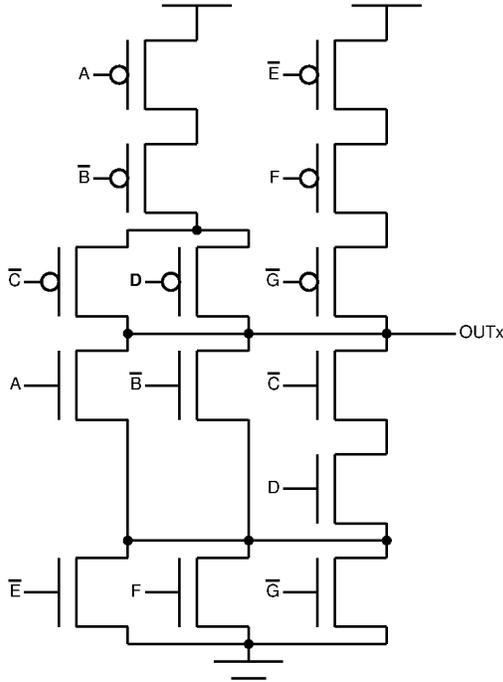


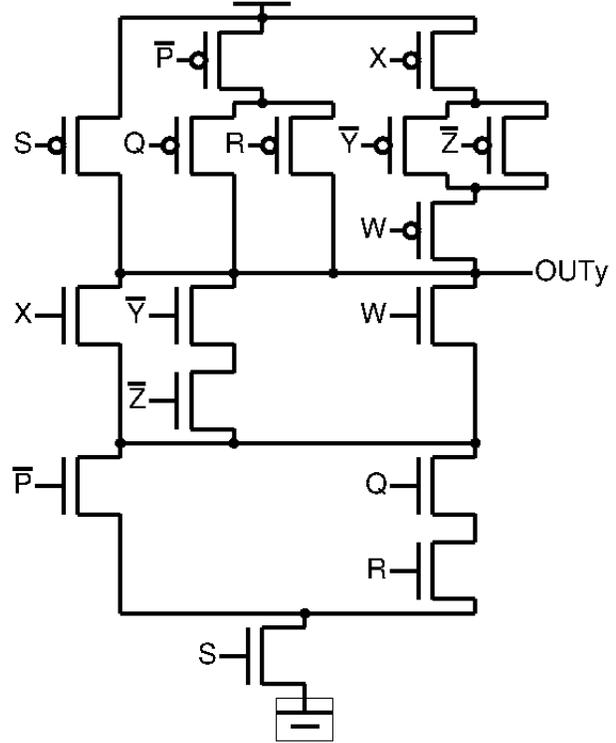
Problem 1 (3 parts, 30 points)

Switch-level Design

Part A (24 points) For each expression below, create a switch level implementation using N and P type switches. Assume both inputs and their complements are available. Your design should contain no shorts or floats. Use as few transistors as possible.



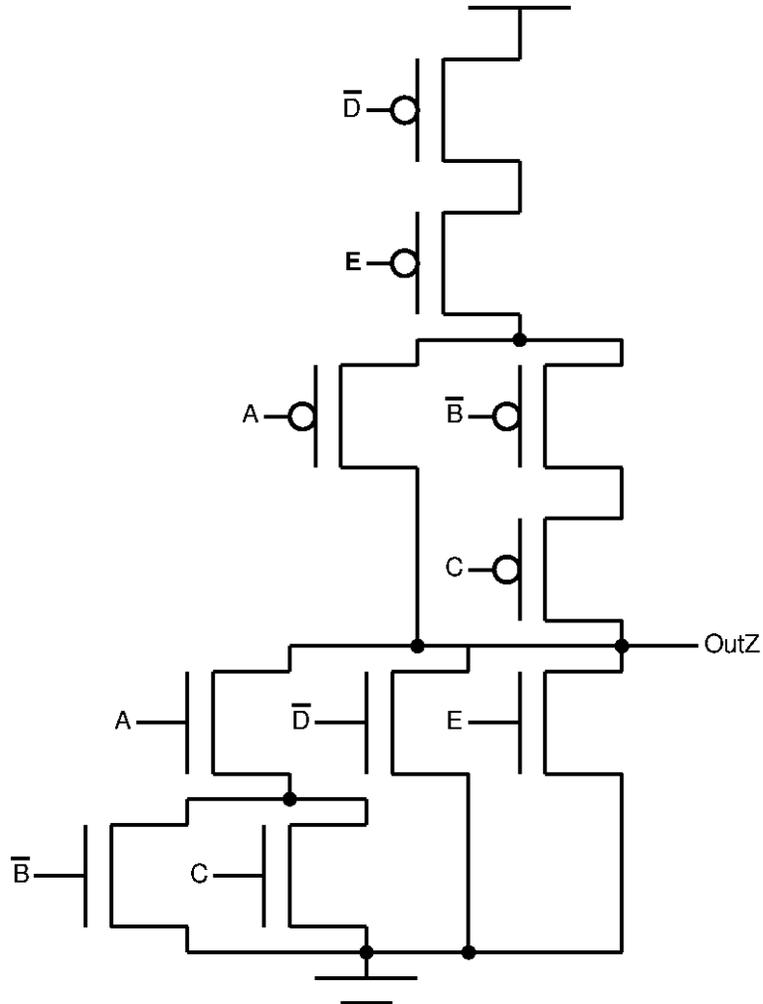
$$OUTx = \bar{A} \cdot B \cdot (C + \bar{D}) + E \cdot \bar{F} \cdot G$$



