THE UNIVERSITY OF BRITISH COLUMBIA
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

ELEC 402 Assignment 4: NAND3 Simulation and Layout

Shidi Xi (90506643)

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3-input NAND gate Simulation and Layout

Area and delay

Table 1: Performance parameters summary.

$tpLH$ (ps)	$tpHL$ (ps)	Average tp (ps)	Area (μm^2)	Area$\times$delay $(\mu m^2 ps)$
13.9	17.6	15.7	0.207	3.25

Layout and DRC

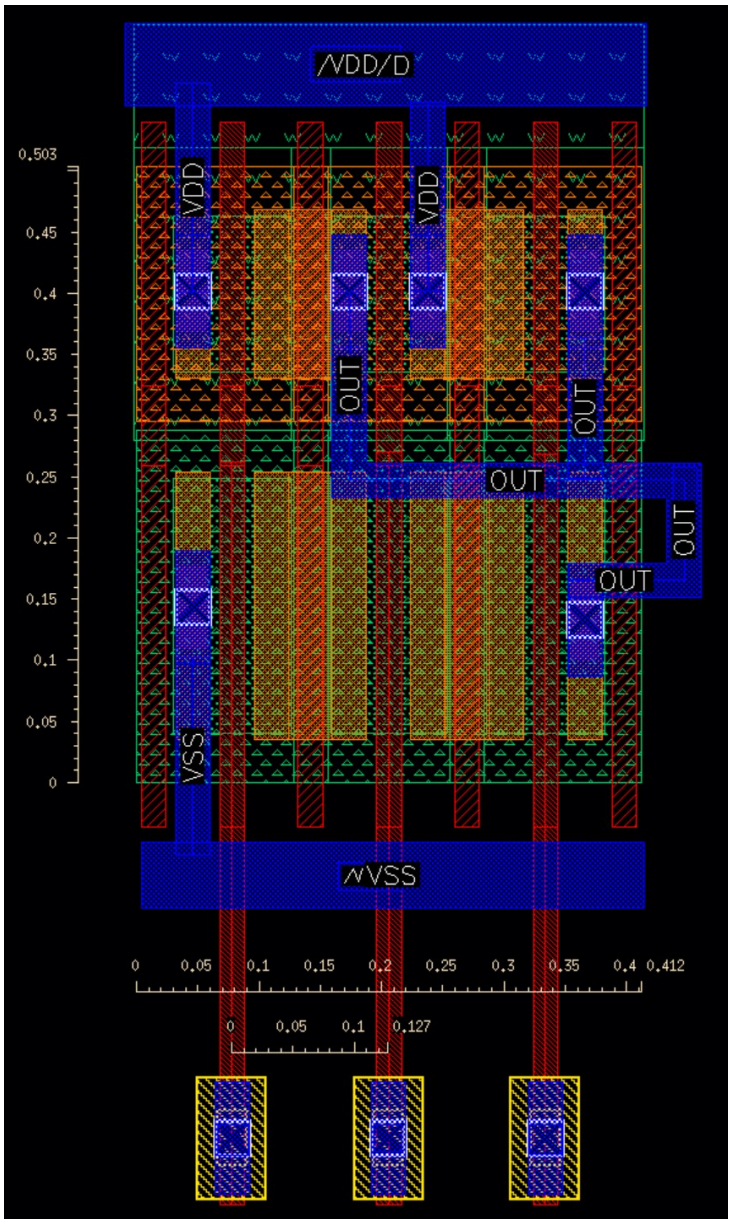

Figure 1: Layout of the 3-input NAND gate.

