Midterm

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Q1

a)

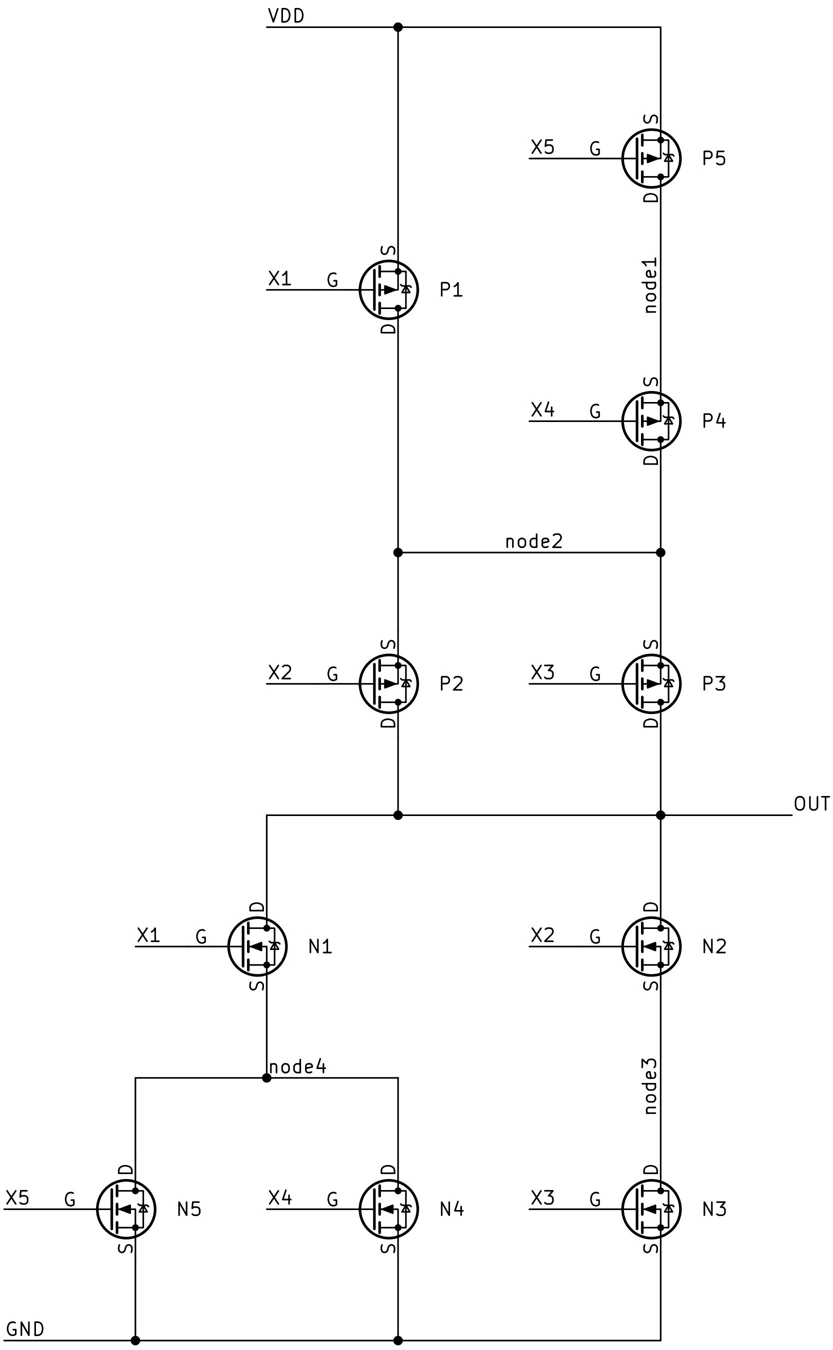

Figure 1: Schematic of the five input function.

b)

Output function is $\overline{[(X4 + X5).X1 + X2.X3]}$

c)

Nodes are name in the Figure 1.

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MP1 node2 X1 VDD VDD CMOSP W=0.5u L=0.2u
MP2 OUT X2 node2 VDD CMOSP W=0.5u L=0.2u
MP3 OUT X3 node2 VDD CMOSP W=0.5u L=0.2u
MP4 node2 X4 node1 VDD CMOSP W=0.5u L=0.2u
MP5 node1 X5 VDD VDD CMOSP W=0.5u L=0.2u

MN1 OUT X1 node4 0 CMOSN W=0.5u L=0.2u
MN2 OUT X2 node3 0 CMOSN W=0.5u L=0.2u
MN3 node3 X3 0 0 CMOSN W=0.5u L=0.2u
MN4 node4 X4 0 0 CMOSN W=0.5u L=0.2u
MN5 node4 X5 0 0 CMOSN W=0.5u L=0.2u
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Q2

