

Class 12

D. W. Parent

EE224

Test Bench examples:

$$f=ab+ac+bc$$

Static (AOI or NAND)

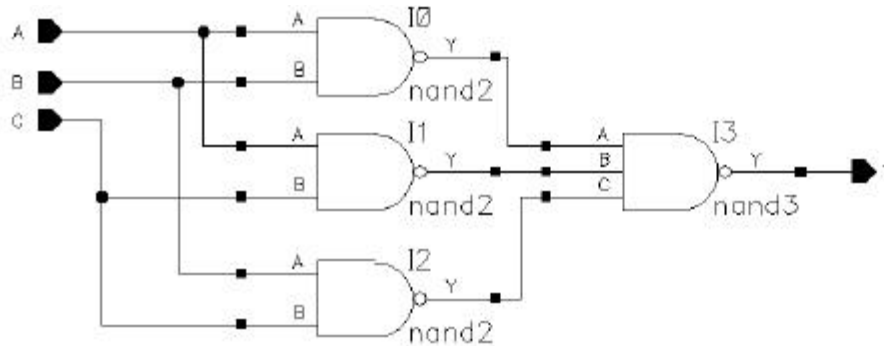
- Verify logic (NV verilog)
- Find worst case
- Toggle worst case to verify logic

Dynamic (AOI, AND/OR, DNAND, Static NAND)

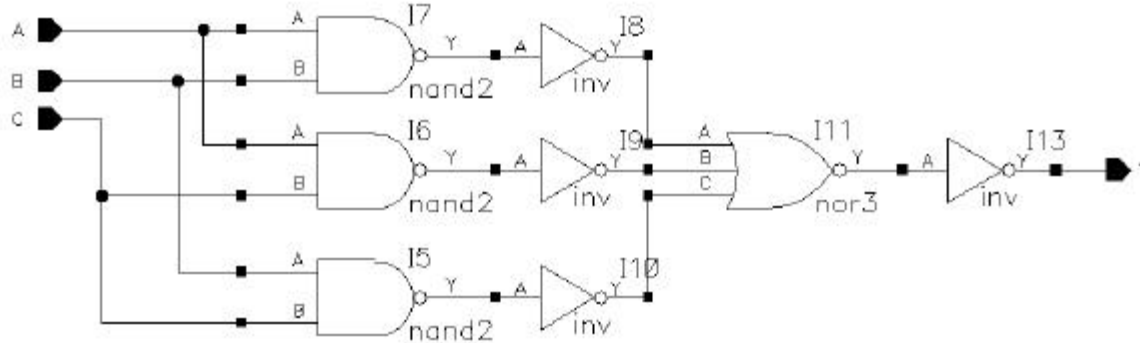
- Verify logic (NC verilog requires extra step)
- Decide, footed, weak keeper, clock phase, pre-charge evaluate times
- Test at low speeds
- Test at high speeds
- With a weak keeper you have to validate FS and SF model corners

We can use logic effort to decide which circuit topology to use.
Try static CMOS first.

nand/nand



and/or

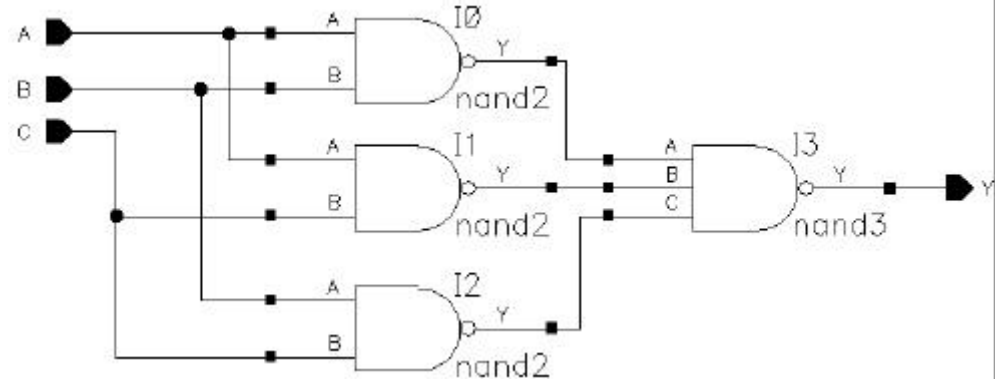


AOI



Review: For each implementation what is the worst case delay path?

