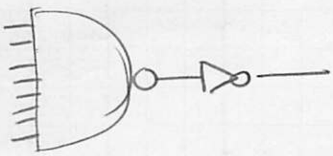
## Revisit AND gate

$\log_4(40) = 2.66$



$G = \frac{10}{3} \times 1$

$H = 12$

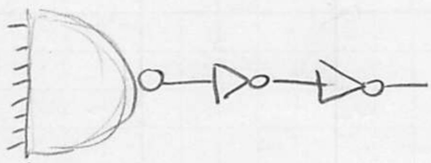
$B = 1$

$P = 8 + 1$

$F = GHB = \frac{10}{3} 12 = 40$

$F^{\frac{1}{2}} = 6.325$

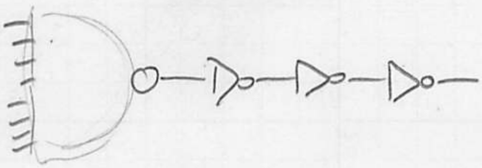
$\hat{D} = 2 \times 6.325 + 9 = 21.65$



$F = 40 \quad P = 10$

$F^{\frac{1}{3}} = 3.42$

$\hat{D} = 3 \times 3.42 + 10 = 20.26$



$F = 40 \quad P = 11$

$F^{\frac{1}{4}} = 2.51$

$\hat{D} = 4 \times 2.51 + 11 = 21.06$

## Problem 1

A) $G = 1 \times 2 \times 1 = 2$

$H = (32 \times 3)/10 = 9.6$

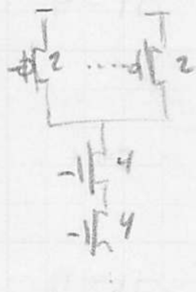
$B = 8$

$F = GHB = 2 \times 9.6 \times 8 = 153.6$

$\hat{f} = \sqrt[3]{153.6} = 5.36$

$\hat{D} = 3 \times 5.36 + (1 + 4 + 1)$

$= 16.08 + 6 = 22.08$




$g = \frac{6}{3} = 2$

$p = \frac{2 \times 4 + 4}{3} = 4$

B)

$$C_{IN,i} = \frac{g}{\hat{f}} C_{OUT}$$

$$C_{IN,Z} = \frac{1}{5.36}(32\times3) = 17.91$$

$$C_{IN,Y} = \frac{2}{5.36}(17.91) = 6.68$$

$$C_{IN,X} = \frac{1}{5.36}(6.68\times 8) = 9.97$$

↑ Branching effort (the $\times 8$)

C) $\log_4(153.6) = \frac{\log_{10}(153.6)}{\log_{10}(4)} = \frac{2.186}{0.602} = \underline{3.6}$

D) 8 input inverters

$$C_g = 8\times10 = 80C$$

$$C_d = 8\times10 = 80C$$

$$C_{TOT} = 160C$$

16 output inverters

$$C_g = 16\times17.9 = 286C$$

$$C_d = 16\times17.9 = 286C$$

$$C_{TOT} = 572C$$

16 NAND gates — 4 inputs

$$C_g = 4\times16\times6.68 = 427C$$

$$C_d = 16\times(4\times2.23 + 4.45) = 214C$$

$$C_{TOT} = 640C$$




$$C_{SW} = 160 + 572 + 640 + (16\times96) = \underline{2{,}908\,C}$$

## PROBLEM 2

A)
$G = 1 \times 1 \times 2 \times 1$
$H = (32 \times 3)/10 = 96$
$B = 8$
$F = GHB = 153.6$

} SAME AS BEFORE

$\hat{f} = \sqrt[4]{153.6} = 3.52$

$\hat{D} = 4 \times 3.52 + (1 + 1 + 4 + 1)$

$= 14.08 + 7 = 21.08$

$\frac{21.08}{22.08} = 0.954$ so 4.5% faster

B)
$C_{in,z} = \frac{1}{3.52}(32 \times 3) = 27.2$

$C_{in,y} = \frac{2}{3.52}(27.2) = 15.5$

$C_{in,x} = \frac{1}{3.52}(8 \times 15.5) = 35.23$

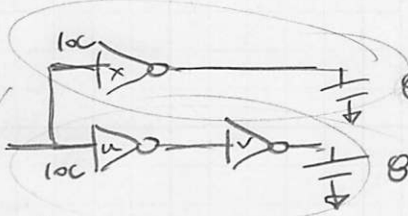
$C_{in,u} = \frac{1}{3.52}(35.23) = 10$

NOTE: Very different sizing for gates
AND overall $C_{sw}$ is much higher

Since performance benefit is minor and area/energy is so much higher, probably better off using the three stage design

## PROBLEM 3

FOCUS ON JUST THE FORK, OPTIMALLY SIZE EACH PATH




$8 \times 6.68C = 53C$

$8 \times 6.68C = 53C$

$G = 1$

$H = \frac{53C}{10C} = 5.3C$

$B = 1$

$F = GHB = 5.3$

$\hat{f} = \sqrt[2]{5.3} = 2.3$

$\hat{D} = 2 \times 2.3 + 2 = 6.6\tau$

$C_{IN} = \frac{g}{f} C_{OUT} = \frac{1}{2.3} 53 = 23C$

$d = gh + p$

$d = 1 \cdot \frac{53C}{10C} + 1 = 6.3\tau$

2 INVERTER BRANCH IS A BIT SLOWER

OVERALL DELAY THROUGH 2 INVERTER BRANCH IS

$d_u = 1 \cdot \frac{23}{10} + 1 = 2.3 + 1 = 3.3$

$d_v = 1 \cdot \frac{53}{23} + 1 = 2.3 + 1 = 3.3$

$d_y = 2 \cdot \frac{17.91}{6.68} + 4 = 5.36 + 4 = 9.36$

$d_z = 1 \cdot \frac{96}{17.91} + 1 = 5.36 + 1 = 6.36$

**22.32**

22.32 is pretty close to 22.08