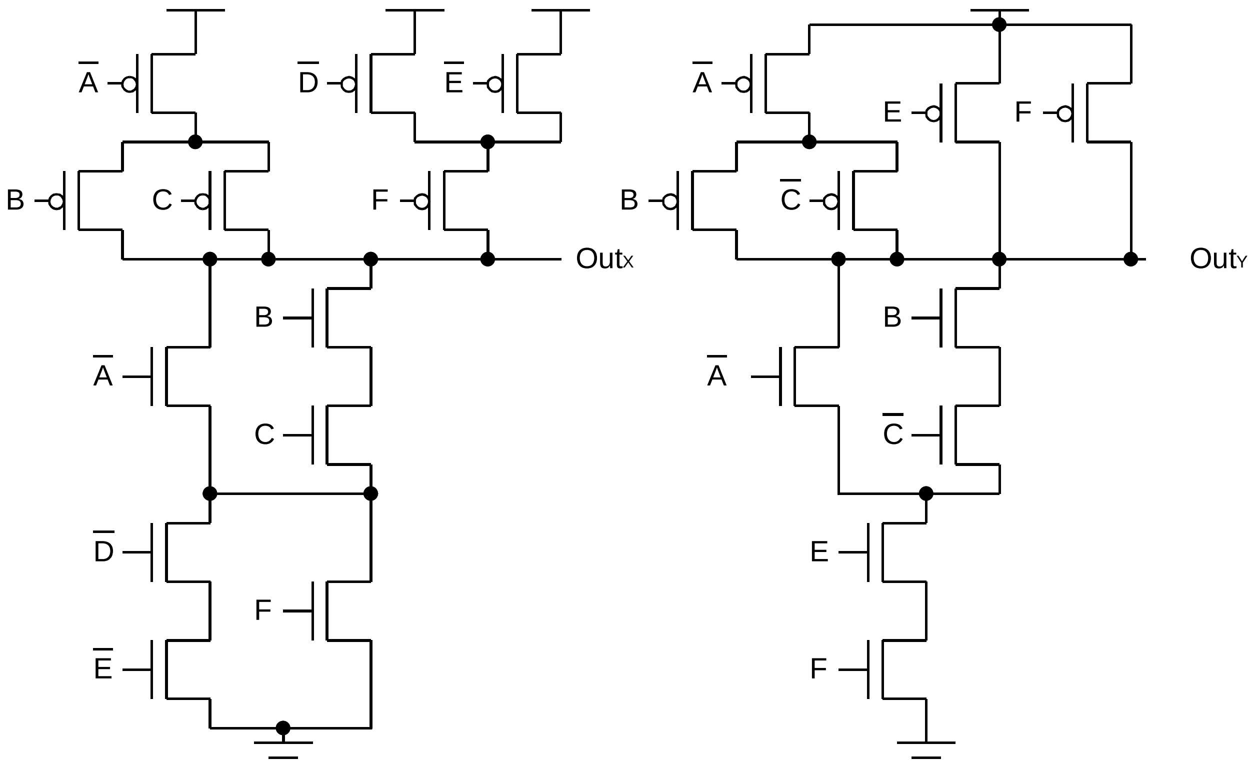
Problem 1 (2 parts, 20 points) Switch-level Design

Several incomplete circuits are shown below. Complete each circuit by adding the needed switching network so the output is pulled high or low for all combinations of inputs (i.e., no floats or shorts). Complete each circuit (pull down, pull up, or both) and write the expression if one is not given. Assume both inputs and complements are available.



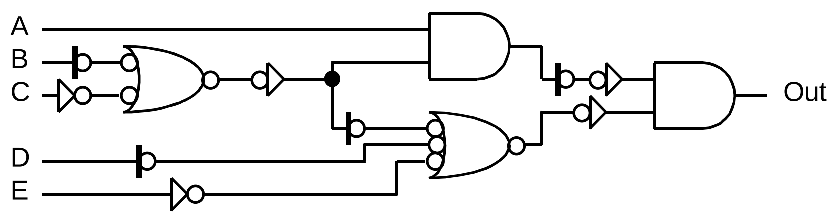
OUTx = $A \cdot \left(\overline{B} + \overline{C}\right) + \left(D + E\right) \cdot \overline{F}$

OUTy = $\overline{(\overline{A} + B \cdot \overline{C}) \cdot E \cdot F}$

Problem 2 (2 parts, 28 points) Mixed Logic Reengineering

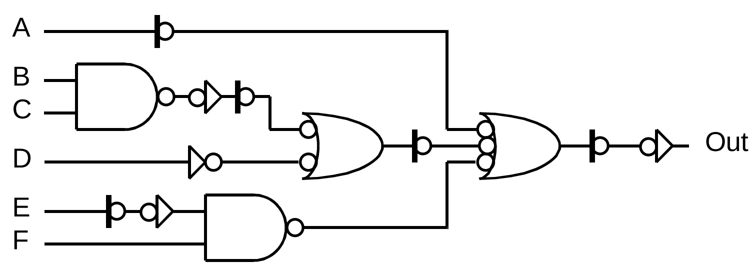
For the following expressions, implement the Boolean expression using the specified gate type. Use correct mixed-logic notation. **Do not simplify the expression**. You may use multi-input gates. Minimize the total transistors (switches) required. When possible, use common subexpressions to reduce gate counts. Also determine the number of switches used in each implementation.

Part A (14 points) Implement $A \cdot \overline{(\overline{B}+C)} \cdot (\overline{(\overline{B}+C)} + \overline{D} + E)$ using only **AND** and **NOT** gates.