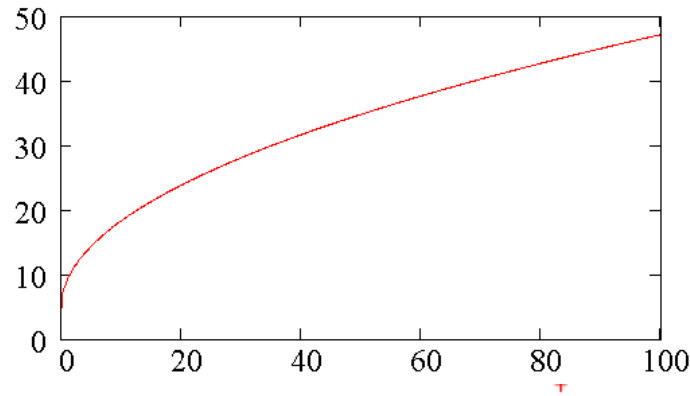
Logical Effort Nand/Nand.



$$G := \frac{4}{3} \cdot 1 \cdot \frac{5}{3} \cdot 1$$

$$P := 2 + 3$$

$$B := 1 \quad N := 2$$

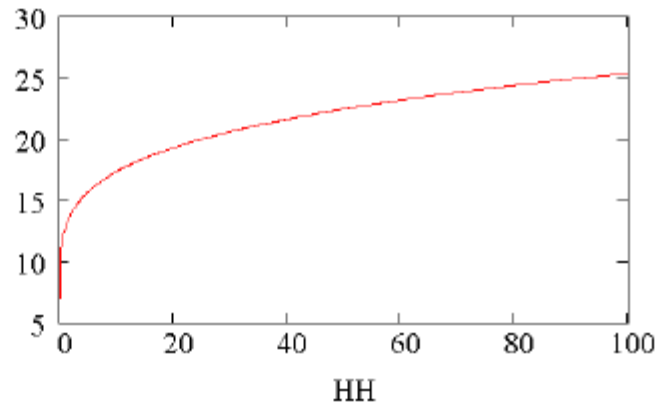


no buffer

$$\underline{N \cdot (G \cdot B \cdot 2HH)}^{\frac{1}{N} + P}$$

$$G := \frac{4}{3} \cdot 1 \cdot \frac{5}{3} \cdot 1 \cdot 1 \cdot 1$$

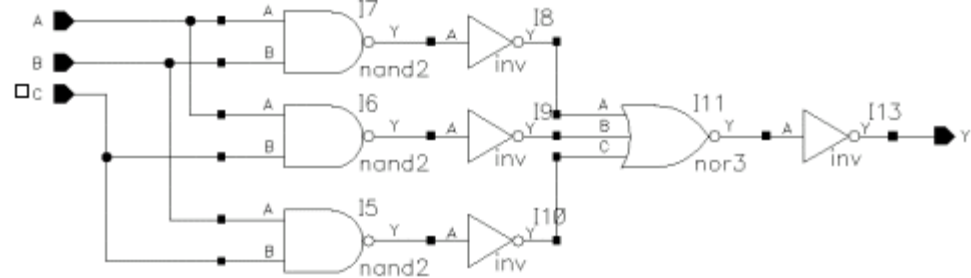
$$P := 2 + 3 + 1 + 1 \quad B := 1 \quad N := 4$$



