EEC 116 HW #5 solution

Fall 2011

#1.1

$$C_L = C_{pp} + C_{fringe} = \frac{\varepsilon_r}{h}\left(w - \frac{t}{2}\right) + \frac{2\pi\,\varepsilon_r}{\log\left(\frac{2h}{t}+1\right)}$$

$$= \frac{3.9}{0.4\,\mu m}\left(0.4\,\mu m - \frac{0.6\,\mu m}{2}\right) + \frac{2\pi \cdot 3.9}{\log\left(\frac{2\cdot 0.4\,\mu m}{0.6\,\mu m}+1\right)}$$

$$= 0.975 + 66.59$$

C_L per unit length $= C_L \times \varepsilon_0 = \underline{598\ pF/m}$

* To find C_c, use formula for C_L, except: $H=S$, $W=T$, $T=W$,

$$C_c = \frac{\varepsilon_r}{S}\left(T - \frac{W}{2}\right) + \frac{2\pi\,\varepsilon_r}{\log\left(\frac{2\cdot S}{W}+1\right)}$$

$$= \frac{3.9}{0.6\,\mu m}\left(0.6\,\mu m - \frac{0.4\,\mu m}{2}\right) + \frac{2\pi\ 3.9}{\log\left(\frac{2\cdot 0.6\,\mu m}{0.4\,\mu m}+1\right)}$$

$$= 2.6 + 40.70$$

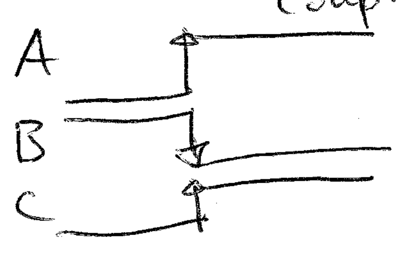
C_c per unit length $= \underline{383\ pF/m}$

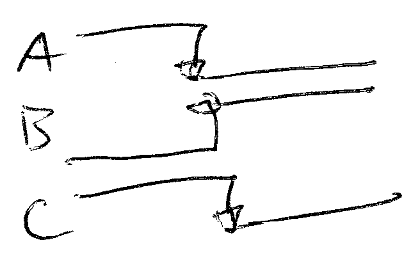
#1.2.

Optimistic, the worst case needs to take Miller effect into account. The calculated values does not.

#1.3

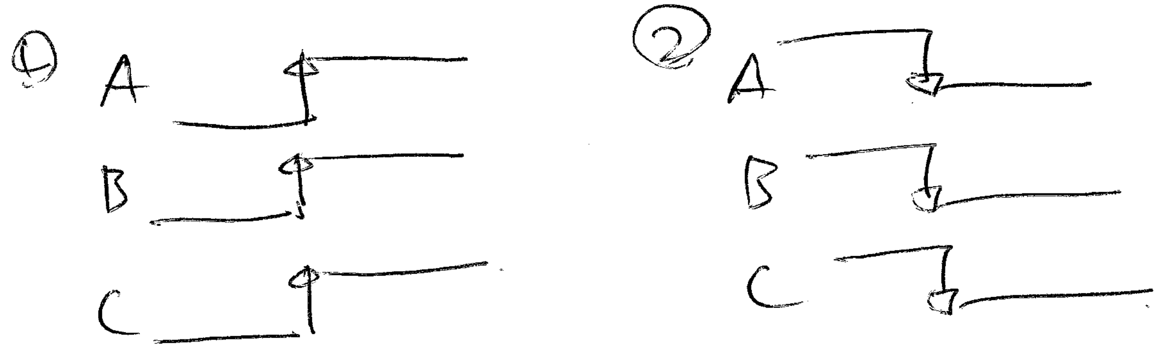
2 possible worst case patterns, both give same ~~coupling~~ coupling capacitance.

① 

② 

$C_{total} = \underline{4C_c + C_L}$.

1.4. Best Case → 2 cases, same C_{tot}.



$$C_{total} = \cancel{0 \cdot C_c} + C_L = C_L.$$

1.5.

$$Al: \rho = 2.7 \times 10^{-8}\ \Omega \cdot m$$

resistance per unit length

$$= r = \frac{\rho}{T \cdot W} = \frac{2.7 \times 10^{-8}\ \Omega\text{-}m}{0.6 \cdot 0.4\ \mu m^2} = 0.1125\ \Omega/\mu m$$

1.6

Best:

$$t = \frac{0.1125 \overset{\Omega \cdot m}{\vee} \times 598 \frac{pF}{m} \times (1\ mm)^2}{2}$$

$$= 33.6\ \mu s$$

Worst:

$$t = \frac{0.1125\ \Omega \cdot m \times (4C_c + C_L) \times (1\ mm)^2}{2}$$

$$= 0.1125 \times 2130\ pF/m \times (1\ mm)^2$$

$$= 239.6\ \mu s$$

2.1

note: $I_{ds,p\,(SAT)} = I_{ds,n\,(SAT)} = \dfrac{\left(150 \times 10^{-6} \times \frac{4}{1}\right)}{2}(2.5 - 0.6)^2 = 1.083\ mA$

$$I_{ds,p\,(Tri)} = I_{ds,n\,(Tri)} = \left(150 \times 10^{-6} \times \frac{4}{1}\right)\left[(2.5-0.6) \times 1.25 - \frac{1.25^2}{2}\right] = 0.956\ mA$$

3.1

node ①: $$t_1 = \frac{\frac{50\,m\Omega}{sq} \times \frac{1\,cm}{2.5\,\mu m} \times \left(5.4\frac{aF}{\mu m^2} \times 2.5\,\mu m \times 1\,cm + \frac{12\,aF}{\mu m} \times 2 \times 1\,cm\right)}{2}$$

$$= \frac{200 \times (1.35\times10^{-13} + 2.4\times10^{-13})}{2}$$

$$= \underline{\underline{37.5\ ps}}$$

node ②: $t_2 = t_1 \times 4$ because $t \propto L^2$

$$= \underline{\underline{150\ ps}}$$

node ③: $t_3 = t_2 + t_1 \times \frac{1}{4}$

$$= 150\ ps + 9.375\ ps$$

$$= \underline{\underline{159.375\ ps}}$$

3.2

The minimum hold time is the largest skew expected between nodes 1 and 3.