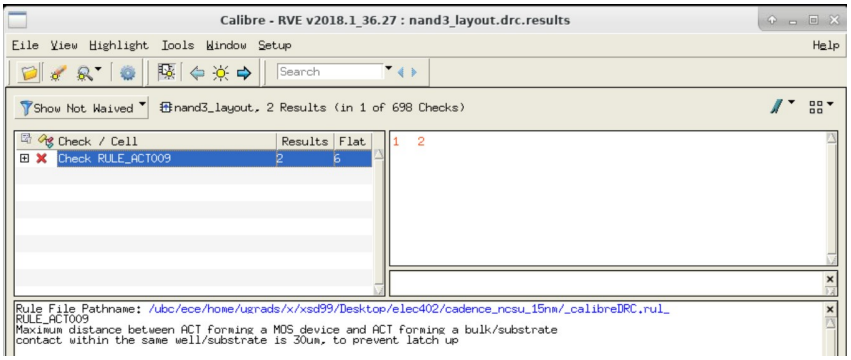

Figure 2: DRC results, the only error is ACT009 which can be ignored for this project.

Delay simulation

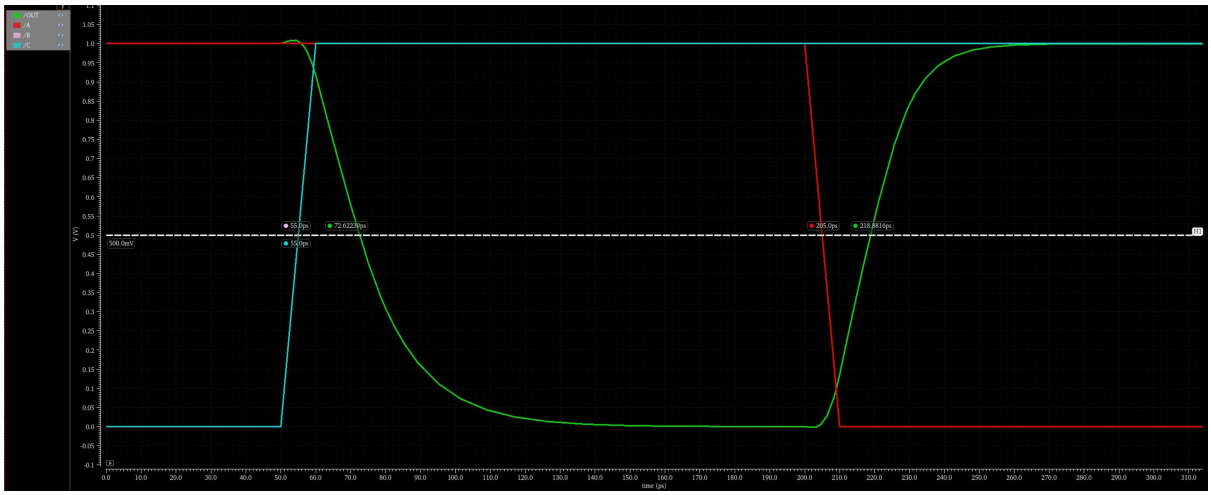

Figure 3: Simulation waveform using the netlist of the layout after PEX.

Testbench schematic

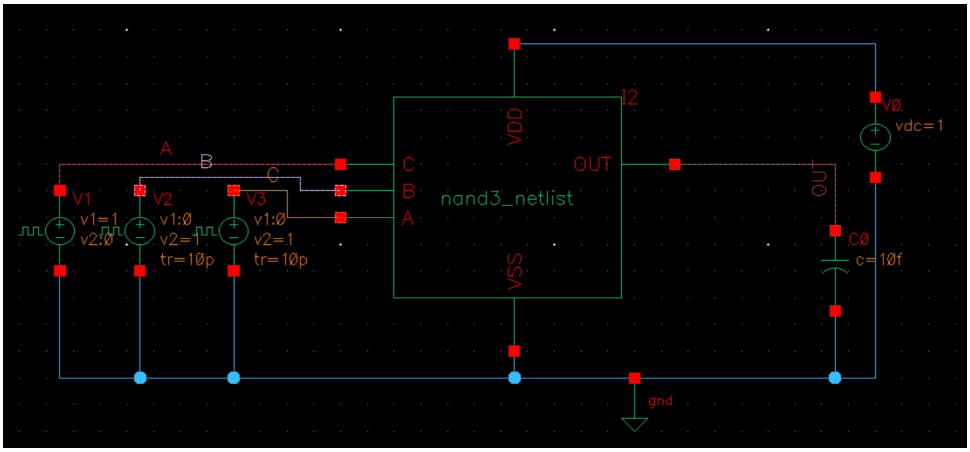

Figure 4: Testbench netlist used for the PEX simulation.