with buffer

$$\underline{N \cdot (G \cdot B \cdot 2HH \cdot B)}^{\frac{1}{N} + P}$$

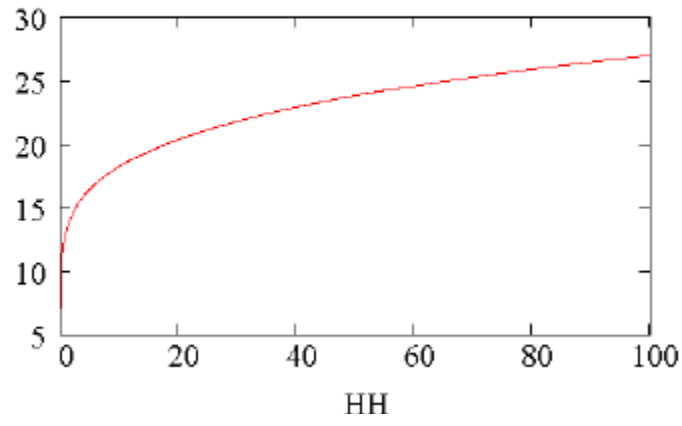
Logical Effort AND/OR



$$G := \frac{4}{3} \cdot 1 \cdot \frac{7}{3} \cdot 1$$

$$P := 2 + 1 + 3 + 1 \quad B := 1 \quad N := 4$$

$$\frac{N \cdot (G \cdot B \cdot 2HH)}{N} + P$$

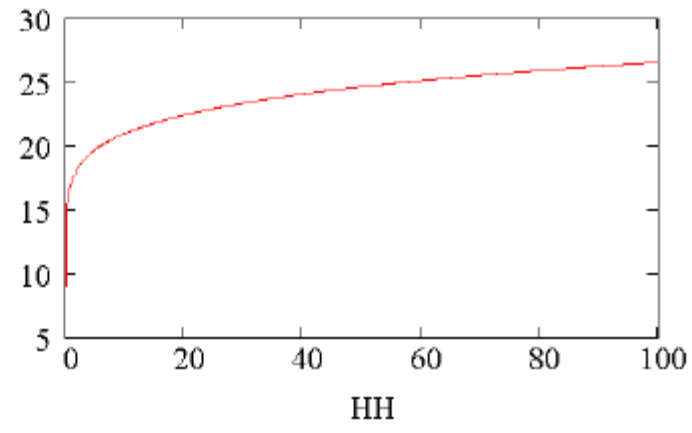


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$$G := \frac{4}{3} \cdot 1 \cdot \frac{7}{3} \cdot 1$$

$$P := 2 + 1 + 3 + 1 + 1 + 1 \quad B := 1 \quad N := 6$$

$$\frac{N \cdot (G \cdot B \cdot 2HH \cdot B)}{N} + P$$

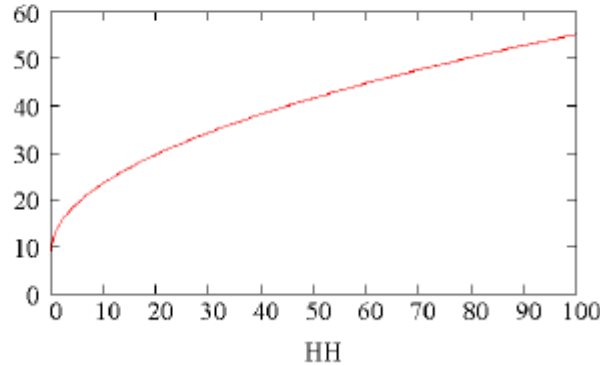


with buffer

Logical Effort AOI

$$G := \frac{6+2}{3} \cdot \frac{1}{1} \quad P := \frac{3 \cdot 6 + 3 \cdot 2}{3} + 1 \quad B := 2 \quad N := 2$$

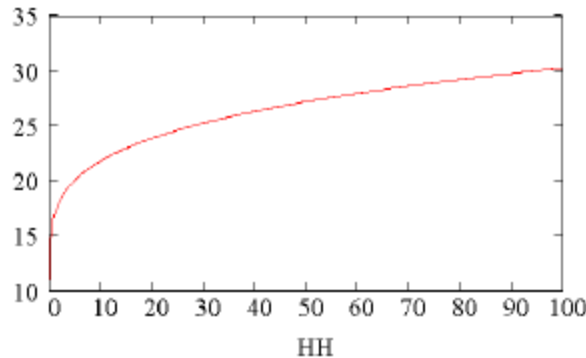
$$\frac{N \cdot (G \cdot B \cdot HH)^{\frac{1}{N}}}{N+P}$$



no buffer

$$G := \frac{6+2}{3} \cdot \frac{1}{1} \cdot \frac{1}{1} \cdot \frac{1}{1} \quad P := \frac{3 \cdot 6 + 3 \cdot 2}{3} + 1 + 1 + 1 \quad B := 2 \quad N := 4$$

