Sizing Dynamic Gates

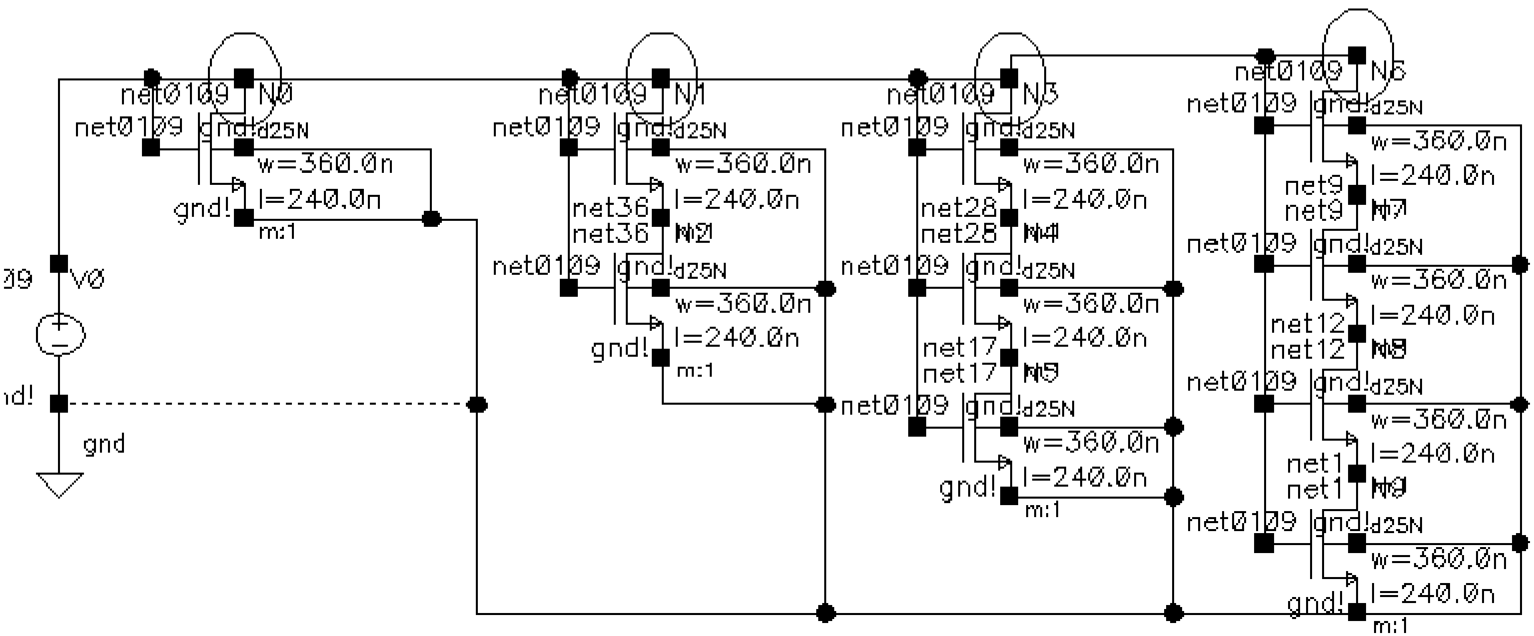
EE224

D. W Parent

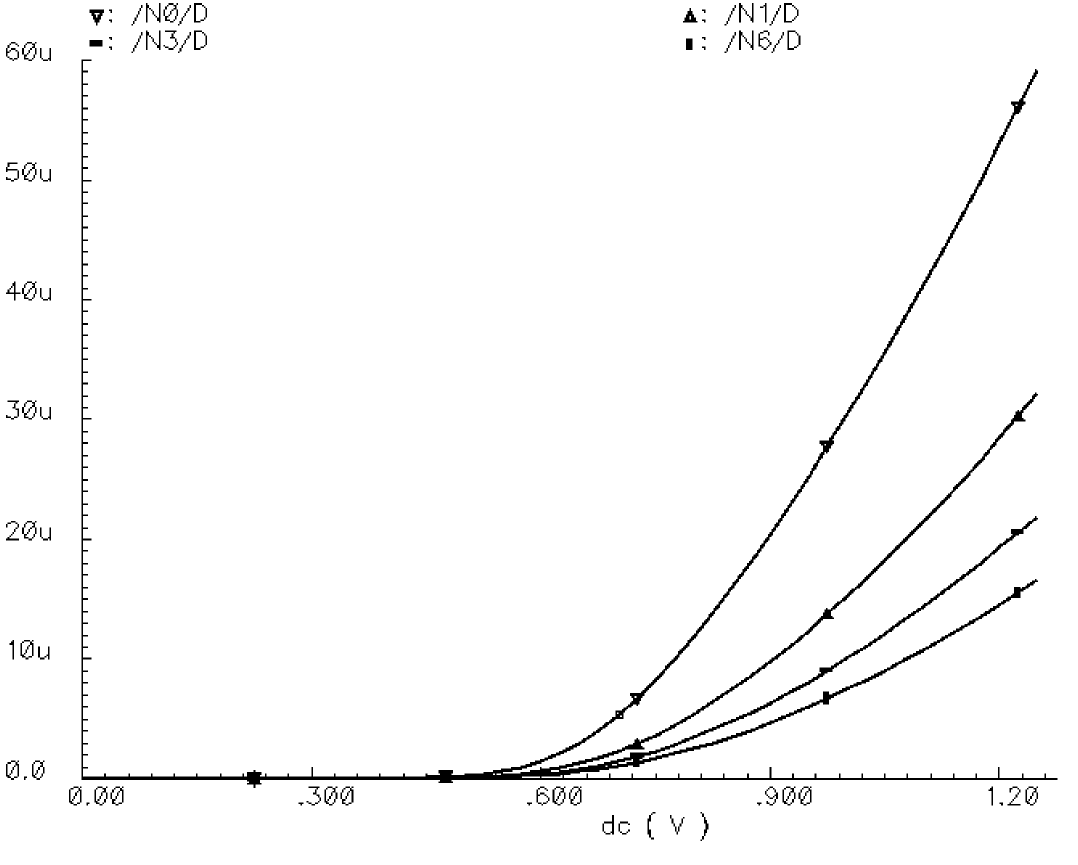
Equivalent Inverter Model Modifications

- We know to scale WN by 2 for a 2 input NAND, but:
  - What about velocity saturation?
  - What about the Body effect?
- Lets run some simulations of stacked transistors, and measure there respective currents.

Stacked NMOS



Stacked NMOS



Stacked NMOS

# Series (WN=360n)	Current	Relative Current	WN Scale Factor
1	59.166	1	1
2	32.15	0.543386404	1.8
3	21.93	0.370652064	2.7
4	16.59	0.280397526	3.6
# Series (WN=2u)	Current	Relative Current	WN Scale Factor
1	301	1	1
2	160	0.531561462	1.9
3	108	0.358803987	2.8
4	81	0.26910299	3.7
# Series (WN=2u)	Current	Relative Current	WN Scale Factor
1	1794	1	1
2	948	0.528428094	1.9
3	638	0.355629877	2.8
4	479	0.267001115	3.7

Stacked PMOS

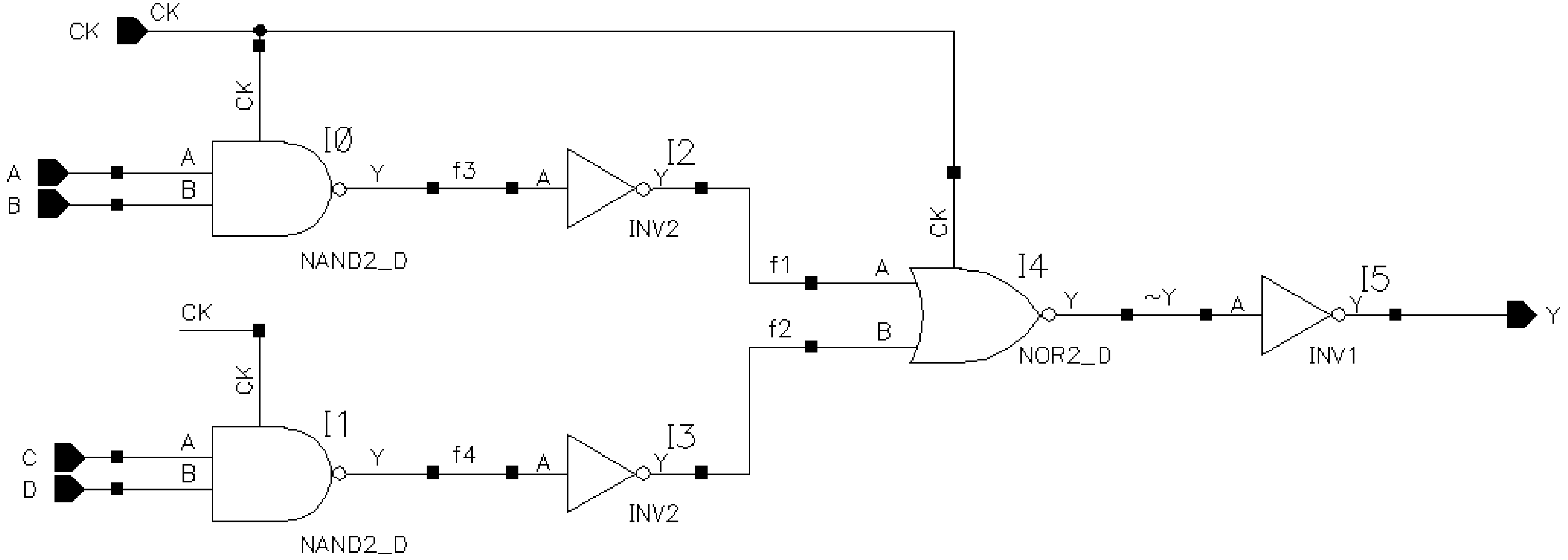
# Series WP=360n)	Current	Relative Current	WP Scale Factor
1	21	1	1
2	10	0.476190476	2.1
3	6.5	0.30952381	3.2
4	4.8	0.228571429	4.4
# Series (WP=1.98)	Current	Relative Current	WP Scale Factor
1	105	1	1
2	51	0.485714286	2.1
3	33.6	0.32	3.1
4	24.95	0.237619048	4.2
# Series (WP=12u)	Current	Relative Current	WP Scale Factor
1	654	1	1
2	312.6	0.477981651	2.1
3	203.9	0.3117737	3.2
4	151	0.23088685	4.3

