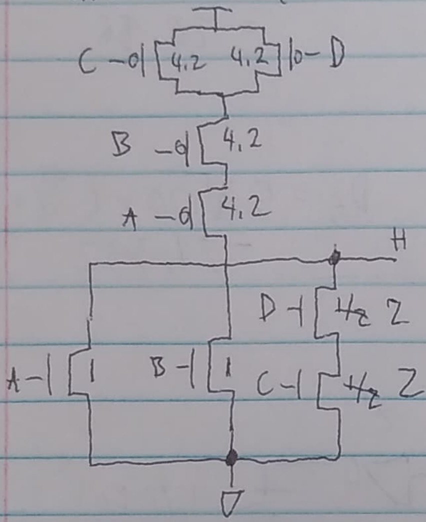
(2) Compound Gate

(a,b) Team 6: $H = ((A+B)+CD)'$

Using $\frac{W}{L}_p = \frac{7\lambda}{2\lambda}$ & $\frac{W}{L}_N = \frac{5\lambda}{2\lambda}$

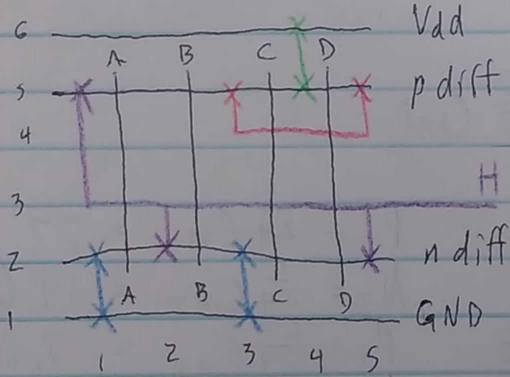
initial size: PMOS: 1.4 NMOS: 1



(c) $g_{a,b} = \frac{4.2+1}{2.4} = \frac{5.2}{2.4} = \frac{13}{6} \cong 2.167$

$g_{c,d} = \frac{4.2+2}{2.4} = \frac{6.2}{2.4} = \frac{31}{12} \cong 2.583$

$p = \frac{4.2+1+1+2}{2.4} = \frac{8.2}{2.4} = \frac{41}{12} \cong 3.417$



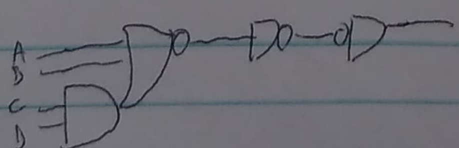
Area $= (6 \times 8\lambda)(5 \times 8\lambda) = 30 \cdot 64\,\lambda^2 = 1920\,\lambda^2$

For delay

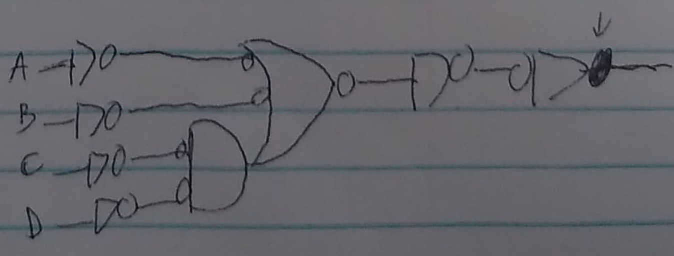
(d) ~~$F = GHB = \frac{31}{12} \cdot 1 \cdot 1 = \frac{31}{12}$~~ $P = \frac{41}{12}$ if $\underset{(rho)}{\rho} = 4$ $\hat{N} = \log_\rho F = 3.705$

$H = \frac{170C}{\frac{31}{12}C} = \frac{2040}{31} \cong 65.806$ $F = GHB = \frac{2040}{12} = 170$

(e) 3-4 stages are ideal



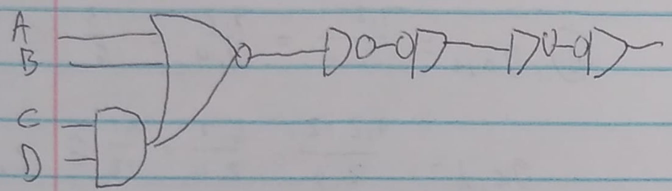
no bubble



e cont.