$$OUTy = \overline{(X + \bar{Y} \cdot \bar{Z} + W) \cdot (\bar{P} + Q \cdot R) \cdot S}$$

$$\overline{OUTy} = (X + \bar{Y} \cdot \bar{Z} + W) \cdot (\bar{P} + Q \cdot R) \cdot S$$

Part B (6 points) Given the pull-down network below, draw the missing pull-up network so that the circuit contains no floats or shorts. Also, write the Boolean expression computed by the completed circuit. (The expression should have complements only over the individual input signals, not over subexpressions.)



$$Out_Z = (\bar{A} + B \cdot \bar{C}) \cdot D \cdot \bar{E}$$

Problem 2 (3 parts, 20 points)

Boolean Algebra

Part A (5 points) Transform the following Boolean expression to a form where it can be implemented using switches (i.e., there should only be bars over input variables, not over operations). The behavior of the expression should remain unchanged. **Do not implement.**

$$Out_A = \overline{A} \cdot \overline{B} \cdot \overline{C} + D \cdot \overline{E} \cdot \overline{F} \cdot G$$

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

Part B (6 points) Derive a canonical sum of products (using minterms) and a product of sums (using maxterms) expression for the truth table below.

A	B	C	$F_{(A,B,C)}$
0	0	0	0
1	0	0	1
0	1	0	1
1	1	0	0
0	0	1	1
1	0	1	0
0	1	1	1
1	1	1	1

$$\text{Standard SOP}_{(\text{MINTERMS})} = A\overline{B}\overline{C} + \overline{A}B\overline{C} + \overline{A}\overline{B}C + \overline{A}BC + ABC$$

$$\text{Standard POS}_{(\text{MAXTERMS})} = (A+B+C) \cdot (\overline{A}+\overline{B}+C) \cdot (\overline{A}+B+\overline{C})$$

Part C (9 points) Translate the following standard sum of products (which uses minterms) to the equivalent standard product of sums (using maxterms) by first filling in the truth table below and then deriving the standard product of sums from it.