Various Currents and Ratios

# Series (W=360n)	NMOS Current	PMOS Current	Ratio
1	59.166	21	2.8
2	32.15	10	3.2
3	21.93	6.5	3.4
4	16.59	4.8	3.5
# Series (W=1.98u)	Current	Current	
1	301	105	2.9
2	160	51	3.1
3	108	33.6	3.2
4	81	24.95	3.2
# Series (W=12u)	Current	Current	
1	1794	654	2.7
2	948	312.6	3
3	638	203.9	3.1
4	479	151	3.2

What happened to 2.322?

Example


CK
CK
CK
I0
A
B
A
B
Y
f3
A
I2
Y
INV2
NAND2_D
CK
I4
f1
A
Y
~Y
A
I5
Y
Y
f2
B
NOR2_D
INV1
CK
CK
I1
C
D
A
B
Y
f4
A
I3
Y
INV2
NAND2_D

How much time to assign each level?

- ¼ time
  - INV1 LH
  - NOR2 HL
  - INV2 LH
  - NAND2 HL
- ½ time
  - INV1 HL
  - NOR2 LH
  - INV2 HL
  - NAND2 LH

For the inverters we want the low to high transition ratio ½ the low to high.

For the nand/nor we want the low to high transition ration twice the low to high.

The propagation delays are no longer symmetric!

How do we modify our equations?

- R was a ratio that ensured symmetric propagation delays.
  - We modify R to take into account non symmetric delays.
    - R~2.322 gave us a $\tau_{plh}/\tau_{phl}=1$
    - We want for the inverters $\tau_{plh}/\tau_{phl}=1/2$
      - RNEW=R x 2
    - We want for the nand/nor $\tau_{plh}/\tau_{phl}=2$
      - RNEW=R/2 (Note: WN of the NAND is scaled by 1.9)

TSMC24 NAND3 Example

$A := 6150\Omega$ $\quad C_{JSWN} := 4.44\cdot 10^{-12}\frac{F}{cm}$ $\quad C_{JN} := 1.92\cdot 10^{-7}\frac{F}{cm^2}$ $\quad C_{GDO} := 6.27\cdot 10^{-12}\frac{F}{cm}$

$L_N := .24\cdot 10^{-4}cm$ $\quad K_{EQ} := \frac{-2\sqrt{.99}}{-2.5}\cdot\left(\sqrt{.99+2.5}-\sqrt{.99}\right)$ $\quad K_{EQ} = 0.695$ $\quad D_D := .6\cdot 10^{-4}cm$

$C_g := 10\cdot 10^{-15}F$ $\quad N := 5$ $\quad N_{SN} := 3$

$\tau_{PHL} := .2\cdot 10^{-9}s$ $\quad M := 3$ $\quad N_{SP} := 1$ $\quad S := 1$

$R := 2.322\cdot\frac{N_{SP}\cdot S}{N_{SN}}$ $\quad R = 0.774$

$$W_N := \frac{C_g + C_{JSWN}\cdot 2\cdot D_D\cdot K_{EQ}\cdot(N+M)}{\frac{\tau_{PHL}}{N_{SN}\cdot L_N\cdot A} - (N + M\cdot R)\cdot\left(C_{JSWN}\cdot 2K_{EQ} + C_{JN}\cdot D_D K_{EQ} + 2\cdot C_{GDO}\right)}$$

$W_N = 5.063\times 10^{-5}cm$ $\quad$ Note: Any W values below 360nm are non-physical solutions.

$W_P := R\cdot W_N$ $\quad W_P = 3.919\times 10^{-5}cm$

Final Values

$\tau_{PHL\_Measured} := (189 - 15) \cdot 10^{-12} s$ $\quad$ $Error := \frac{\tau_{PHL\_Measured} - \tau_{PHL}}{\tau_{PHL}} \cdot 100$ $\quad$ $Error = -13$

$\tau_{PLH\_Measured} := (2305 - 2025) \cdot 10^{-12} s$ $\quad$ $Error := \frac{\tau_{PLH\_Measured} - \tau_{PLH}}{\tau_{PLH}} \cdot 100$ $\quad$ $Error = 12$

$W_N := \frac{\tau_{PHL\_Measured}}{\tau_{PHL}} \cdot W_N$ $\quad$ $W_N = 4.405 \times 10^{-5} cm$

420

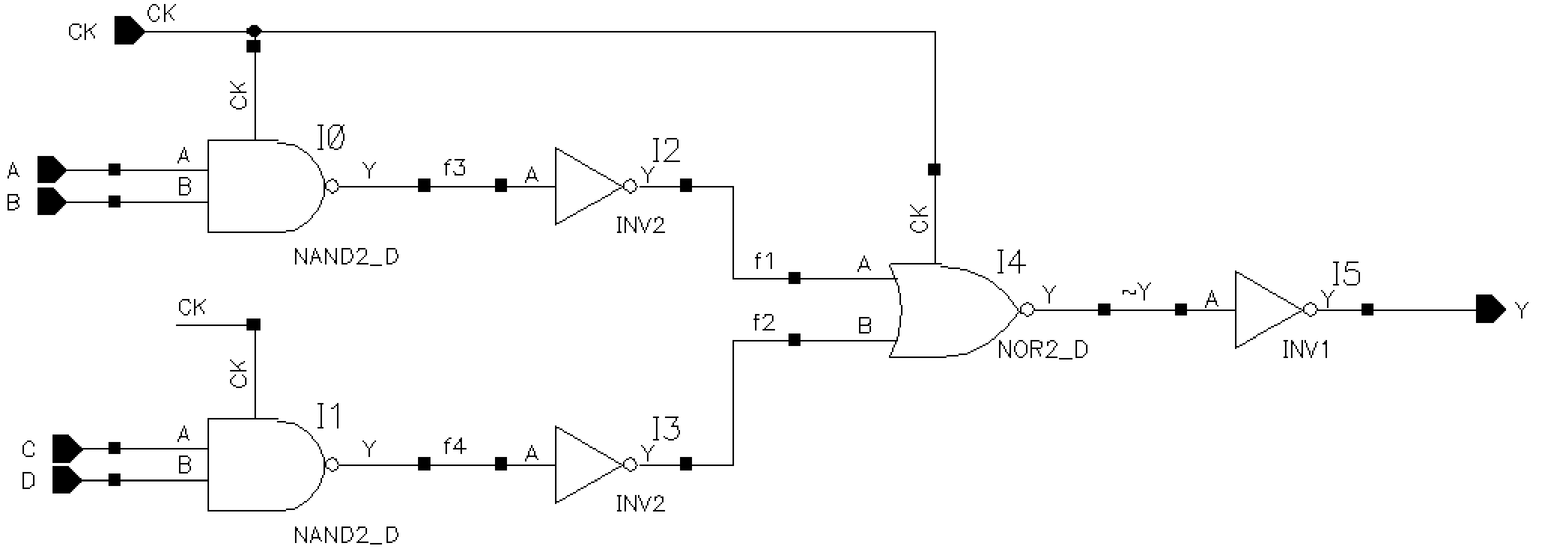
$W_P := \frac{\tau_{PLH\_Measured}}{\tau_{PLH}} \cdot W_P$ $\quad$ $W_P = 4.389 \times 10^{-5} cm$

$\tau_{PHL\_Measured} := (208 - 15) \cdot 10^{-12} s$ $\quad$ $Error := \frac{\tau_{PHL\_Measured} - \tau_{PHL}}{\tau_{PHL}} \cdot 100$ $\quad$ $Error = -3.5$

$\tau_{PLH\_Measured} := (2273 - 2025) \cdot 10^{-12} s$ $\quad$ $Error := \frac{\tau_{PLH\_Measured} - \tau_{PLH}}{\tau_{PLH}} \cdot 100$ $\quad$ $Error = -0.8$

In this case WN and WP both round to 420nm!

