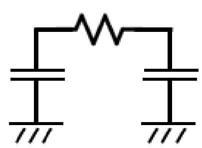
Homework Assignment 6

(Due Mar. 30th at the beginning of the class)

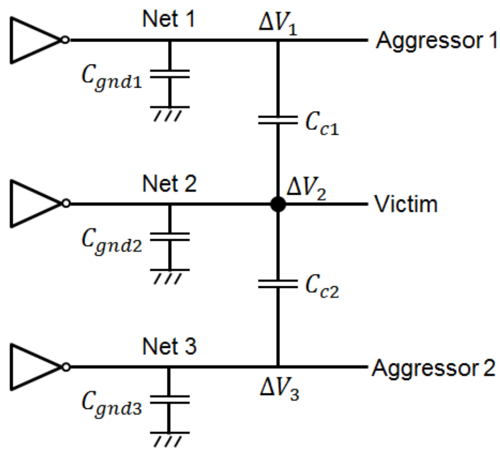
1. [Wire Resistance and Capacitance, **20 points**]
   - [**Submit**] Compute the resistance of the following wire:
     - $\boldsymbol{R = (2.0 \cdot 10^{-8}\ \Omega \cdot m) \cdot \frac{100\mu m}{0.28\mu m \cdot 0.14\mu m} = \frac{0.02 \cdot 100}{0.28 \cdot 0.14}\Omega = 51.02\Omega}$
     - $\rho = 2.0 \cdot 10^{-8}\ \Omega \cdot m$
     - $\varepsilon_{OX} = 2.0 \cdot 10^{-11}\ F/m$
     - width: 0.14μm
     - spacing between the wire and the ground plane: 0.28μm
     - length: 100μm
     - thickness: 0.28μm
     - spacing between two laterally-adjacent wires: 0.14μm
   - [**Submit**] Compute the area capacitance of the above wire:
     - $\boldsymbol{C_{Area} = (2.0 \cdot 10^{-11} F/m) \cdot \frac{0.14\mu m \cdot 100\mu m}{0.28\mu m} = 1fF}$
   - [**Submit**] Compute the lateral capacitance of the above wire.
     - $\boldsymbol{C_{Lateral} = (2.0 \cdot 10^{-11} F/m) \cdot \frac{0.28\mu m \cdot 100\mu m}{0.14\mu m} = 4fF}$
   - [**Submit**] Compute the fringe capacitance of the above wire.
     - $\boldsymbol{C_{Fringe} = (2.0 \cdot 10^{-11} F/m) \cdot ln\left(1 + \frac{0.28\mu m}{0.28\mu m}\right) * 100\mu m = 1.38fF}$
   - [**Submit**] The above wire is driven by a buffer whose output resistance is 1kΩ. The other end of the wire is connected to a gate whose input capacitance is 5fF. Compute Elmore delay at the load. $C_{wire} = 2 * C_{area} + 2 * C_{lateral} + 4 * C_{fringe}$. Use the PI model to model the above wire.



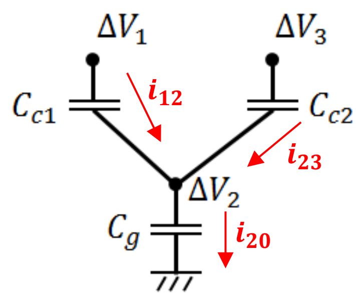
$\boldsymbol{C_{wire} = 2fF + 8fF + 5.52fF = 15.52fF.}$

$$\boldsymbol{\tau = R_{out}(C_{wire} + C_L) + R_{wire}\left(\frac{C_{wire}}{2} + C_L\right) = 1k(20.52f) + 51.02(12.76f) = 21.17ps.}$$

2. [Coupling, **10 points**]
   - In real designs, a victim net is usually surrounded by multiple aggressors. The following models a victim net surrounded by two aggressors.



- To compute ΔV_2, we can use the following model:



- [**Submit**] Represent ΔV_2 as a function of $\Delta V_1, \Delta V_3, C_{c1}, C_{c2}, and\ C_g$.

$$i_{12} + i_{23} = i_{20}$$

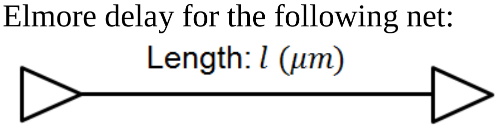
$$i_{12} = C_{c1}\frac{\Delta V_1 - \Delta V_2}{\Delta t}, i_{23} = C_{c2}\frac{\Delta V_3 - \Delta V_2}{\Delta t}, i_{20} = C_g\frac{\Delta V_2}{\Delta t}$$

$$C_{c1}\frac{\Delta V_1 - \Delta V_2}{\Delta t} + C_{c2}\frac{\Delta V_3 - \Delta V_2}{\Delta t} = C_g\frac{\Delta V_2}{\Delta t}$$

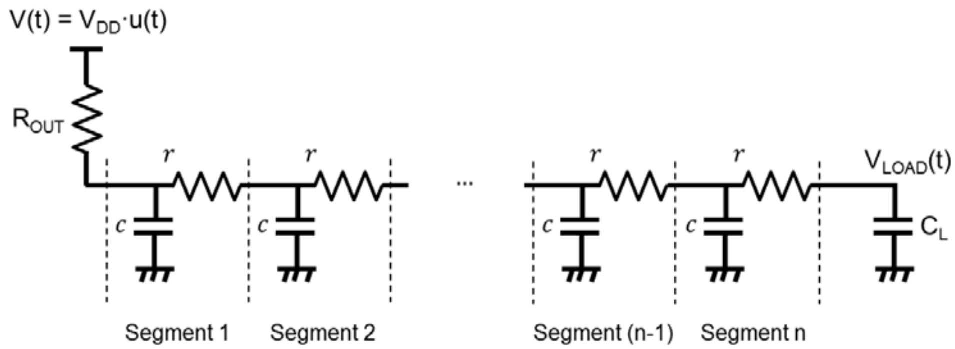
$$\Delta V_1 \cdot C_{c1} + \Delta V_3 \cdot C_{c2} = \Delta V_2(C_{c1} + C_{c2} + C_g)$$

$$\therefore \Delta V_2 = \frac{\Delta V_1 \cdot C_{c1} + \Delta V_3 \cdot C_{c2}}{C_{c1} + C_{c2} + C_g}$$

3. [Elmore Delay, **10 points**]
   - We want to compute Elmore delay for the following net:



   - This net is modeled as follows:



- R_w: Total wire resistance
- C_w: Total wire capacitance
- $r = \frac{R_w}{n}, c = \frac{C_w}{n}$
- [**Submit**] Compute Elmore Delay at the load when n goes to infinity. Represent the delay as a function of R_{OUT}, C_L, R_w, and C_w.

$$\tau_n = R_{OUT}(C_w + C_L) + R_w C_L + r \cdot (n-1) \cdot c + r \cdot (n-2) \cdot c + \cdots + r \cdot c$$

$$= R_{OUT}(C_w + C_L) + R_w C_L + rc\frac{n(n-1)}{2}$$

$$= R_{OUT}(C_w + C_L) + R_w C_L + R_w C_w \frac{n(n-1)}{2n^2}$$

$$\tau = \lim_{n\to\infty} \tau_n = R_{OUT}(C_w + C_L) + R_w C_L + \frac{R_w C_w}{2}$$