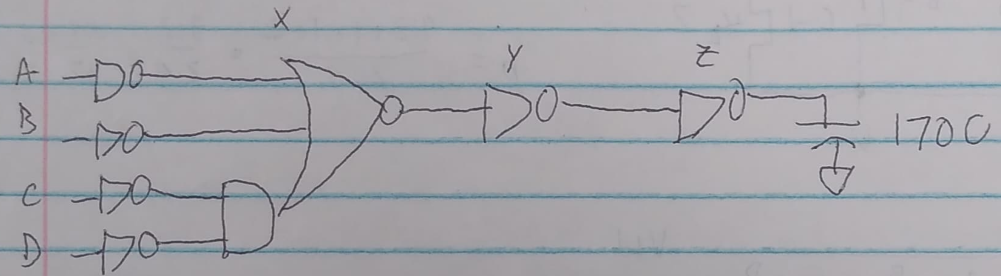
$D_3 = 3\sqrt[3]{170} + \left(\frac{41}{12} + 1 + 1\right)$
$= 22.036$

$D_4 = 4\sqrt[4]{170} + \left(1 + \frac{41}{12} + 1 + 1\right)$
$= 20.86$



$D_5 = 5\sqrt[5]{170} + \left(\frac{41}{12} + 1 + 1 + 1 + 1\right)$
$= 21.382$

f



$\hat{f} = g\frac{C_{out}}{C_{in}} \Leftrightarrow C_{in} = \frac{g}{\hat{f}} C_{out}$

$C_{inZ} = \frac{1}{\hat{f}}(170) = 47.08$

$C_{inY} = \frac{1}{\hat{f}}(C_{inZ}) = 13.038$

$C_{inX} = \frac{31(C_{inY})}{12\hat{f}} = 9.328$

$C_{in} = \frac{1}{\hat{f}}(C_{inX}) = 2.583$

*C_{inX} is on the and gate portion

$P_Z = \frac{1.4}{2.4} C_{inZ} = 27.463$
$N_Z = \frac{1}{2.4} C_{inZ} = 19.617$
$P_Y = \frac{1.4}{2.4} C_{inY} = 7.606$
$N_Y = \frac{1}{2.4} C_{inY} = 5.432$
$P_X = \frac{4.2}{6.2} C_{inX} = 6.319$
$N_X = \frac{2}{6.2} C_{inX} = 3.009$
$P_{in} = \frac{1.4}{2.4} C_{in} = 1.507$
$N_{in} = \frac{1}{2.4} C_{in} = 1.076$

$A\bar{B}C\bar{D}$ $\bar{A} \to A$ Falling

$\bar{A}\bar{B}\bar{C}\bar{D} \to AB\bar{C}\bar{D}$

$\bar{A}\bar{B}\bar{C}D$

Best falling $\bar{A}\bar{B}C\bar{D}$

OR

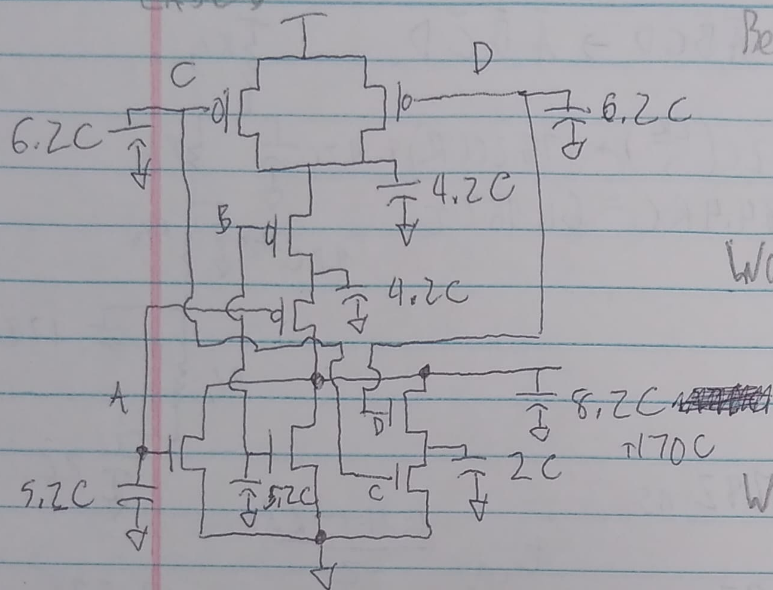
$\bar{A}\bar{B}\bar{C}\bar{D} \to AB\bar{C}\bar{D}$

OR

$\bar{A}\bar{B}\bar{C}D$

$\bar{A}\bar{B}\bar{C}\bar{D} \to AB\bar{C}\bar{D}$

9



Best Rising

$A\bar{B}\bar{C}\bar{D} \to \bar{A}\bar{B}\bar{C}\bar{D}$

Worst Falling

$\bar{A}\bar{B}\bar{C}D \to \bar{A}\bar{B}CD$

Worst Rising

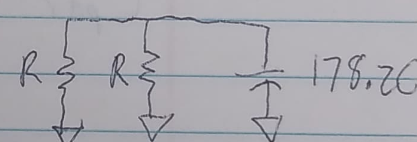
$\bar{A}\bar{B}CD \to \bar{A}\bar{B}\bar{C}D$