Dynamic Example



Design this circuit to work at 1GHz Clock with a 50% duty Cycle

How much time to assign each level?

- ¼ time
  - INV1 LH
  - NOR2 HL
  - INV2 LH
  - NAND2 HL
- ½ time
  - INV1 HL
  - NOR2 LH
  - INV2 HL
  - NAND2 LH

For the inverters we want the low to high transition ratio ½ the low to high.

For the nand/nor we want the low to high transition ration twice the low to high.

The propagation delays are no longer symmetric!

How do we assign the timing budget?

- T=1ns
- 1/2T=.5ns
- .1ns uncertainty in the clock so lets design for the time for A, B, C, or D to get to Y to be .4ns, or .1n for the fall times of the nand/nor and the rise time of the inverter
  - .2ns for the rise time of the nand/nor and the fall time of the inverter

Inverter 1

$A := 6150\Omega$ $\quad C_{JSWN} := 4.44\cdot 10^{-12}\frac{F}{cm}$ $\quad C_{JN} := 1.92\cdot 10^{-7}\frac{F}{cm^2}$ $\quad C_{GDO} := 6.27\cdot 10^{-12}\frac{F}{cm}$

$L_N := .24\cdot 10^{-4}cm$ $\quad K_{EQ} := \frac{-2\sqrt{.99}}{-2.5}\cdot\left(\sqrt{.99+2.5}-\sqrt{.99}\right)$ $\quad K_{EQ} = 0.695$ $\quad D_D := .6\cdot 10^{-4}cm$

$C_g := 10\cdot 10^{-15}F$ $\quad N := 1$ $\quad N_{SN} := 1$

$\tau_{PHL} := .1\cdot 10^{-9}s$ $\quad M := 1$ $\quad N_{SP} := 1$ $\quad S := 2$ $\quad R := 2.322\cdot\frac{N_{SP}\cdot S}{N_{SN}}$ $\quad R = 4.644$

$$W_N := \frac{C_g + C_{JSWN}\cdot 2\cdot D_D\cdot K_{EQ}\cdot(N+M)}{\frac{\tau_{PHL}}{N_{SN}\cdot L_N\cdot A} - (N + M\cdot R)\cdot\left(C_{JSWN}\cdot 2K_{EQ} + C_{JN}\cdot D_D K_{EQ} + 2\cdot C_{GDO}\right)}$$

$W_N = 2.039\times 10^{-5}cm$ $\quad$ Note: Any W values below 360nm are non-physical solutions.

$W_P := R\cdot W_N$ $\quad W_P = 1.672\times 10^{-4}cm$ $\quad W_N := 3.6\cdot 10^{-5}cm$ $\quad W_P := R\cdot W_N$ $\quad W_P = 1.672\times 10^{-4}cm$

Inverter 1

$$\tau_{PLH} := \tau_{PHL} \cdot \frac{1}{2}$$

$$\tau_{PHL\_Measured} := (116 - 15) \cdot 10^{-12} s \qquad Error := \frac{\tau_{PHL\_Measured} - \tau_{PHL}}{\tau_{PHL}} \cdot 100 \qquad Error = 1$$

$$\tau_{PLH\_Measured} := (2086 - 2025) \cdot 10^{-12} s \qquad Error := \frac{\tau_{PLH\_Measured} - \tau_{PLH}}{\tau_{PLH}} \cdot 100 \qquad Error = 22$$

$$\tau_{PLH\_Measured} = 6.1 \times 10^{-11} s$$

$$W_N := \frac{\tau_{PHL\_Measured}}{\tau_{PHL}} \cdot W_N \qquad W_N = 3.636 \times 10^{-5} cm$$

$$W_P := \frac{\tau_{PLH\_Measured}}{\tau_{PLH}} \cdot W_P \qquad W_P = 2.04 \times 10^{-4} cm$$

$$\tau_{PHL\_Measured} := (124 - 15) \cdot 10^{-12} s \qquad Error := \frac{\tau_{PHL\_Measured} - \tau_{PHL}}{\tau_{PHL}} \cdot 100 \qquad Error = 9$$

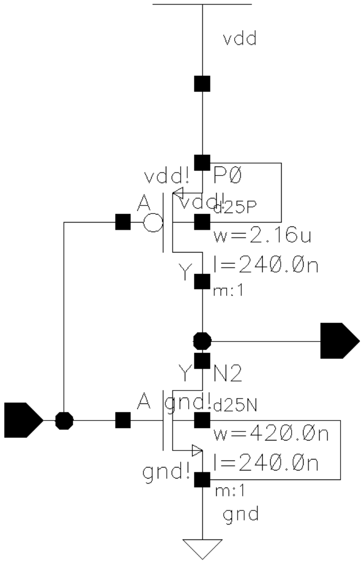
$$\tau_{PLH\_Measured} := (2078 - 2025) \cdot 10^{-12} s \qquad Error := \frac{\tau_{PLH\_Measured} - \tau_{PLH}}{\tau_{PLH}} \cdot 100 \qquad Error = 6$$

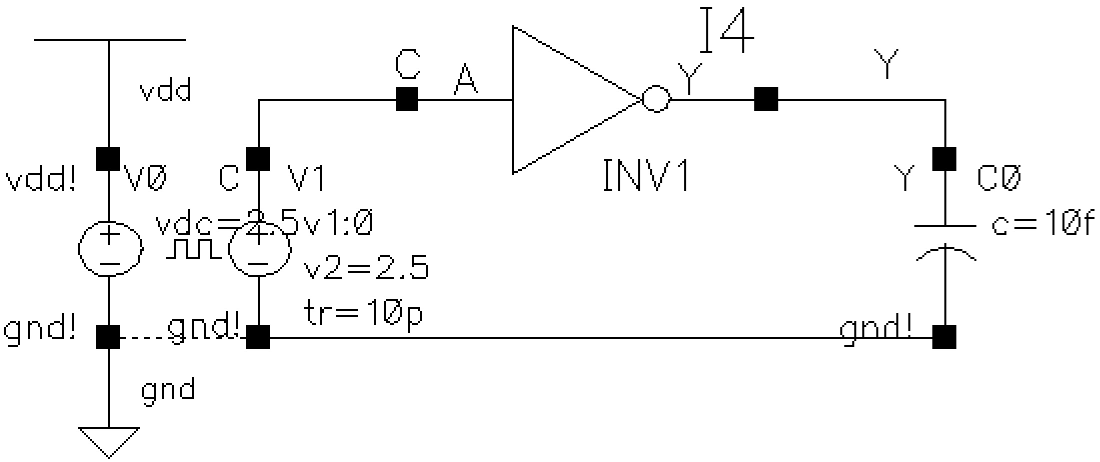
Inverter 1

$$W_N := \frac{\tau_{PHL\_Measured}}{\tau_{PHL}} \cdot W_N \qquad W_N = 3.963 \times 10^{-5}\,\text{cm}$$

$$W_P := \frac{\tau_{PLH\_Measured}}{\tau_{PLH}} \cdot W_P \qquad W_P = 2.162 \times 10^{-4}\,\text{cm}$$

WN rounds to 420n and WP rounds to 2.16u





NOR Dynamic

$A := 6150\Omega$ $\quad C_{JSWN} := 4.44 \cdot 10^{-12} \frac{F}{cm}$ $\quad C_{JN} := 1.92 \cdot 10^{-7} \frac{F}{cm^2}$ $\quad C_{GDO} := 6.27 \cdot 10^{-12} \frac{F}{cm}$

$L_N := .24 \cdot 10^{-4} cm$ $\quad K_{EQ} := \frac{-2\sqrt{.99}}{-2.5} \cdot \left(\sqrt{.99 + 2.5} - \sqrt{.99}\right)$ $\quad K_{EQ} = 0.695$ $\quad D_D := .6 \cdot 10^{-4} cm$

$C_g := 9.38 \cdot 10^{-15} F$ $\quad N := 3$ $\quad N_{SN} := 2$

$\tau_{PHL} := .1 \cdot 10^{-9} s$ $\quad M := 1$ $\quad N_{SP} := 1$ $\quad S := \frac{1}{2}$ $\quad R := 2.322 \cdot \frac{N_{SP} \cdot S}{N_{SN}}$ $\quad R = 0.58$

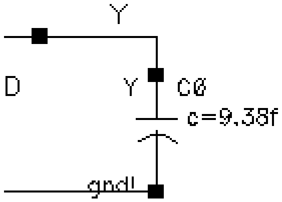
$$W_N := \frac{C_g + C_{JSWN} \cdot 2 \cdot D_D \cdot K_{EQ} \cdot (N + M)}{\frac{\tau_{PHL}}{N_{SN} \cdot L_N \cdot A} - (N + M \cdot R) \cdot \left(C_{JSWN} \cdot 2K_{EQ} + C_{JN} \cdot D_D K_{EQ} + 2 \cdot C_{GDO}\right)}$$

$W_N = 4.468 \times 10^{-5} cm$ $\quad$ Note: Any W values below 360nm are non-physical solutions.

