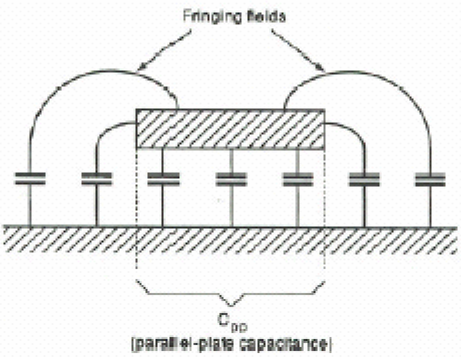
UNIVERSITY OF CALIFORNIA, BERKELEY
College of Engineering
Dept. of Electrical Engineering and Computer Sciences

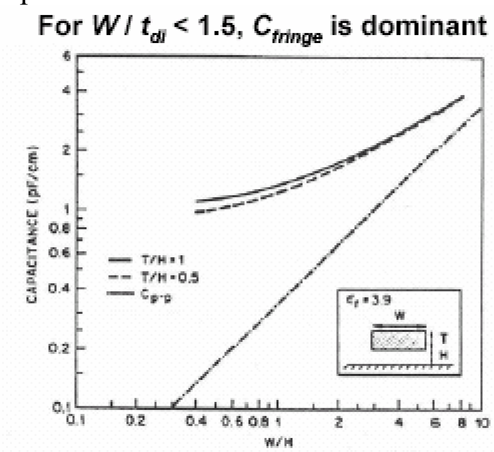
EECS 40 **Fall 2003**

Homework #12 Solutions

Problem 1

Model for determining interconnect capacitiance:





Wire capacitance per unit length:

$$c_{wire} \cong c_{pp} + c_{fringe} = \frac{w\varepsilon_{di}}{t_{di}} + \frac{2\pi\varepsilon_{di}}{\log(t_{di}/H)} \qquad w = W - \frac{H}{2}$$

First calculate the resistance and capacitance of the wire:

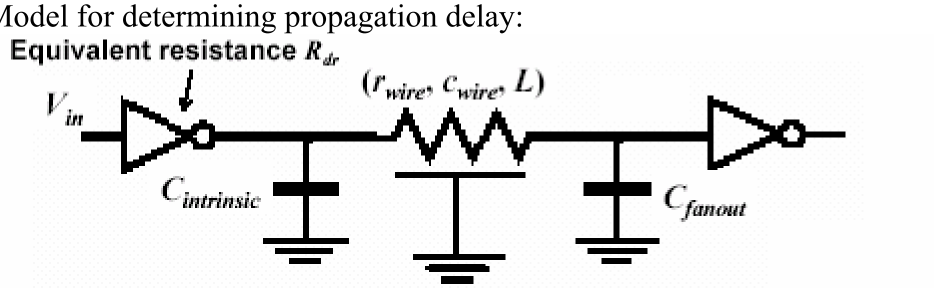
R_{wire} = (ρL)/(HW) = (2.7μΩ-cm x L)/(0.5 x 10^{-4}cm x 1 x 10^{-4}cm) = 540L [Ω/cm]

w = W – H/2 = 1 x 10^{-4}cm - 0.5 x 10^{-4}cm/2 = 0.75 x 10^{-4}cm

$C_{wire\_per\_unit\_length}$ = [(0.75 x 10^{-4}cm x 3.45 x 10^{-13} F/cm) / 1 x 10^{-4}cm] + [(2 x 3.14 x 3.45 x 10^{-13} F/cm)/log(1/0.5)] = 7.46 x10^{-12} F/cm

C_{wire} = 7.4597 x10^{-12} x L [F/cm]

Model for determining propagation delay:



$$t_p = 0.69R_{dr}C_{intrinsic} + 0.69(R_{dr} + R_{wire})C_{fanout} + (0.69R_{dr} + 0.38R_{wire})C_{wire}$$

Substituting in the values for all the components in the above equation we get:

The propagation delay of Inverter A is given by the equation above.
Substituting in the values for all the components in the above equation we get:

$t_p = 0.69(10k\Omega)(3 \times 10^{-15}F) + 0.69(10k\Omega + 540L)(3 \times 10^{-15}F) + [0.69(10k\Omega) + 0.38(540L)]\ 7.4597 \times 10^{-12} \times L$

$t_p = 4.14 \times 10^{-11} + 5.1473 \times 10^{-8} \times L + 1.5307 \times 10^{-9} \times L^2$

We must solve for L using the following constraint:

interconnect delay = $0.5(t_p)$

$5.1472 \times 10^{-8} \times L + 1.5307 \times 10^{-9} \times L^2 = 0.5(4.14 \times 10^{-11} + 5.1475 \times 10^{-8} \times L + 1.53 \times 10^{-9} \times L^2)$

$-2.07 \times 10^{-11} + 2.5735 \times 10^{-8} \times L + 7.6537 \times 10^{-10} \times L^2 = 0$

Solving for L yields: $L = 8.035 \times 10^{-3}$ cm = 80.35μm.

Problem 2

For this problem we assume the simple parallel-plate model as we are told that fringing-field capacitance is negligible. The equation we use to calculate the wire capacitance is given on slide 6, lecture 37:

$$C_{pp} = \frac{\varepsilon_{di}}{t_{di}} WL$$

a) $R_{wire1} = (\rho L)/(HW) = (2.7\mu\Omega\text{-cm} \times 500 \times 10^{-4}\text{cm})/(0.5 \times 10^{-4}\text{cm} \times 2 \times 10^{-4}\text{cm}) = 13.5\Omega$

R_{wire1} is much smaller than R_{dr} of Inverter A: $13.5\Omega << 10\ k\Omega$

Hence $(R_{wire1} + R_{dr}) \approx R_{dr} = 10\ k\Omega$.

$C_{wire1} = C_{wire2} = C_{pp} = [(2 \times 10^{-4}\text{cm} \times 500 \times 10^{-4}\text{cm} \times 3.45 \times 10^{-13}\ \text{F/cm}) / 1 \times 10^{-4}\text{cm}] = 34.5$ fF

$C_C = \varepsilon_{di} \times H \times L$ / spacing

$C_C = 3.45 \times 10^{-13}$ F/cm $\times\ 0.5 \times 10^{-4}$cm $\times\ 500 \times 10^{-4}$cm / 0.5×10^{-4}cm

$C_C = 17.25$ fF

$C_{in2} = 3$fF from Problem 1.

$C_{out1} = 3$fF from Problem 1.

$\tau_D = (C_{out1}R_{dr}) + (R_{wire1} + R_{dr})[C_{wire1} + (C_{wire2}C_C)/(C_{wire2} + C_C) + C_{in2}]$

$\tau_D \approx 3\text{fF} \times 10\ k\Omega + 10\ k\Omega[34.5\text{fF} + 34.5\text{fF}\ (17.25\text{fF})/(34.5\text{fF} + 17.25\text{fF}) + 3\text{fF}]$

$\tau_D \approx 0.52$ ns

c) $\tau_D = (C_{out1}R_{dr}) + (R_{wire1} + R_{dr})[C_{wire1} + C_C + C_{in2}]$

$\tau_D \approx 3\text{fF} \times 10\ k\Omega + 10\ k\Omega(34.5\text{fF} + 17.25\text{fF} + 3\text{fF})$

$\tau_D \approx 0.58$ ns