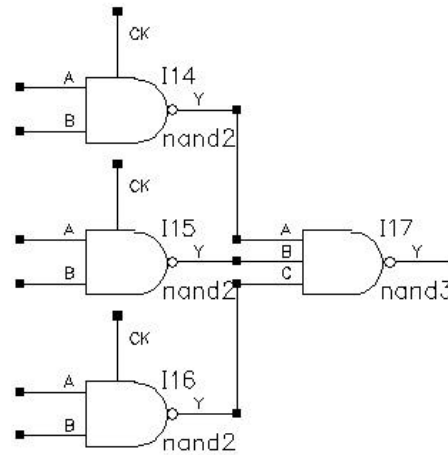
$$\frac{N \cdot (G \cdot B \cdot HH)^{\frac{1}{N}}}{N+P}$$



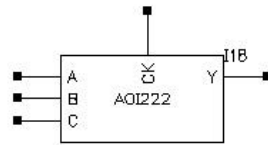
with two buffer

There are three dynamic implementations for this function.

dNAND/NAND

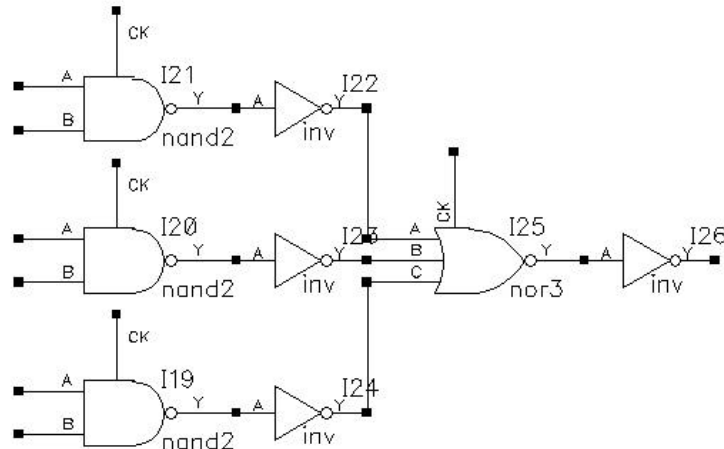


dAOI222



Test Bench?