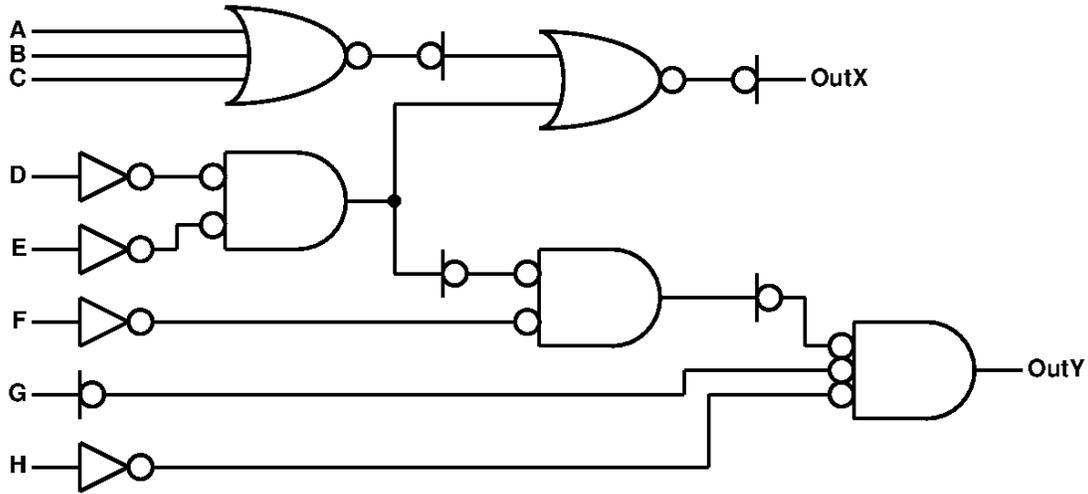
$$\text{Standard SOP}_{(\text{MINTERMS})} = \overline{A}\overline{B}C + A\overline{B}C + A\overline{B}\overline{C} + AB\overline{C} + ABC$$

A	B	C	$F_{(A,B,C)}$
0	0	0	0
1	0	0	1
0	1	0	0
1	1	0	1
0	0	1	1
1	0	1	1
0	1	1	0
1	1	1	1

$$\text{Standard POS}_{(\text{MAXTERMS})} = (A+B+C) \cdot (A+\overline{B}+\overline{C}) \cdot (A+\overline{B}+C)$$

Problem 3 (3 parts, 30 points)

Mixed Logic Reengineering



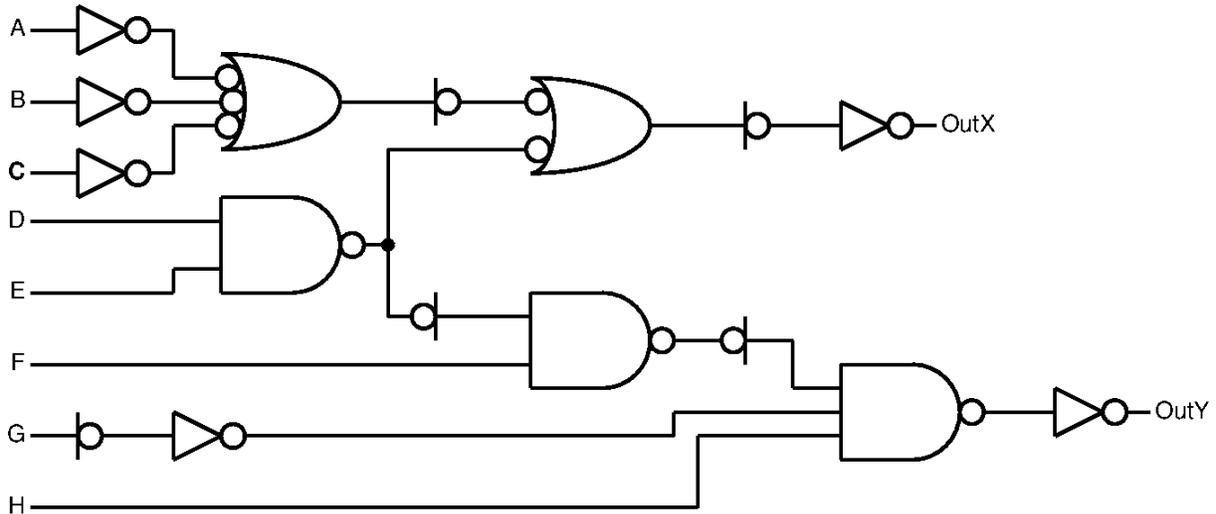
Part A (10 points) Write the output expression for the gate design shown above. Also determine the number of switches used in its implementation.