$W_P := R \cdot W_N$ $\quad W_P = 2.594 \times 10^{-5} cm$ $\quad W_P := 3.6 \cdot 10^{-5} cm$ $\quad W_N := \frac{W_N}{R}$ $\quad W_N = 7.697 \times 10^{-5} cm$

NOR Dynamic

$$\tau_{PLH} := \tau_{PHL} \cdot 2$$



$$\tau_{PHL\_Measured} := (102 - 15) \cdot 10^{-12} s \qquad Error := \frac{\tau_{PHL\_Measured} - \tau_{PHL}}{\tau_{PHL}} \cdot 100 \qquad Error = -13$$

$$\tau_{PLH\_Measured} := (2311 - 2025) \cdot 10^{-12} s \qquad Error := \frac{\tau_{PLH\_Measured} - \tau_{PLH}}{\tau_{PLH}} \cdot 100 \qquad Error = 43$$

$$W_N := \frac{\tau_{PHL\_Measured}}{\tau_{PHL}} \cdot W_N \qquad W_N = 6.696 \times 10^{-5} cm$$

$$W_P := \frac{\tau_{PLH\_Measured}}{\tau_{PLH}} \cdot W_P \qquad W_P = 3.709 \times 10^{-5} cm$$

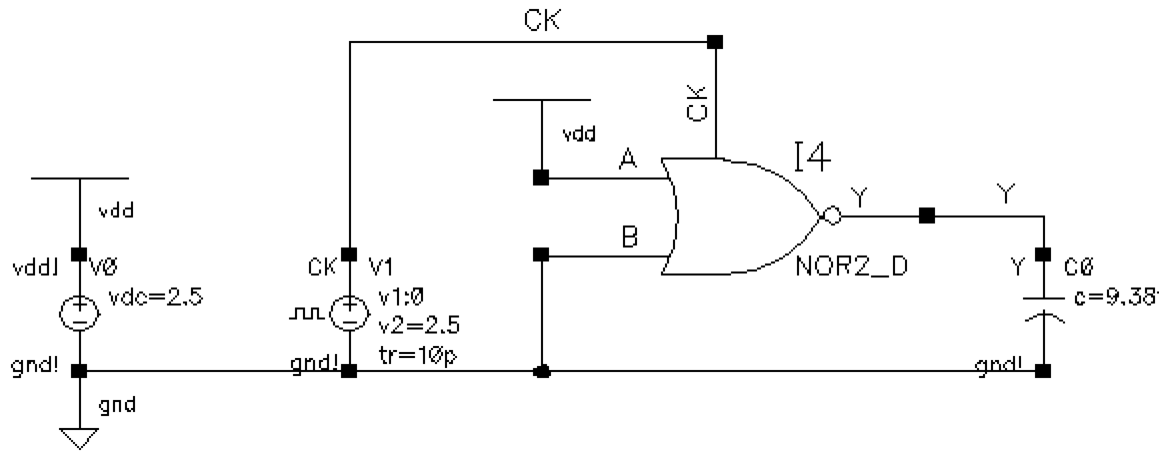
$$\tau_{PHL\_Measured} := (108 - 15) \cdot 10^{-12} s \qquad Error := \frac{\tau_{PHL\_Measured} - \tau_{PHL}}{\tau_{PHL}} \cdot 100 \qquad Error = -7$$

$$\tau_{PLH\_Measured} := (2290 - 2025) \cdot 10^{-12} s \qquad Error := \frac{\tau_{PLH\_Measured} - \tau_{PLH}}{\tau_{PLH}} \cdot 100 \qquad Error = 32.5$$

$$W_N := \frac{\tau_{PHL\_Measured}}{\tau_{PHL}} \cdot W_N \qquad W_N = 6.228 \times 10^{-5} cm$$

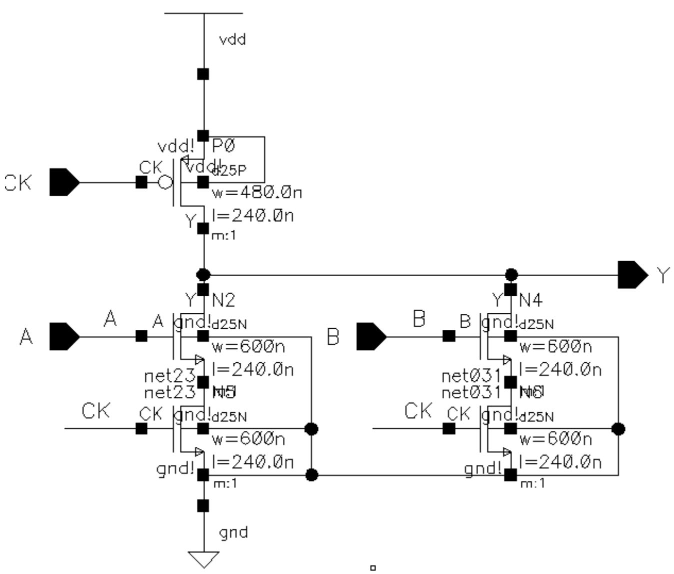
$$W_P := \frac{\tau_{PLH\_Measured}}{\tau_{PLH}} \cdot W_P \qquad W_P = 4.914 \times 10^{-5} cm$$

NOR Dynamic



$$\tau_{PHL\_Measured} := (114 - 15) \cdot 10^{-12}\,s \qquad Error := \frac{\tau_{PHL\_Measured} - \tau_{PHL}}{\tau_{PHL}} \cdot 100 \qquad Error = -1$$

$$\tau_{PLH\_Measured} := (2233 - 2025) \cdot 10^{-12}\,s \qquad Error := \frac{\tau_{PLH\_Measured} - \tau_{PLH}}{\tau_{PLH}} \cdot 100 \qquad Error = 4$$



WN rounds to 600nm and WP rounds to 480nm

Inverter 2

$A := 6150\Omega$ $\quad C_{JSWN} := 4.44\cdot10^{-12}\frac{F}{cm}$ $\quad C_{JN} := 1.92\cdot10^{-7}\frac{F}{cm^2}$ $\quad C_{GDO} := 6.27\cdot10^{-12}\frac{F}{cm}$

$L_N := .24\cdot10^{-4}cm$ $\quad K_{EQ} := \frac{-2\sqrt{.99}}{-2.5}\cdot\left(\sqrt{.99+2.5}-\sqrt{.99}\right)$ $\quad K_{EQ} = 0.695$ $\quad D_D := .6\cdot10^{-4}cm$

$C_g := 1.5\cdot10^{-15}F$ $\quad N := 1$ $\quad N_{SN} := 1$

$\tau_{PHL} := .1\cdot10^{-9}s$ $\quad M := 1$ $\quad N_{SP} := 1$ $\quad S := 2$ $\quad R := 2.322\cdot\frac{N_{SP}\cdot S}{N_{SN}}$ $\quad R = 4.644$

$$W_N := \frac{C_g + C_{JSWN}\cdot2\cdot D_D\cdot K_{EQ}\cdot(N+M)}{\frac{\tau_{PHL}}{N_{SN}\cdot L_N\cdot A} - (N+M\cdot R)\cdot\left(C_{JSWN}\cdot2K_{EQ} + C_{JN}\cdot D_D K_{EQ} + 2\cdot C_{GDO}\right)}$$

$W_N = 4.254\times10^{-6}cm$

Note: Any W values below 360nm are non-physical solutions.

