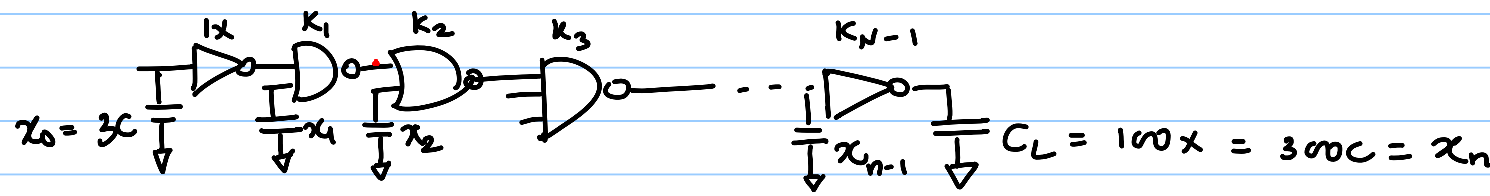
03/10/2019

EE 5311

MODULE 4 - COMBINATIONAL CIRCUITS

GATE SIZING



$N \rightarrow$ # of gates in the path.

$x_k \rightarrow$ I/P cap of the $(k+1)^{th}$ gate.

$d_k = g_k h_k + p_k.$

Minimize $d = \sum_{k=1}^{N} d_k$

$(x_1 \; x_2 \; \ldots \; x_n)$

$d = \sum (g_k h_k + p_k) = \sum g_k h_k + \sum p_k.$ not a fcn of $(x_0 \; x_1 \cdots x_n)$

min $\sum g_k h_k$.

Let

$f_k = g_k h_k$.

$h_k = \frac{\text{o/p load cap}}{\text{i/p cap}} = \frac{x_k}{x_{k-1}}$

$g_k =$ ind of $(x_0 \; x_1 \cdots x_n)$

$$\prod_{k=1}^{N} f_k = \prod g_k \cdot h_k = G\,H$$

$$G = \prod_{k=1}^{N} g_k \qquad H = \prod_{k=1}^{N} h_k$$

$G = \prod g_k$ = Const number = PATH LOGICAL EFFORT

$H = \prod h_k = \frac{x_1}{x_0} \cdot \frac{x_2}{x_1} \cdots \frac{x_N}{x_{N-1}} = \frac{x_N}{x_0}$ = PATH ELECTRICAL EFFORT

NOT a fn of $x_1\, x_2 \cdots x_{N-1}$

min $\sum f_k$. $\qquad \prod f_k$ = Constant

$$AM \geq GM \Rightarrow \frac{\sum_{k=1}^{N} f_k}{N} \geq \left(\prod_{k=1}^{N} f_k\right)^{1/N}$$

Soln to min problem.

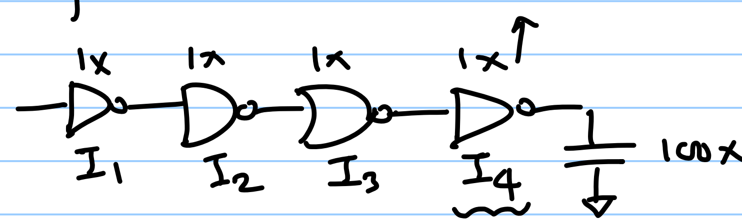
is $f_K = (GH)^{1/N}$

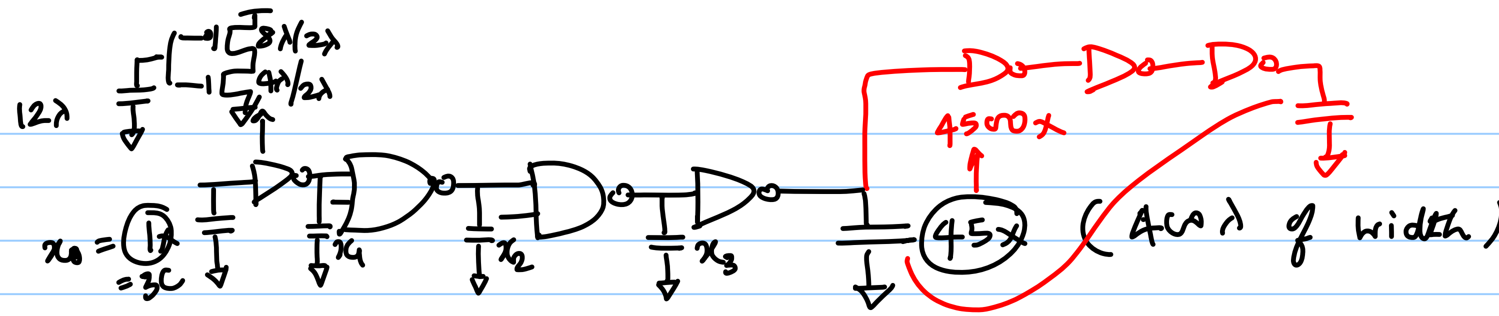
$\Rightarrow \sum f_K = N \cdot (GH)^{1/N}$

$\Rightarrow$ min delay $= \sum f_K + \sum p_K = N\,(GH)^{1/N} + P$

Let $GH = F$ = PATH EFFORT

f_K = STAGE EFFORT





g	1	$5/3$	$4/3$	1	$G = 20/9$
h	x_1	x_2/x_1	x_3/x_2	$45/x_3$	$H = \text{O/P CAP}/\text{I/P CAP} = 45$
p	1	2	2	1	$P = \sum p_k = 6$

$$(f_k = g h) \quad x_1 \quad \left(\tfrac{5}{3}\right)\left(\tfrac{x_2}{x_1}\right) \quad \left(\tfrac{4}{3}\right)\left(\tfrac{x_3}{x_2}\right) \quad \left(\tfrac{45}{x_3}\right) = 3.14$$

$$F = GH = 20/9 \times 45 = 100.$$

OPTIMAL STAGE EFFORT $= (F)^{1/N} = (100)^{1/4} \simeq 3.14$

$\Rightarrow$ MIN DELAY $= N \cdot (F^{1/N}) + P = 18.6$

$$f_k = 3.14$$

$$\frac{x_1}{1} = 3.14$$

$$\left(5/3\right)\left(x_2/x_1\right) = 3/4$$

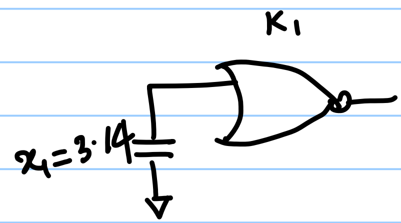
$$\Rightarrow \quad x_2 = \frac{3}{5} \times 3.14 \times (3.14) = 6$$

$$\frac{4}{3} \times \frac{x_3}{x_2} = 3.14$$

$$\Rightarrow \quad x_3 = \frac{3}{4} \times (3.14) \times 6 = 13.93$$

$$\left(\frac{x_4}{x_3}\right) = 3.14$$

$$\left(\frac{45}{13.93}\right) \sim 3.14$$



$$5 \cdot K_1 C = 3.14 \times 3C$$

$$\therefore \; K_1 = \frac{6 \times 3C}{5C} \implies K_1 = 3.6$$

$G = 20/9$

$H = 4500$

$\Rightarrow \quad F = (GH) = 10^4$

$\Rightarrow \quad \text{MIN DELAY} = N \cdot F^{1/N} + P$

$= 4 \times (10^4)^{1/4} + 6$

$= 46$

Stage effort $= f_K = F^{1/N} = 10$