Problem 1: Denard Scaling

Power density stays constant, \( \frac{P}{A} = \frac{dA}{\text{area}} \)

\[ A' = A/s^2 \]

so \( (\text{Power})' = dA/s^2 \)

\[ c' = c/s \; \text{can ignore } d_j V' = V/s \]

so \[ P' = A' \cdot s \cdot c' \cdot \frac{1}{s^2} \cdot V' \cdot f \cdot s^2 \]

\[ P' = d \cdot c' \cdot V'^2 \cdot (f/s) \]

so \( f \) will scale with \( s \)

all of this assumes \( s > 1 \) \( \Rightarrow s = \frac{1}{k} \) when \( k = 0.7 \)

\[ \text{New power } = (P)(0.7)^2 \]

\[ P' = 9.8 \text{W} \] \( (2.5 \text{ pts}) \)

\[ f' = f(0.7) = 5.7 \text{ GHz} \] \( (2.5 \text{ pts}) \)

Problem 2: Noise Margins

answers may vary due to nature of plot, it's just important for the numbers to be generally correct

\[ V_{OH} \approx 1.7 \text{V} \]

\[ V_{OL} \approx 0.3 \text{V} \]

\[ V_{IH} \approx 1.3 \text{V} \]

\[ V_{IL} \approx 0.7 \text{V} \]

\[ \text{Noise Margin } (H) = NM_H = V_{OH} - V_{IH} = 0.4 \text{V} \]

\[ \text{Noise Margin } (L) = NM_L = V_{IL} - V_{OL} = 0.4 \text{V} \]

3 pt

2 pt
Problem 3

(1) black box implements NAND gate

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(2) A

(3) B

(4) C

(3) Setup of the graph:
- VDD = 1.5V
- Vout = 0V
- V_in = 0.5V
- 1.5V

(4) Propagation delay is 5 μs

Sorry for the messiness; it's okay if the don't show VDD. Most important for the students to draw the slope ≈ 1 points (dark dots)

(given number accounts for rise time & 50% & what not)
Problem 4

(1) XNOR(\(A, B\)) has the following truth table

\[
\begin{array}{ccc}
\text{A} & \text{B} & \text{Y} \\
0 & 0 & 1 \\
0 & 1 & 0 \\
1 & 0 & 0 \\
1 & 1 & 1 \\
\end{array}
\]

Based on truth table: \(C_0 = 1, C_2 = 1\)

\(C_1 = 0, C_5 = D\)

(2.5 pts)

Students need to recognize that "\(C\)" inputs allow them to select which input combinations yield a 0 & which ones yield a 1.

(2) Yes! This logic block effectively models every possible input combination for the inputs \((A & B)\).

- The "\(C\)" inputs allow the user to pick which input combination results in a 1 & which combinations result in 0.
- This block will model any combinational function in sum-of-product form.

Any explanation that touches on any of these should get credit.

2.5 pts
Problem 5

(1) Students may write out entire truth table... that's too much work for me but great for them. They could also simplify expression first.

\[(\overline{A}B)(\overline{C}D + \overline{C}D)(E+F) = \]
\[\overline{A}B + (\overline{C}D + \overline{C}D) + (E+F) = \]
\[A + B + (\overline{C}D + \overline{C}D) + E+F = \]
\[A + B + \overline{C}D + \overline{C}D + E+F = \]

Simpler truth table based off the above expression is

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(2.5 pts)

(2) Could just present the simplified expression from part 1 or can go the following route:

\[Y' = \overline{A}BCDE' + \overline{A}B'C'D'E' \]
\[Y = (A\overline{B}CDE' + \overline{A}B'C'D'E') \]
\[Y = (A\overline{B}CDE' + \overline{A}B'C'D'E') \]
\[Y = (A+B+C+D+E+F)(A+B+C+D+E+F) \]
\[Y = (A+B+C+D+E+F) \]

Then simplify to:

\[Y = A+B+C+D+E+F \]

(2.5 pts)
Problem 6

1) \[(\overline{A \overline{B} + C})(A + B)(\overline{B} + AC)) = \overline{A \overline{B}C}\]

\[(\overline{A \overline{B}A} + \overline{A \overline{B}B} + AC + BC)(\overline{B} + AC) = \]

\[(AC + BC)(B \overline{A} + B \overline{C}) = \]

\[AC \overline{A} \overline{B} + \overline{A} \overline{B} BC + B \overline{C} AC + B \overline{C} BC = \overline{A \overline{B}C} = \overline{A \overline{B}C} \checkmark \]

2) \[\overline{A \overline{B}} + AB + \overline{A} \overline{B} = \overline{A} + B\]

\[\overline{A} \overline{B} + \overline{A} \overline{B} + AB = \]

\[\overline{A} (\overline{B} + B) + AB = \overline{A} + B\]

\[\overline{A} + AB + \overline{A} \overline{B} = \]

\[\overline{A} + B(A + A) = \overline{A} + B \checkmark \]

(Because you can... why not!)

3) \[\overline{A(A + B)} + (B + AA)(A + B) = \overline{A} + B\]

\[\overline{A}A + \overline{A}B + (B + A)(A + \overline{B}) = \]

\[\overline{A}B + AB + \overline{B}B + A + \overline{A} \overline{B} = \]

\[(\overline{A} + A)B + A(1 + \overline{B}) = \overline{A} + B \checkmark \]

\[A + B = A + B \checkmark \]