$W_P := R\cdot W_N$ $\quad W_P = 1.976\times10^{-5}cm$ $\quad W_P := 3.6\cdot10^{-5}cm$ $\quad W_N := \frac{W_N}{R}$ $\quad W_N = 9.16\times10^{-7}cm$

Note: This is still non-physical set WN=WP=360n

$W_N := .360\cdot10^{-4}cm$ $\quad W_P := W_N$

Inverter 2

$$\tau_{PLH} := \tau_{PHL} \cdot \frac{1}{2}$$

$$\tau_{PHL\_Measured} := (43 - 15) \cdot 10^{-12} s \qquad Error := \frac{\tau_{PHL\_Measured} - \tau_{PHL}}{\tau_{PHL}} \cdot 100 \qquad Error = -72$$

$$\tau_{PLH\_Measured} := (2089 - 2025) \cdot 10^{-12} s \qquad Error := \frac{\tau_{PLH\_Measured} - \tau_{PLH}}{\tau_{PLH}} \cdot 100 \qquad Error = 28$$

$$W_N := \frac{\tau_{PHL\_Measured}}{\tau_{PHL}} \cdot W_N \qquad W_N = 1.008 \times 10^{-5} cm \qquad W_N := .360 \cdot 10^{-4} cm$$

$$W_P := \frac{\tau_{PLH\_Measured}}{\tau_{PLH}} \cdot W_P \qquad W_P = 4.608 \times 10^{-5} cm$$

Inverter 2

$\tau_{PHL\_Measured} := (45 - 15) \cdot 10^{-12} s$ $\quad$ $Error := \frac{\tau_{PHL\_Measured} - \tau_{PHL}}{\tau_{PHL}} \cdot 100$ $\quad$ $Error = -70$

$\tau_{PLH\_Measured} := (2080 - 2025) \cdot 10^{-12} s$ $\quad$ $Error := \frac{\tau_{PLH\_Measured} - \tau_{PLH}}{\tau_{PLH}} \cdot 100$ $\quad$ $Error = 10$

$W_N := \frac{\tau_{PHL\_Measured}}{\tau_{PHL}} \cdot W_N$ $\quad$ $W_N = 1.08 \times 10^{-5} cm$ $\quad$ $W_N := .360 \cdot 10^{-4} cm$

$W_P := \frac{\tau_{PLH\_Measured}}{\tau_{PLH}} \cdot W_P$ $\quad$ $W_P = 5.069 \times 10^{-5} cm$

$\tau_{PHL\_Measured} := (46 - 15) \cdot 10^{-12} s$ $\quad$ $Error := \frac{\tau_{PHL\_Measured} - \tau_{PHL}}{\tau_{PHL}} \cdot 100$ $\quad$ $Error = -69$

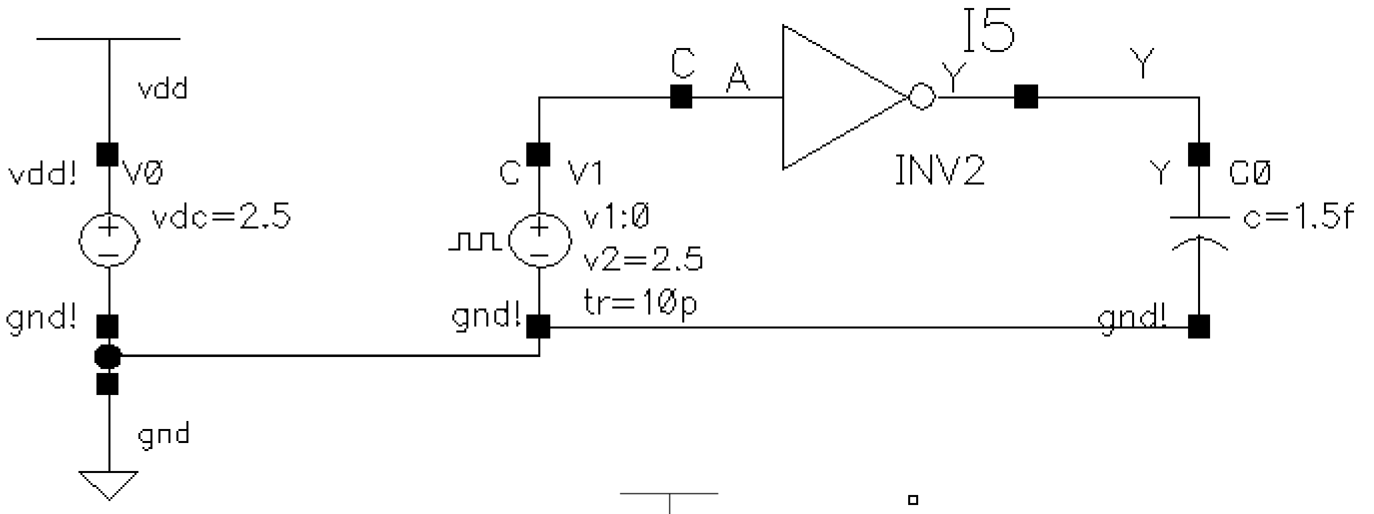
$\tau_{PLH\_Measured} := (2077 - 2025) \cdot 10^{-12} s$ $\quad$ $Error := \frac{\tau_{PLH\_Measured} - \tau_{PLH}}{\tau_{PLH}} \cdot 100$ $\quad$ $Error = 4$

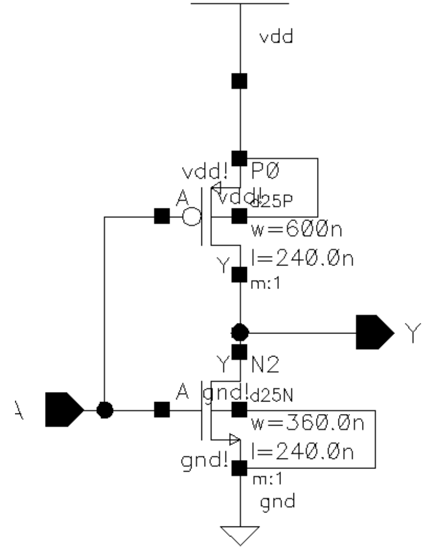
I just picked WP=600n
WN=360n

$\tau_{PHL\_Measured} := (48 - 15) \cdot 10^{-12} s$ $\quad$ $Error := \frac{\tau_{PHL\_Measured} - \tau_{PHL}}{\tau_{PHL}} \cdot 100$ $\quad$ $Error = -67$

$\tau_{PLH\_Measured} := (2074 - 2025) \cdot 10^{-12} s$ $\quad$ $Error := \frac{\tau_{PLH\_Measured} - \tau_{PLH}}{\tau_{PLH}} \cdot 100$ $\quad$ $Error = -2$

Inverter 2


vdd
vdd!
V0
vdc=2.5
gnd!
gnd
C
C
A
I5
Y
Y
INV2
V1
v1:0
v2=2.5
tr=10p
gnd!
Y
C0
c=1.5f
gnd!


vdd
vdd!
P0
A
vdd!
d25P
w=600n
l=240.0n
Y
m:1
Y
Y
N2
A
gnd!
d25N
w=360.0n
l=240.0n
gnd!
m:1
gnd

Nand Dynamic

$A := 6150\Omega$ $\quad C_{JSWN} := 4.44\cdot 10^{-12}\frac{F}{cm}$ $\quad C_{JN} := 1.92\cdot 10^{-7}\frac{F}{cm^2}$ $\quad C_{GDO} := 6.27\cdot 10^{-12}\frac{F}{cm}$

$L_N := .24\cdot 10^{-4}cm$ $\quad K_{EQ} := \frac{-2\sqrt{.99}}{-2.5}\cdot\left(\sqrt{.99+2.5}-\sqrt{.99}\right)$ $\quad K_{EQ} = 0.695$ $\quad D_D := .6\cdot 10^{-4}cm$

$C_g := 3.5\cdot 10^{-15}F$ $\quad N := 5$ $\quad N_{SN} := 3$

$\tau_{PHL} := .1\cdot 10^{-9}s$ $\quad M := 1$ $\quad N_{SP} := 1$ $\quad S := \frac{1}{2}$ $\quad R := 2.322\cdot\frac{N_{SP}\cdot S}{N_{SN}}$ $\quad R = 0.387$

$$W_N := \frac{C_g + C_{JSWN}\cdot 2\cdot D_D\cdot K_{EQ}\cdot(N+M)}{\frac{\tau_{PHL}}{N_{SN}\cdot L_N\cdot A} - (N + M\cdot R)\cdot\left(C_{JSWN}\cdot 2K_{EQ} + C_{JN}\cdot D_D K_{EQ} + 2\cdot C_{GDO}\right)}$$

$W_N = 6.986\times 10^{-5}\,cm$ $\qquad$ Note: Any W values below 360nm are non-physical solutions.