Question 2

a

$$\overline{Y} = (A+B)CD$$
$$Y = \overline{(A+B)CD}$$

b

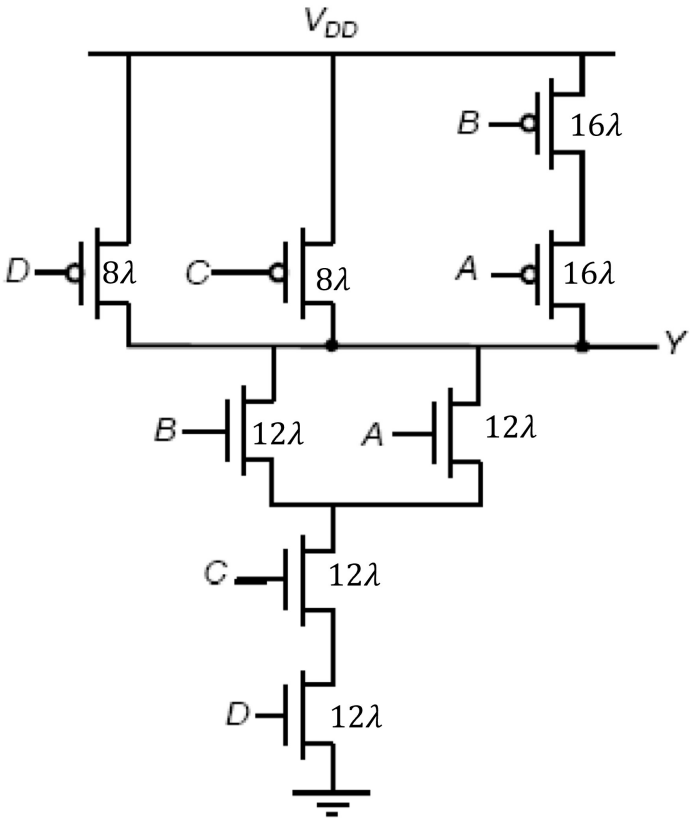

Figure 5: Sized inverters.

c

worst case t_{pLH}

Input pattern: $ABC = 101$ and $D = 1 \rightarrow 0$. Simulation netlist and waveform shown in Figure 6 and Figure 7 respectively.