dand/dor



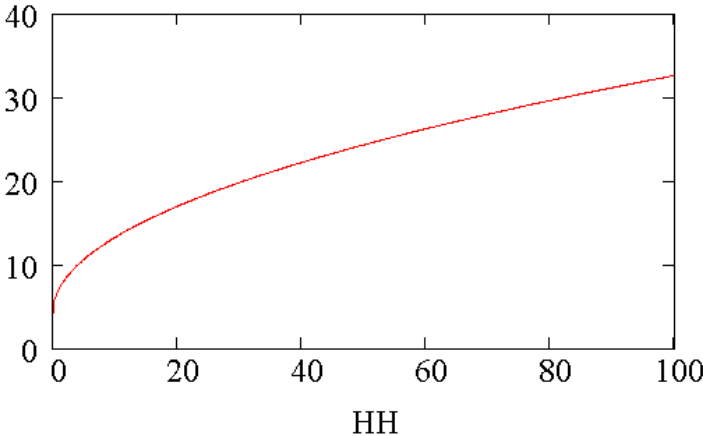
dAOI222

$$G := \frac{3}{3} \cdot 1$$

$$P := \frac{10}{3} + 1$$

$$B := 1 \quad N := 2$$

$$\frac{N \cdot (G \cdot B \cdot 2HH)^{\frac{1}{N}}}{N+P}$$

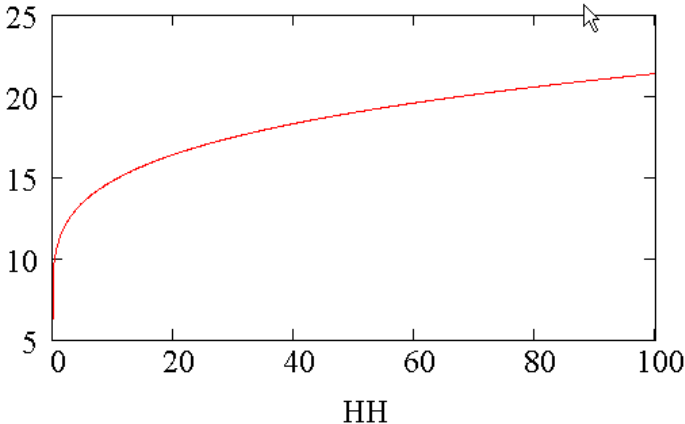


$$G := \frac{3}{3} \cdot 1 \cdot 1 \cdot 1$$

$$P := \frac{10}{3} + 1 + 1 + 1$$

$$B := 1 \quad N := 4$$

$$\frac{N \cdot (G \cdot B \cdot 2HH \cdot B)^{\frac{1}{N}}}{N+P}$$



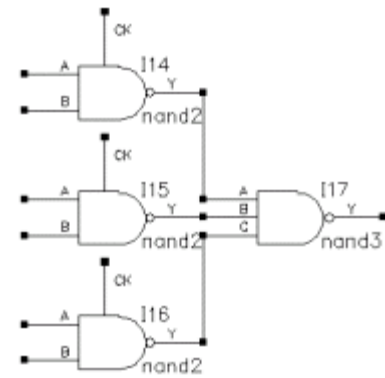
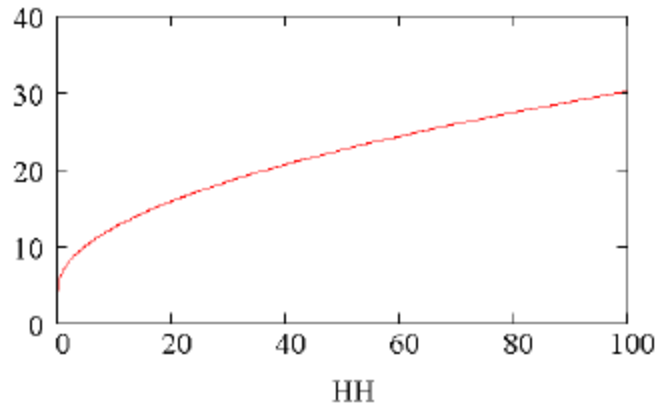
dNAND/NAND