$W_P := R\cdot W_N$ $\quad W_P = 2.704\times 10^{-5}\,cm$

$\tau_{PLH} := 2\cdot\tau_{PHL}$ $\quad W_P := .36\cdot 10^{-4}cm$ $\quad W_N := \frac{W_P}{R}$ $\quad W_N = 9.302\times 10^{-5}\,cm$

Nand Dynamic

$\tau_{PHL\_Measured} := (101 - 15) \cdot 10^{-12} s$ $\quad$ $Error := \frac{\tau_{PHL\_Measured} - \tau_{PHL}}{\tau_{PHL}} \cdot 100$ $\quad$ $Error = -14$

$\tau_{PLH\_Measured} := (2304 - 2025) \cdot 10^{-12} s$ $\quad$ $Error := \frac{\tau_{PLH\_Measured} - \tau_{PLH}}{\tau_{PLH}} \cdot 100$ $\quad$ $Error = 39.5$

$W_N := \frac{\tau_{PHL\_Measured}}{\tau_{PHL}} \cdot W_N$ $\quad$ $W_N = 8 \times 10^{-5} cm$

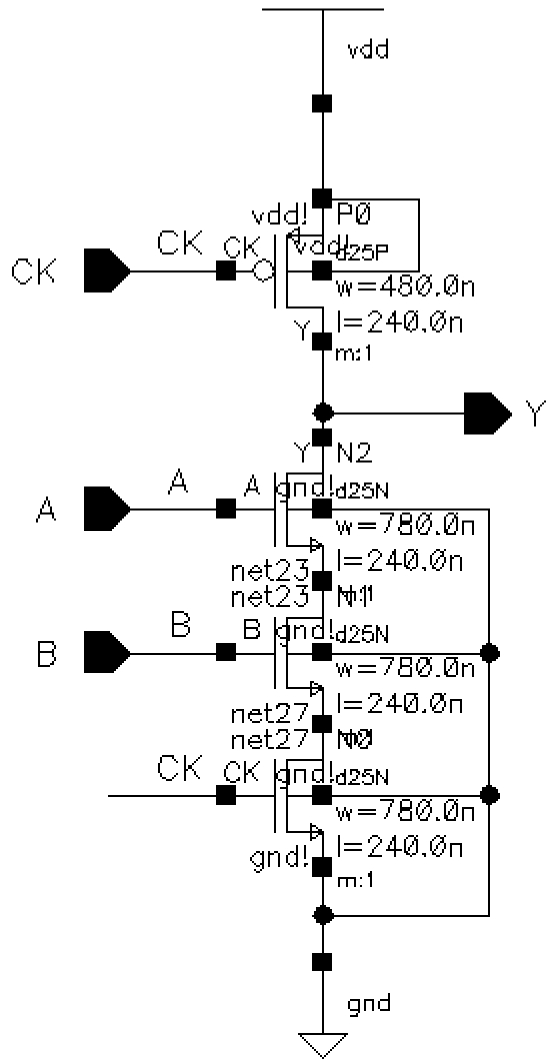
$W_P := \frac{\tau_{PLH\_Measured}}{\tau_{PLH}} \cdot W_P$ $\quad$ $W_P = 5.022 \times 10^{-5} cm$

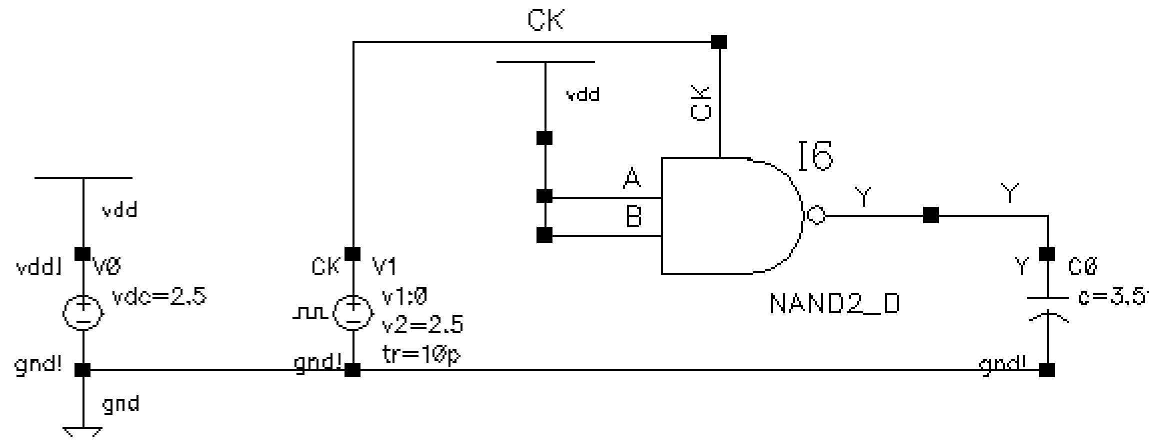
$\tau_{PHL\_Measured} := (108 - 15) \cdot 10^{-12} s$ $\quad$ $Error := \frac{\tau_{PHL\_Measured} - \tau_{PHL}}{\tau_{PHL}} \cdot 100$ $\quad$ $Error = -7$

$\tau_{PLH\_Measured} := (2218 - 2025) \cdot 10^{-12} s$ $\quad$ $Error := \frac{\tau_{PLH\_Measured} - \tau_{PLH}}{\tau_{PLH}} \cdot 100$ $\quad$ $Error = -3.5$

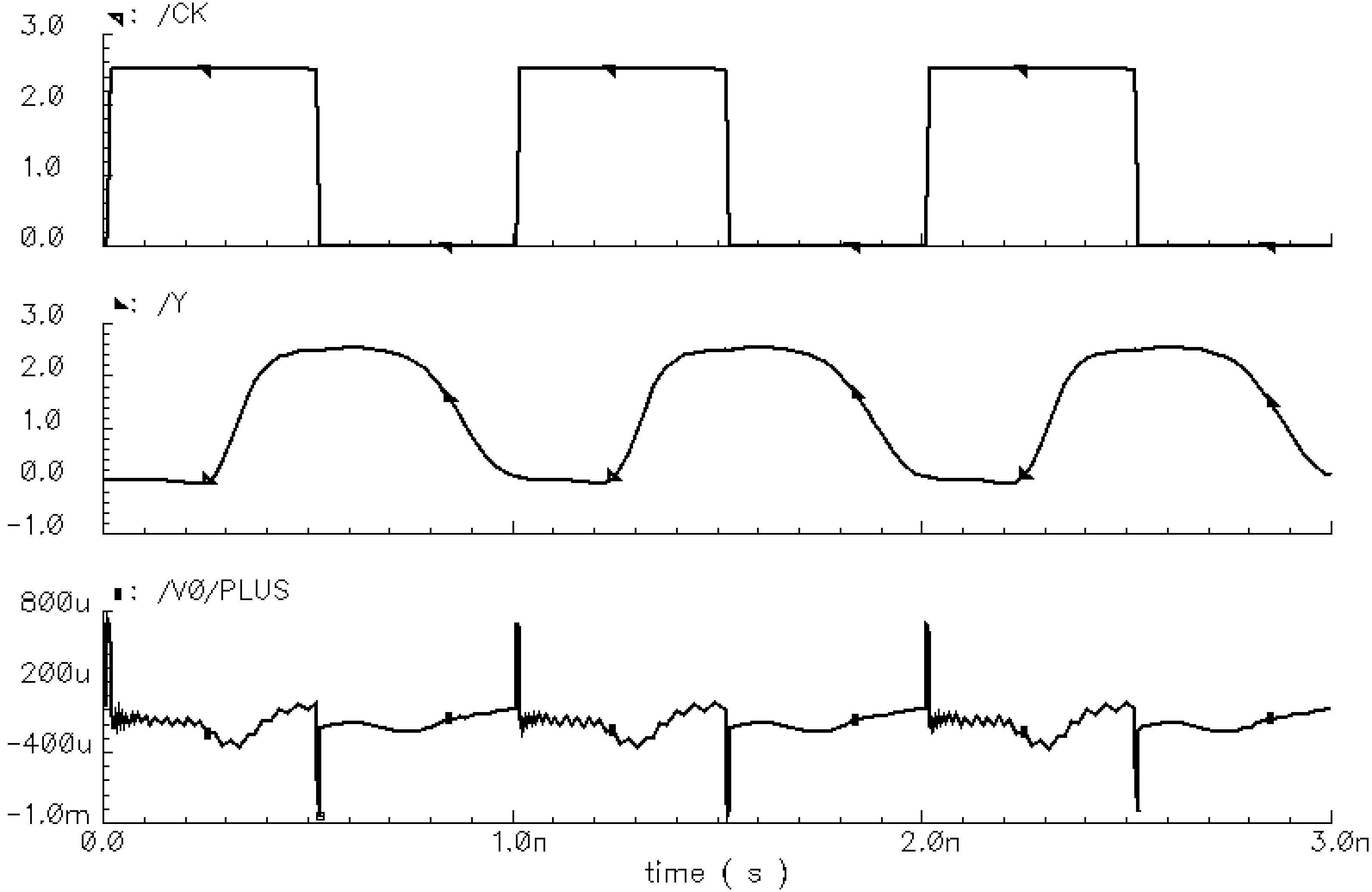
WN rounded to 780n and WP to 480n

Nand Dynamic



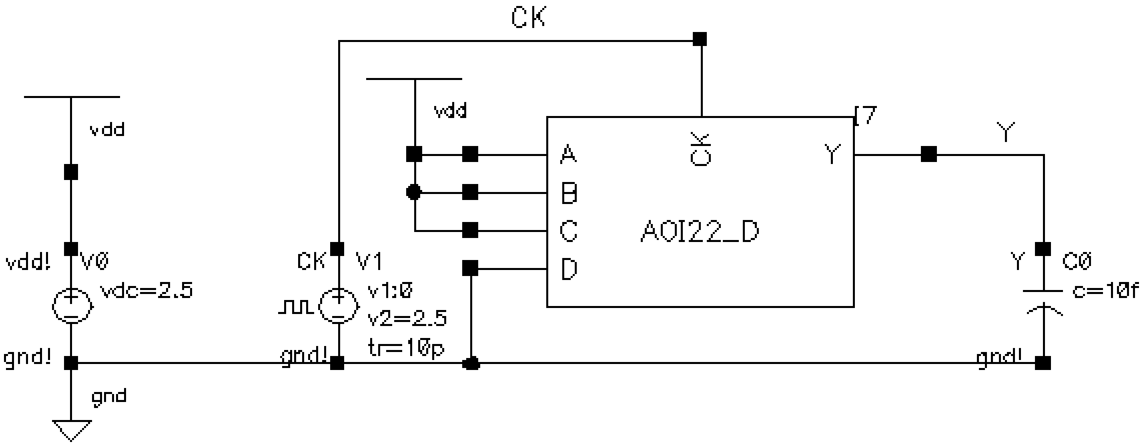


It works!