Before starting calculations, I determine all necessary values in Equation 1, units are given in square brackets. C_L, $W_{N(1)}$, $J_{N(max)}$, $J_{P(max)}$, and L_{min} given in the tech file. $CGSO$ is a value from mosfet model. C_{OX} can be calculated usign $\frac{\epsilon_{ox}}{t_{ox}}$ where ϵ_{ox} is approximately 3.453e-13$[F/cm^2]$, and t_{ox} is from the mosfet model.

$$\begin{aligned} C_L &= 5.00\text{e-}12[F] \\ J_{N(max)} &= 508[A/m] \\ J_{P(max)} &= 224[A/m] \\ L_{min} &= 2.00\text{e-}7[m] \\ C_{OX} &= 8.41\text{e-}3[F/m^2] \\ CGSO &= 7.19\text{e-}10[F/m] \\ W_{N(1)} &= 5.00\text{e-}7[m] \end{aligned} \tag{1}$$

Calculation of chain number

Since n is given as 3, I will use it as 3.

Calculation of tapering factor

Then I need to calculate m which is calculated by Equation 2.

$$n = \left[\frac{C_L}{\left(1 + \sqrt{\frac{J_{N(max)}}{J_{P(max)}}}\right) \cdot (L_{min}.C_{OX} + 2 \cdot CGSO) \cdot W_{N(1)}} \right]^{\frac{1}{n}} \tag{2}$$

And when I put the values to formula:

$$n = \left[\frac{1.00\text{e-}12[F]}{\left(1 + \sqrt{\frac{508[A/m]}{224[A/m]}}\right) \cdot (2.00\text{e-}7[m] \cdot 8.41\text{e-}3[F/m^2] + 2 \cdot 7.19\text{e-}10[F/m]) \cdot 5.00\text{e-}7[m]} \right]^{\frac{1}{3}}$$

And results is 10.85487625. So $m \approx 10.85$.

a)

Inverter	Wn	Wp
1	500n	750n
2	5425n	8137n
3	58861n	88291n

b)

I need to calculate $\mathcal{L}$ which is calculated by Equation 3.

$$\mathcal{L} = \frac{1}{4} \cdot \left(\frac{1}{\sqrt{J_{N(max)}}} + \frac{1}{\sqrt{J_{P(max)}}} \right)^2 \cdot (L_{min} \cdot C_{OX} + 2 \cdot CSGO) \cdot V_{DD} \cdot m \cdot n \tag{3}$$

And when I put the values to formula:

$$\mathcal{L} = \frac{1}{4} \cdot \left(\frac{1}{\sqrt{508[A/m]}} + \frac{1}{\sqrt{224[A/m]}} \right)^2 \cdot (2.00\text{e-}7[m] \cdot 8.41\text{e-}3[F/m^2] + 2 \cdot 7.19\text{e-}10[F/m]) \cdot 1.8[V] \cdot 10.85 \cdot 3$$

And results is 5.64931e-10. So $\mathcal{L} \approx 564ps$

c)

Q3

a)

Let's write t_{PLH} t_{PHL} for inverter, 3 input NAND and 3 input NOR gates in general form.

Assume that $R_n = R$ and $R_p = 2R$ beacuse we are using minimum dimensions.

Assume that $C_{load} = C$.

N is 3 for NAND and NOR.

Delay of Inverter

$$
\begin{aligned}
t_{PLH} &\approx 0,7.R_p.C_{load} = 0,7.2R.C && = 1,4RC \\
t_{PHL} &\approx 0,7.R_n.C_{load} = 0,7.R.C && = 0,7RC \\
t_{PD} &= \frac{t_{PLH} + t_{PHL}}{2} = \frac{1,4RC + 0,7RC}{2} && = 1,05RC
\end{aligned}
$$

Delay of NAND

$$
\begin{aligned}
t_{PLH} &\approx 0,7.\frac{R_p}{N}.C_{load} = 0,7.\frac{2R}{3}.C && \approx 0,47RC \\
t_{PHL} &\approx 0,7.N.R_n.C_{load} = 0,7.3.R.C && = 2,1RC \\
t_{PD} &= \frac{t_{PLH} + t_{PHL}}{2} = \frac{0,47RC + 2,1RC}{2} && = 1,285RC
\end{aligned}
$$

Delay of NOR

$$
\begin{aligned}
t_{PLH} &\approx 0,7.N.R_p.C_{load} = 0,7.3.2R.C && = 4,2RC \\
t_{PHL} &\approx 0,7.\frac{R_n}{N}.C_{load} = 0,7.fracR3.C && \approx 0,23RC \\
t_{PD} &= \frac{t_{PLH} + t_{PHL}}{2} = \frac{4,2RC + 0,23RC}{2} && = 2,215RC
\end{aligned}
$$

Delay of NOR + Inverter

$$t_{PD} = 2,215RC + 1,05RC = 3,265RC$$

Delay of Inverters + NAND

$$t_{PD} = 1,05RC + 1,285RC = 2,335RC$$

b)