$$G := \frac{3}{3} \cdot \frac{5}{3}^{1/3}$$

$$P := \frac{4}{3} + 3$$

$$B := 1 \quad N := 2$$

$$\frac{N \cdot (G \cdot B \cdot HH)}{N + P}$$

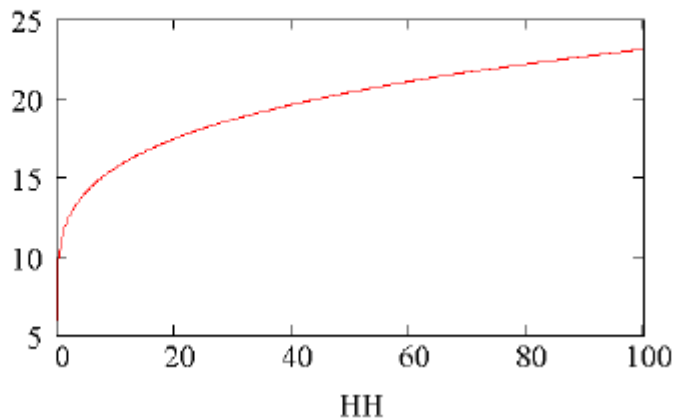


$$G := \frac{3}{3} \cdot \frac{5}{3} \cdot 1 \cdot 1$$

$$P := \frac{4}{4} + 3 + 1 + 1$$

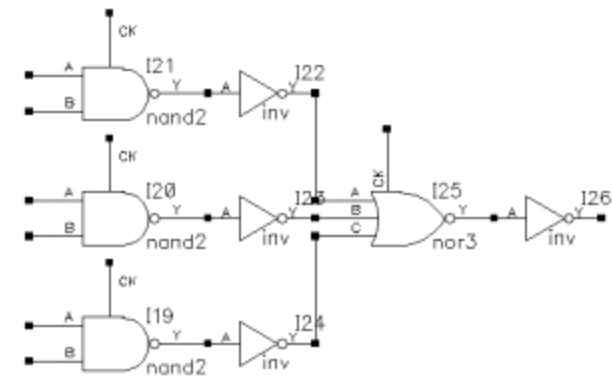
$$B := 1 \quad N := 4$$

$$\frac{N \cdot (G \cdot B \cdot 2HH \cdot B)}{N + P}$$

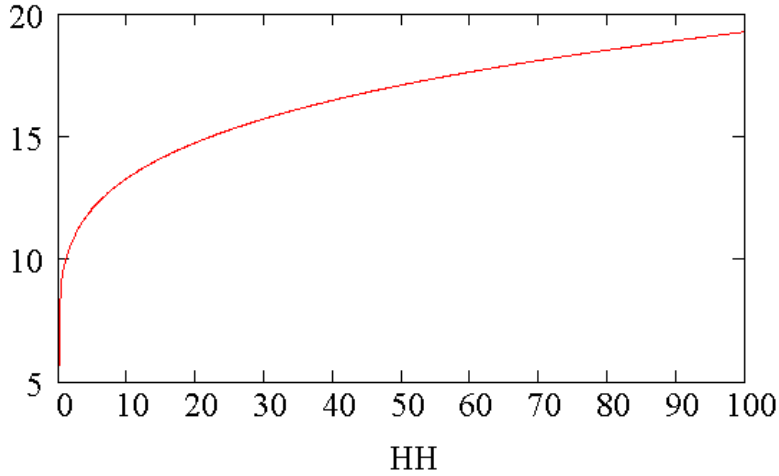


dAND/dOR

$$G := \frac{3}{3} \cdot \frac{1}{1} \cdot \frac{2}{3} \cdot \frac{1}{1} \quad P := \frac{4}{3} + 1 + \frac{7}{3} + 1 \quad B := 2 \quad N := 4$$

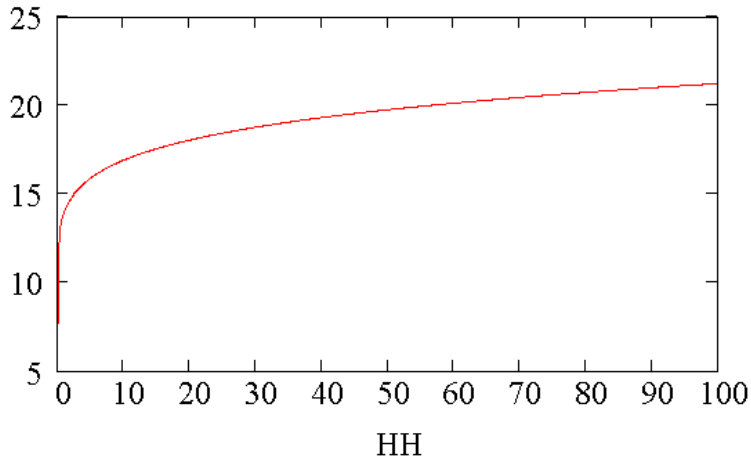


$$\underline{N \cdot (G \cdot B \cdot HH)}^{\frac{1}{N} + P}$$



$$G := \frac{3}{3} \cdot \frac{1}{1} \cdot \frac{2}{3} \cdot \frac{1}{1} \cdot \frac{1}{1} \cdot \frac{1}{1} \quad P := \frac{4}{3} + 1 + \frac{7}{3} + 1 + 1 + 1 \quad B := 2 \quad N := 6$$

$$\underline{N \cdot (G \cdot B \cdot HH)}^{\frac{1}{N} + P}$$



Would we get the same results if
we used our ratios and P?

$$g=2.16+1$$

Test Bench examples:

$$f=ab+bc+ac+(b \text{ xor } c)$$

Static (AOI or NAND)

- Verify logic (NV verilog)
- Find worst case
- Toggle worst case to verify logic

Dynamic (AOI, AND/OR, dynamic Nand/ static nand)

- Verify logic (NC verilog requires extra step)
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