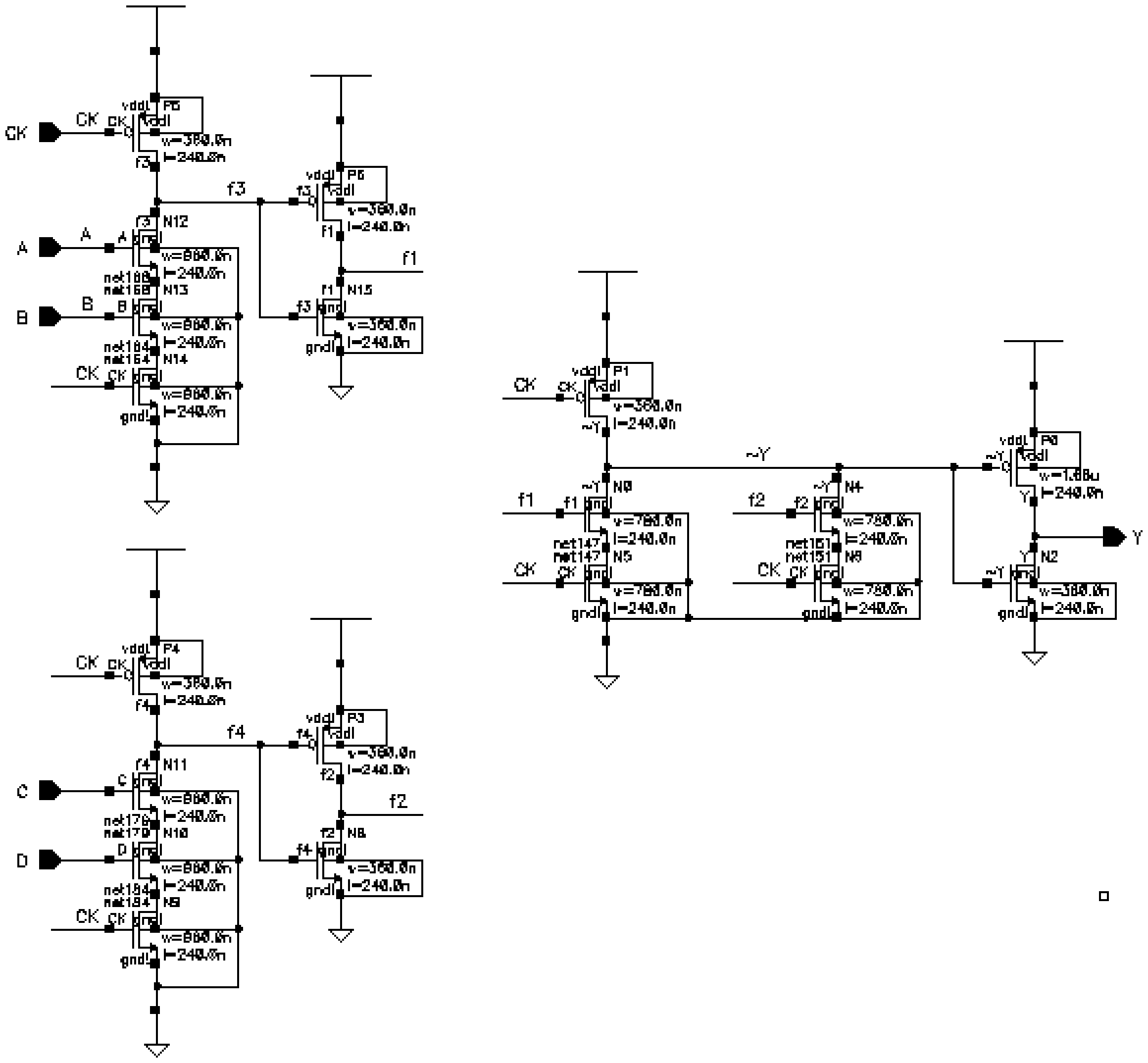
/CK
3.0
2.0
1.0
0.0
/Y
3.0
2.0
1.0
0.0
-1.0
/V0/PLUS
800u
200u
-400u
-1.0m
0.0
1.0n
2.0n
3.0n
time (s)

Testbench

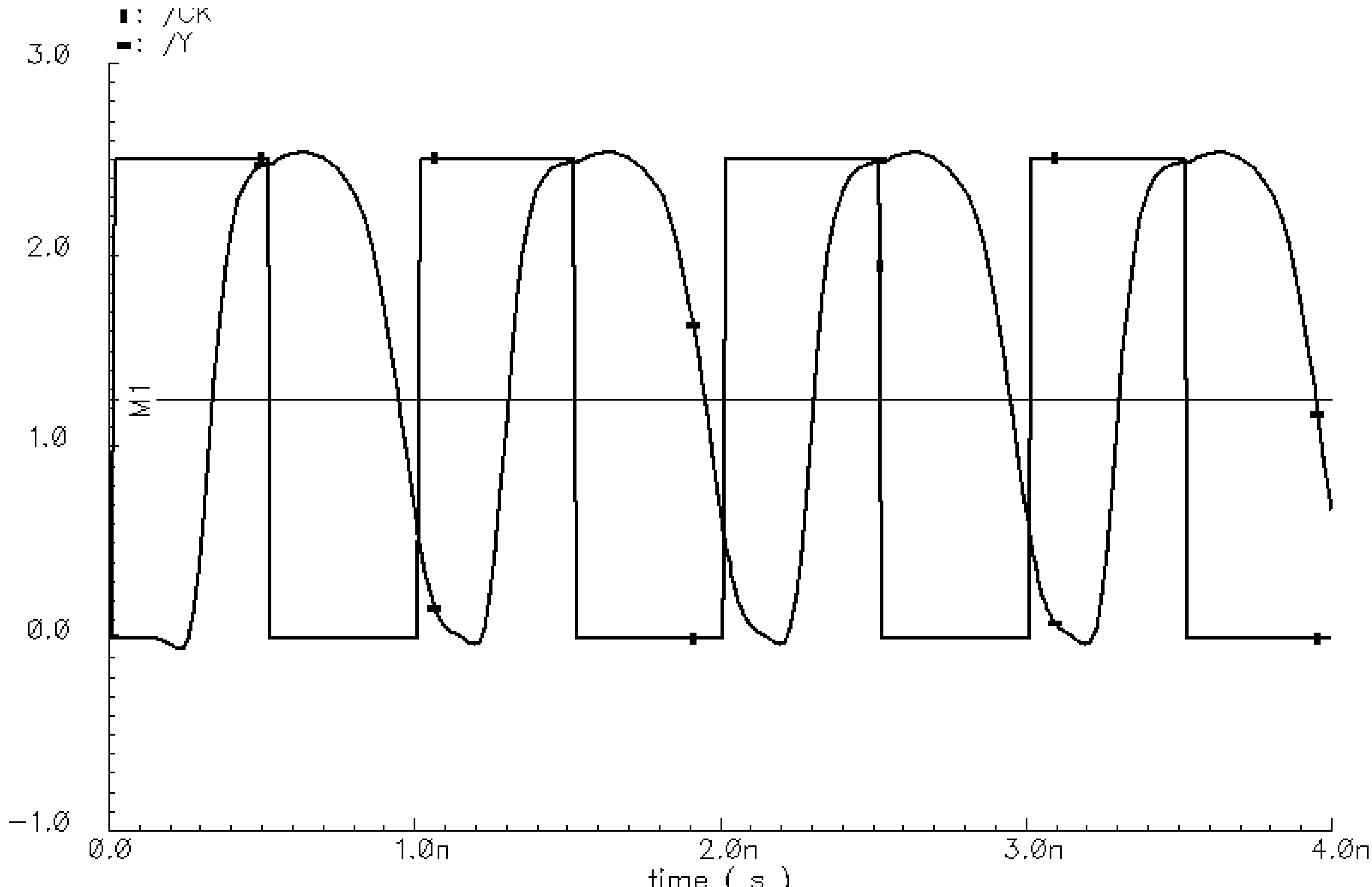


The actual propagation delays were .3ns. I wonder if it would have worked if I just put in the original calculated values?