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

$$OUT_y = \overline{\overline{D} \cdot \overline{E} \cdot F \cdot \overline{G} \cdot H}$$

$$\# \text{ switches} = 2 \times 6T + 3 \times 4T + 4 \times 2T = 32T$$

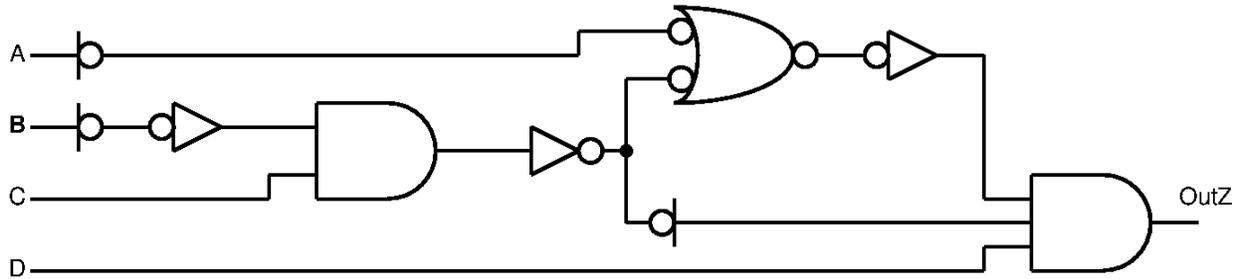
Part B (10 points) Reimplement the behavior below with a mixed logic design style using only NAND gates and inverters. Determine the number of switches used in this implementation.



$$\# \text{ switches} = 2 \times 6T + 3 \times 4T + 6 \times 2T = 36T$$

Part C (10 points) Implement the following expression using *only* AND gates and inverters. Then determine the number of transistors required. Use proper mixed logic notation. Do not modify the expression. Do not assume complements of inputs are available.

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

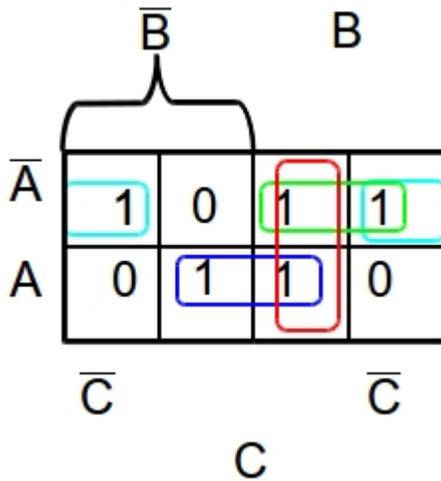


switches = 2x6T + 1x8T + 3x2T = 26T

Problem 4 (2 parts, 20 points)

Karnaugh Maps

Part A (10 points) Given the following Karnaugh Map, circle and list all the prime implicants, indicating which are essential and write the simplified *sum-of-products* (SOP) expression.

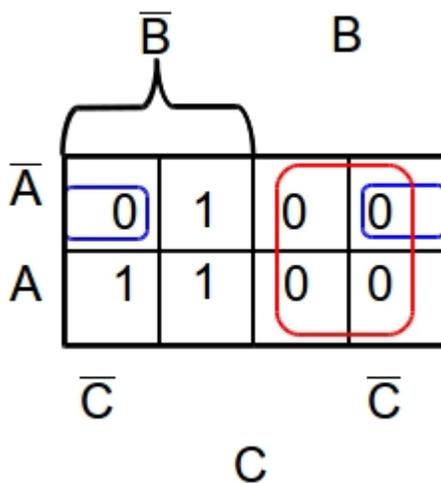


Prime implicants:	Essential?	
	Yes	No
$\bar{A}C$	<input checked="" type="checkbox"/>	<input type="checkbox"/>
AC	<input checked="" type="checkbox"/>	<input type="checkbox"/>
$\bar{A}B$	<input type="checkbox"/>	<input checked="" type="checkbox"/>
BC	<input type="checkbox"/>	<input checked="" type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>

simplified SOP expression $\bar{A}\cdot\bar{C}+A\cdot C+\bar{A}\cdot B$ or $\bar{A}\cdot\bar{C}+A\cdot C+B\cdot C$

Part B (10 points) Simplify the following SOP expression using a Karnaugh Map. Circle and list all the prime implicants, indicating which are essential and write the *product-of-sums* (POS) expression.

$$Out = \bar{A}\bar{B}C + A\bar{B}\bar{C} + A\bar{B}C$$



Prime implicants:	Essential?	
	Yes	No
\bar{B}	<input checked="" type="checkbox"/>	<input type="checkbox"/>
$A+C$	<input checked="" type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>
	<input type="checkbox"/>	<input type="checkbox"/>

Simplified POS expression $\bar{B}\cdot(A+C)$