$C_{in,a,b} = 5.2C$

$C_{in,c,d} = 6.2C$

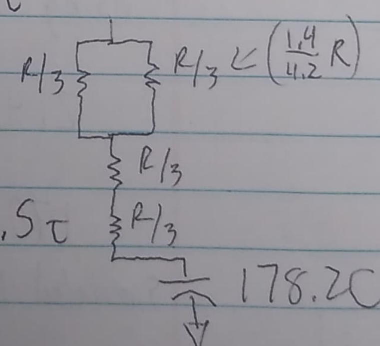
$C_{out} = 8.2C$

Best Case Falling $\bar{A}\bar{B}\bar{C}\bar{D} \to AB\bar{C}\bar{D}$



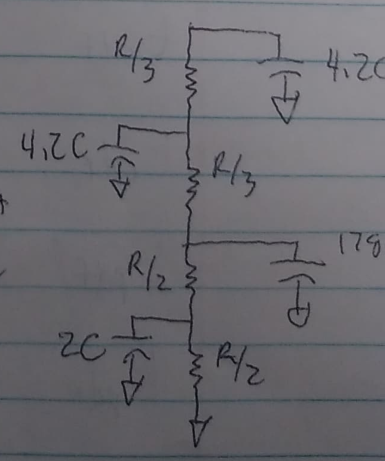
$t_{cdf} = 178.2C \cdot \frac{1}{2}R = 89.1RC = 29.7\tau$

Best Case Rising $A\bar{B}\bar{C}\bar{D} \to \bar{A}\bar{B}\bar{C}\bar{D}$



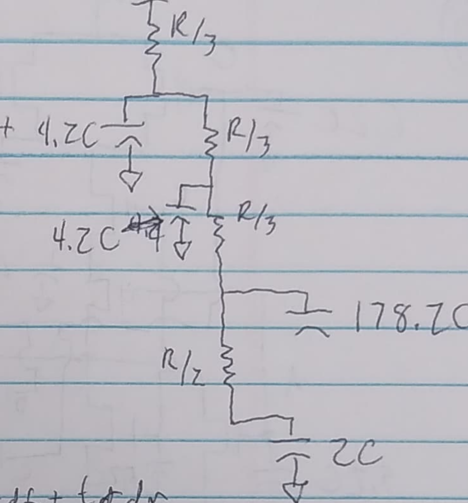
$t_{cdr} = 178.2C \cdot \left(\frac{R}{3} + \frac{R}{3} + \frac{R}{6}\right) = 148.5RC = 49.5\tau$

Worst Case Falling $\bar{A}\bar{B}\bar{C}D \to \bar{A}\bar{B}CD$



$t_{pdf} = 4.2C\left(\frac{R}{3} + \frac{R}{3} + \frac{R}{2} + \frac{R}{2}\right) + 4.2C\left(\frac{R}{3} + \frac{R}{2} + \frac{R}{2}\right) +$
$178.2C\left(\frac{R}{2} + \frac{R}{2}\right) + 2C\left(\frac{R}{2}\right) = 191.8RC$
$= 63.933\tau$

Worst Case Rising $\bar{A}\bar{B}CD \rightarrow \bar{A}\bar{B}\bar{C}D$



$$t_{pdr} = 4.2C\left(\frac{R}{3}\right) + 4.2C\left(\frac{2R}{3}\right) + 178.2C(R) + 2C(R) = 184.4RC = 61.467\tau$$

Using $\tau = 60\ ps$

$t_{cdf} = 29.7\tau = 1.782\ ns$

$t_{cdr} = 49.5\tau = 2.97\ ns$

$$t_{cd} = \frac{t_{cdf} + t_{cdr}}{2} = 2.376\ ns$$

$t_{pdf} = 63.933\tau = 3.836\ ns$

$$t_{pd} = \frac{t_{pdr} + t_{pdf}}{2} = 3.762\ ns$$

$t_{pdr} = 61.467\tau = 3.688\ ns$

Using input capacitance of unit inverter

$2.4C = 6.445\ fF \iff C = 2.685\ fF$

$170C = 456.52\ fF$

Simulated Results

h, i

	schematic	layout
t_{cdf}	2.491 ns	2.397 ns
t_{cdr}	2.162 ns	2.205 ns
t_{pdf}	5.047 ns	5.25 ns
t_{pdr}	2.777 ns	2.604 ns

Schematic $t_{cd} = 2.327$ ns $t_{pd} = 3.912$ ns

Layout $t_{cd} = 2.301$ ns $t_{pd} = 3.927$ ns

The results for propagation delay calculated by hand were both fairly close and fairly far away from actual results. The values ~~obtain~~ obtained for rising and falling best case were much closer to the average when calculated by hand, compared to the simulations. However, the average propagation delay calculated by hand was very close to the simulated average. I believe the differences are due to to simplistic Elmore delay model compared to the simulations the computer can run.