Design the whole circuit flat



Design the whole circuit flat



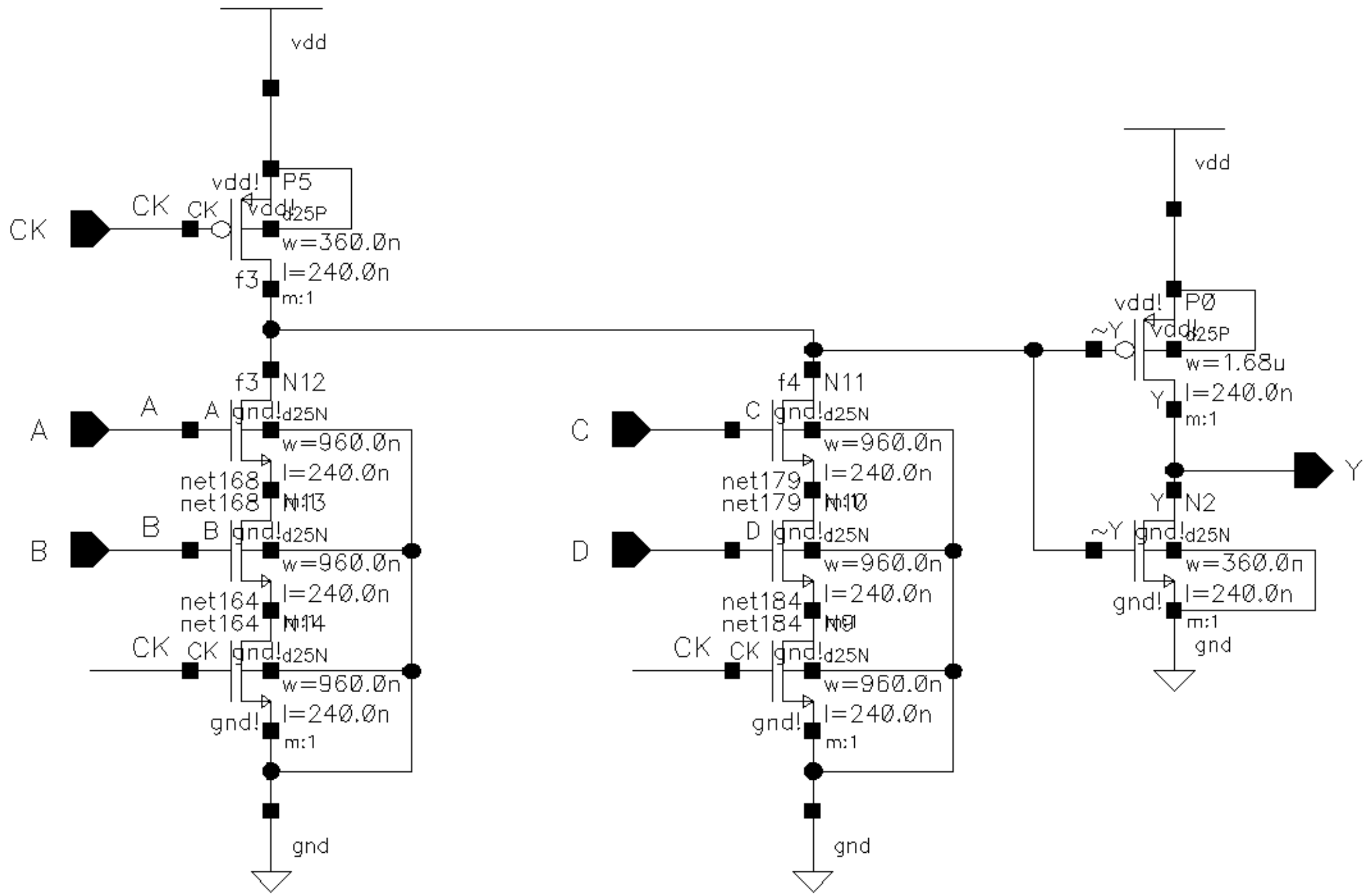
It worked!

- We made specification in the first shot!
- 422ps is the pre-charge time and the evaluate time is well within specification.
- This would be hard to fix because it is not done in isolation. I am also a little bit over .4ns. I could have designed it for 11fF and then run it at 10fF.
- This method was very fast to design.

What about the AOI Technique?

- T is still 4ns, but now each stage will have equal propagation delays because to pre-charge will go through two logic levels and to evaluate will go through two logic levels.
- The propagation delay will go to .2ns

AOI22


vdd
vdd! P5
CK
CK
CK
vdd!
d25P
w=360.0n
l=240.0n
f3
m:1
f3 N12
A
A
A gnd!
d25N
w=960.0n
l=240.0n
net168
net168
B
B
B gnd!
net164
net164
CK
CK gnd!
gnd!
gnd
f4 N11
C
C gnd!
net179
net179
D
D gnd!
net184
net184
vdd
vdd! P0
~Y
d25P
w=1.68u
Y
Y
Y N2
~Y gnd!
w=360.0n
gnd!
gnd

Inverter

$A := 6150\Omega$ $\quad C_{JSWN} := 4.44\cdot 10^{-12}\dfrac{F}{cm}$ $\quad C_{JN} := 1.92\cdot 10^{-7}\dfrac{F}{cm^2}$ $\quad C_{GDO} := 6.27\cdot 10^{-12}\dfrac{F}{cm}$

$L_N := .24\cdot 10^{-4}cm$ $\quad K_{EQ} := \dfrac{-2\sqrt{.99}}{-2.5}\cdot\left(\sqrt{.99+2.5}-\sqrt{.99}\right)$ $\quad K_{EQ} = 0.695$ $\quad D_D := .6\cdot 10^{-4}cm$

$C_g := 3.5\cdot 10^{-15}F$ $\quad N := 1$ $\quad N_{SN} := 1$

$\tau_{PHL} := .2\cdot 10^{-9}s$ $\quad M := 1$ $\quad N_{SP} := 1$ $\quad S := 1$ $\quad R := 2.322\cdot\dfrac{N_{SP}\cdot S}{N_{SN}}$ $\quad R = 2.322$

$$W_N := \frac{C_g + C_{JSWN}\cdot 2\cdot D_D\cdot K_{EQ}\cdot(N+M)}{\dfrac{\tau_{PHL}}{N_{SN}\cdot L_N\cdot A} - (N + M\cdot R)\cdot\left(C_{JSWN}\cdot 2K_{EQ} + C_{JN}\cdot D_D K_{EQ} + 2\cdot C_{GDO}\right)}$$

$W_N = 3.349\times 10^{-6}cm$ $\quad$ Note: Any W values below 360nm are non-physical solutions.

$W_P := R\cdot W_N$ $\quad W_P = 7.776\times 10^{-6}cm$

$W_N := .36\cdot 10^{-4}cm$ $\quad W_P := .36\cdot 10^{-4}cm$

Dynamic AOI22

$A := 6150\Omega$ $\quad C_{JSWN} := 4.44\cdot 10^{-12}\frac{F}{cm}$ $\quad C_{JN} := 1.92\cdot 10^{-7}\frac{F}{cm^2}$ $\quad C_{GDO} := 6.27\cdot 10^{-12}\frac{F}{cm}$

$L_N := .24\cdot 10^{-4}cm$ $\quad K_{EQ} := \frac{-2\sqrt{.99}}{-2.5}\cdot\left(\sqrt{.99+2.5}-\sqrt{.99}\right)$ $\quad K_{EQ} = 0.695$ $\quad D_D := .6\cdot 10^{-4}cm$

$C_g := 2.65\cdot 10^{-15}F$ $\quad N := 8$ $\quad N_{SN} := 3$

$\tau_{PHL} := .2\cdot 10^{-9}s$ $\quad M := 1$ $\quad N_{SP} := 1$ $\quad S := 1$ $\quad R := 2.322\cdot\frac{N_{SP}\cdot S}{N_{SN}}$ $\quad R = 0.774$

$$W_N := \frac{C_g + C_{JSWN}\cdot 2\cdot D_D\cdot K_{EQ}\cdot(N+M)}{\frac{\tau_{PHL}}{N_{SN}\cdot L_N\cdot A} - (N + M\cdot R)\cdot\left(C_{JSWN}\cdot 2K_{EQ} + C_{JN}\cdot D_D K_{EQ} + 2\cdot C_{GDO}\right)}$$

+

$W_N = 2.754\times 10^{-5}cm$ $\quad$ Note: Any W values below 360nm are non-physical solutions.

$W_P := R\cdot W_N$ $\quad W_P = 2.132\times 10^{-5}cm$

$W_N := .36\cdot 10^{-4}cm$ $\quad W_P := W_N$

Dynamic AOI22

- Using the Hand Calculations and not simulating the inverter separately from the aoi allowed me to get close but not meet specification.
- I could not fix it as is.
  - Where is it too slow?
    - If the aoi is too slow it will make the inverter appear too slow.
    - Best to do it separately if it
- I changed my hand calculated for a smaller delay and larger capacitance and used those values.
  - Hit spec!