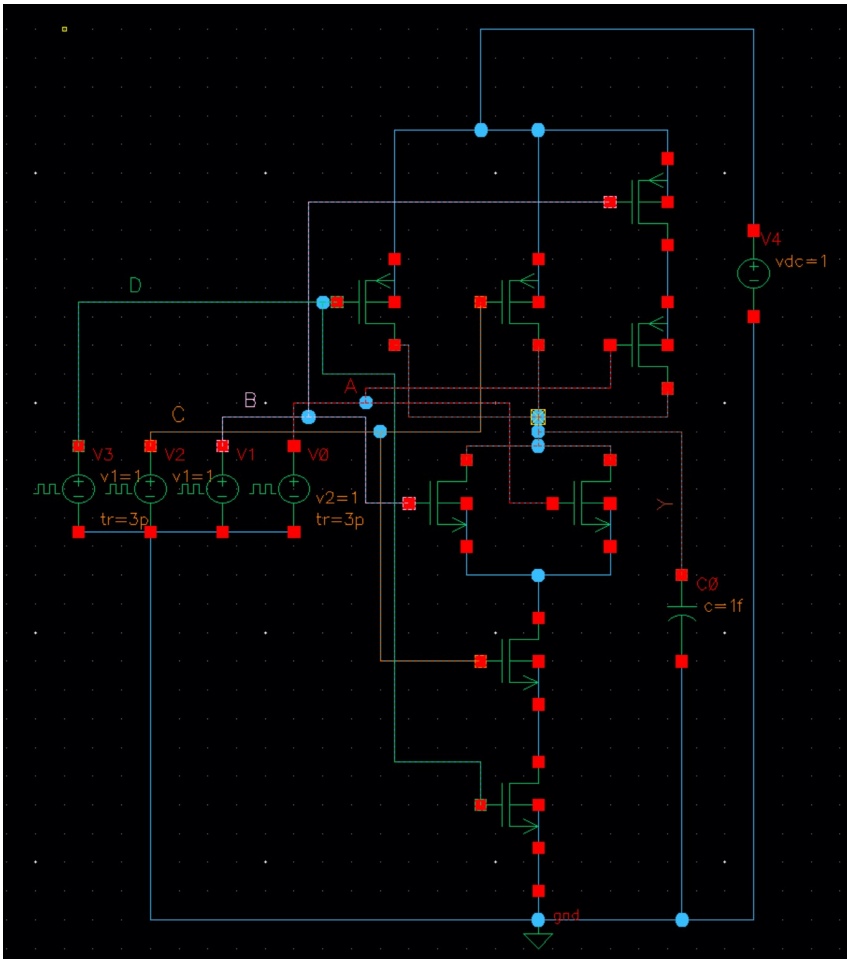

Figure 6: Netlist used for the worst case t_{pLH} and t_{pHL}simulation.

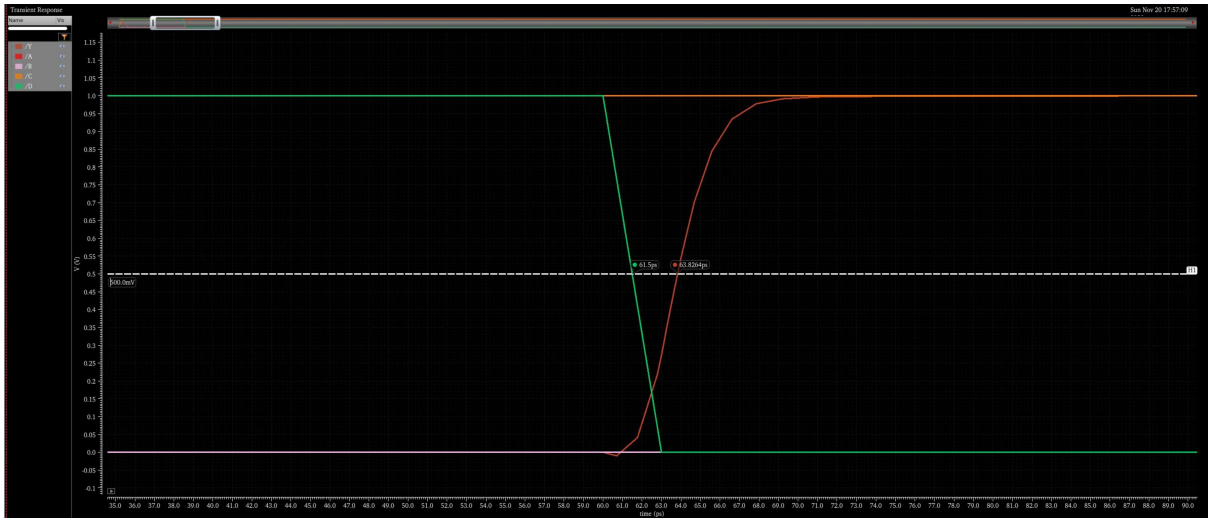

Figure 7: Simulation waveform of the worst case t_{pLH}.

worst case t_{pHL}

Input pattern: $ABC = 011$ and $D = 0 \rightarrow 1$. Simulation netlist and waveform shown in Figure 6 and Figure 8 respectively.