\# switches = 1 x 8t + 3 x 6t + 5 x 2t = 36t

Part B (14 points) Implement $\overline{\overline{A} + (\overline{\overline{B \cdot C} + D}) + \overline{E} \cdot F}$ using only **NAND** and **NOT** gates.



\# switches = 1 x 6t + 3 x 4t + 4 x 2t = 26t

Problem 3 (2 parts, 22 points) Boolean Algebra

Part A (10 points) Transform each of the following Boolean expressions to a form where they are ready for switch level implementation (i.e., there should only be bars over input variables, not over operations). The behavior of the expression should remain unchanged. **Do not implement.**

$Out_X = \overline{(\overline{A+B}) \cdot (C+D) \cdot E + F \cdot \overline{G \cdot H}}$ $\quad (A+B+\overline{C}\cdot\overline{D}+\overline{E})\cdot(\overline{F}+G\cdot H)$

$Out_Y = \overline{((A\cdot\overline{B}+C)\cdot\overline{D})+(\overline{E}\cdot\overline{F})}$ $\quad ((\overline{A}+B)\cdot\overline{C}+D)\cdot(E+F)$

Part B (12 points) For the behavior described by this truth table, (A) write the sum of products expression using minterms, (B) write the product of sums expression using maxterms, and (C) write the simplified sum of products expression (using any simplification technique).

A	B	C	Out
0	0	0	0
1	0	0	0
0	1	0	0
1	1	0	1
0	0	1	1
1	0	1	1
0	1	1	1
1	1	1	0

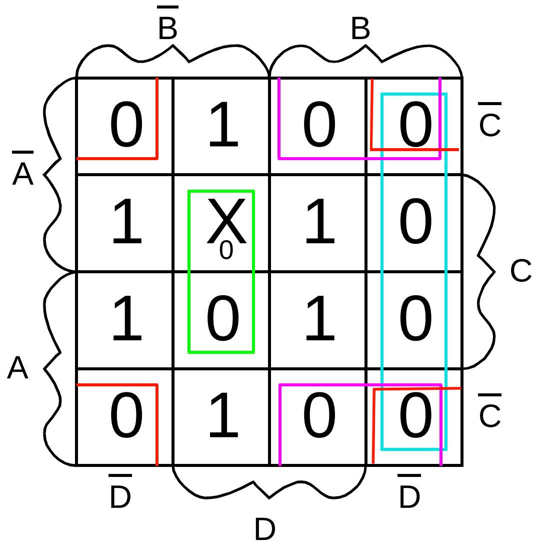
(A) SOP minterm expression $= A\cdot B\cdot\overline{C}+\overline{A}\cdot\overline{B}\cdot C+A\cdot\overline{B}\cdot C+\overline{A}\cdot B\cdot C$

(B) POS maxterm expression $= (A+B+C)\cdot(\overline{A}+B+C)\cdot(A+\overline{B}+C)\cdot(\overline{A}+\overline{B}+\overline{C})$

(C) simplified SOP expression $\overline{B}\cdot C+\overline{A}\cdot C+A\cdot B\cdot\overline{C}$

Problem 4 (2 parts, 30 points) Karnaugh Maps

Part A (12 points) Given the following Karnaugh Map, circle and list <u>all</u> the prime implicants for a *product-of-sums (POS)* expression, indicating which are essential. Derive the simplified *POS* expression.

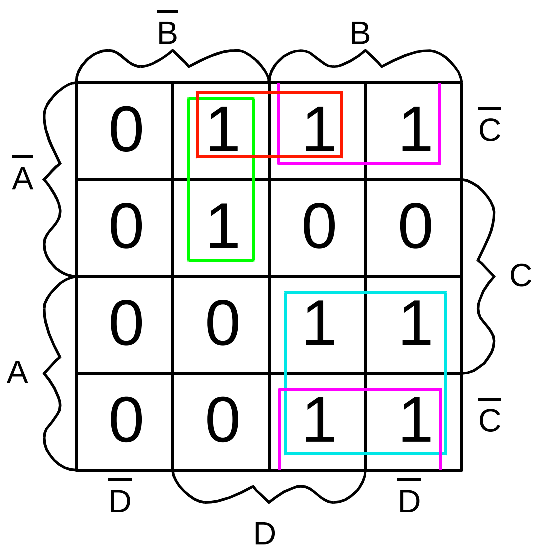


prime implicants	essential? yes	no
$\overline{B} + D$	☒	☐
$\overline{B} + C$	☒	☐
$C + D$	☒	☐
$B + \overline{C} + \overline{D}$	☒	☐
	☐	☐
	☐	☐
	☐	☐
	☐	☐

simplified POS expression $\left(\overline{B}+D\right)\cdot\left(\overline{B}+C\right)\cdot\left(C+D\right)\cdot\left(B+\overline{C}+\overline{D}\right)$

Part B (18 points) For the following expression, derive a simplified ***sum of products*** expression using a Karnaugh Map. Circle and list <u>all</u> the prime implicants for a *sum-of-products (SOP)* expression, indicating which are essential.

$$Out = (B + D)\cdot(\overline{A} + B + \overline{D})\cdot(A + \overline{B} + \overline{C})$$



prime implicants	essential? yes	no
$A\,B$	☒	☐
$B\,\overline{C}$	☒	☐
$\overline{A}\,\overline{C}\,D$	☐	☒
$\overline{A}\,\overline{B}\,D$	☒	☐
	☐	☐
	☐	☐
	☐	☐
	☐	☐

simplified SOP expression $A\cdot B + B\cdot\overline{C} + \overline{A}\cdot\overline{B}\cdot D$