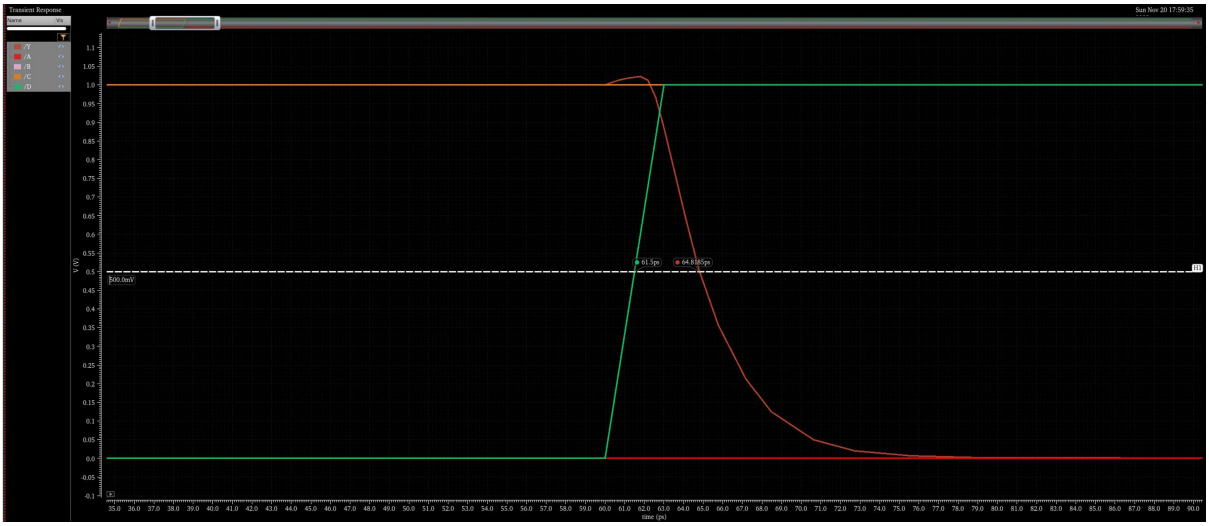

Figure 8: Simulation waveform of the worst case t_{pHL}.

Question 3

a

$$C = sel\overline{A} + selB\overline{B}$$
$$OUT = \overline{C} = (\overline{sel} + A)(\overline{selB} + B)$$

b

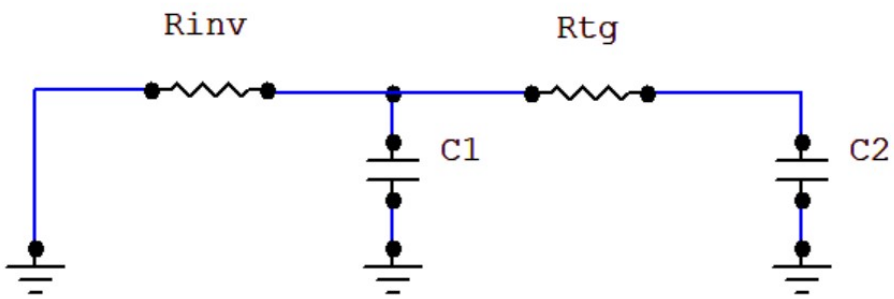

Figure 9: Equivalent circuit.

$$W = 4\lambda = 0.4\mu m$$
$$R_{INV} = R_{TG} = R_{eq}^{N}\frac{L}{W} = R$$
$$C1 = 3C_{eff}W + 2C_{eff}W + C_gW = 5C_{eff}W + C_gW$$
$$C2 = 2 \times 2C_{eff}W + C_gW + 3fC_gW = 4C_{eff}W + (3f+1)C_gW$$

c

$$\begin{aligned} t_1 &= 0.7(2RC2 + RC1) \\ &= 1.4RW(5C_{eff} + C_g) + 0.7RW[4C_{eff} + (3f+1)C_g] \\ &= 0.7RW[14C_{eff} + (3f+3)C_g] \end{aligned}$$

d

$$R_{out} = \frac{R}{f}$$
$$C_{out} = 3fC_{eff}W + 50$$
$$t_2 = 0.7R_{out}C_{out} = 0.7(3C_{eff}WR + \frac{50R}{f})$$

e

$$t_{total} = t_1 + t_2 = 0.7RW[14C_{eff} + (3f+3)C_g] + 0.7(3C_{eff}WR + \frac{50R}{f})$$
$$\frac{dt_{total}}{df} = 3C_gW - 35f^{-2} = 0$$
$$f = \sqrt{\frac{2.1C_gW}{35}}$$