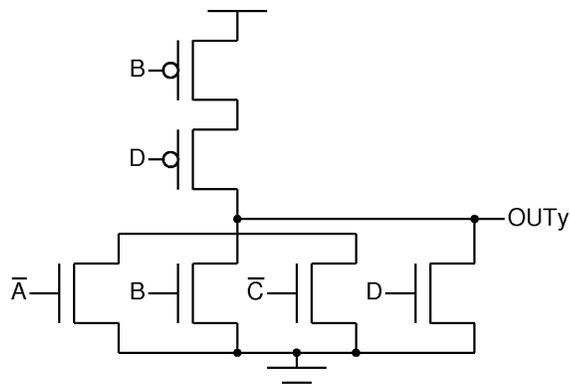
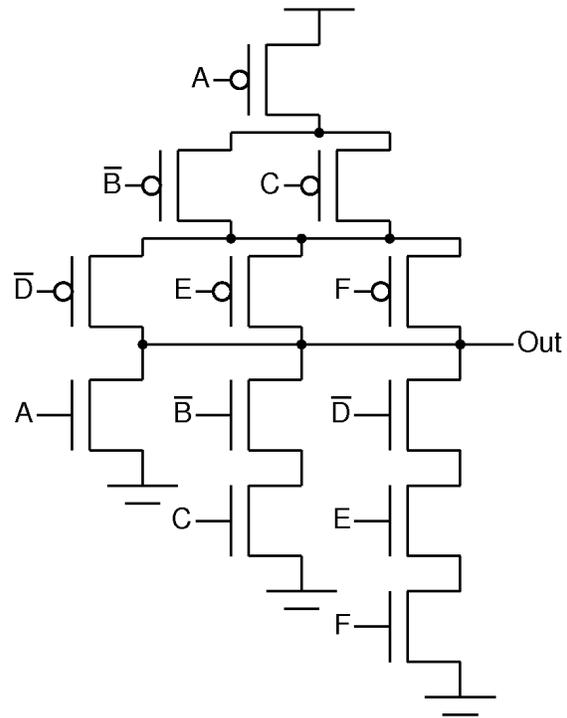
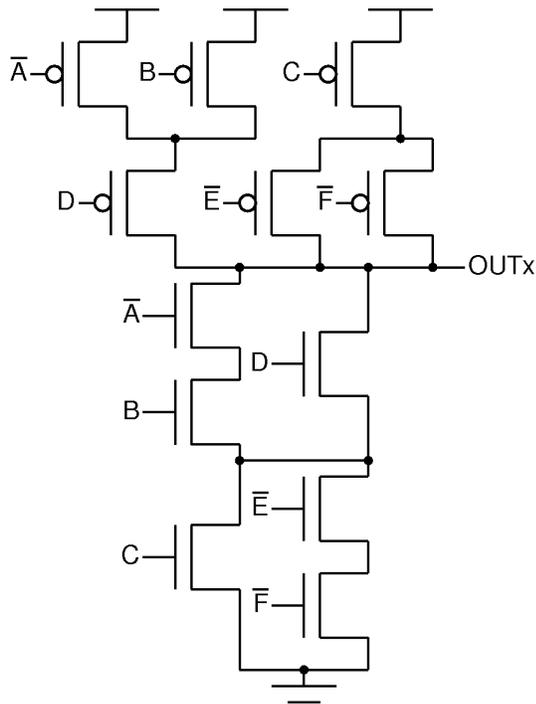


Problem 1 (3 parts, 30 points)

Incomplete Circuits

The three parts below contain (A) a pull up network, (B) a pull down network, and (C) an expression to be implemented. For (A) and (B), complete the missing complementary switching networks so the circuit contains no floats or shorts and write the Boolean expression computed by the completed circuit. For (C), design the entire switching network. Assume the inputs and their complements are available.



$$\text{OUT}_x = (A + \bar{B}) \cdot \bar{D} + \bar{C} \cdot (E + F)$$

$$\text{OUT}_y = \bar{B} \cdot \bar{D}$$

$$\text{OUT}_z = \bar{A} \cdot (B + \bar{C}) \cdot (D + \bar{E} + \bar{F})$$

Problem 2 (2 parts, 20 points)

Boolean Algebra

Part A (12 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.**

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

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


---

$$OUT_y = \overline{\overline{A} \cdot \overline{B} + \overline{C} \cdot \overline{D} + \overline{E}}$$

$$OUT_y = A + B + C + D + E$$


---

Part B (8 points) Derive the behavior of the following canonical product of sums (using maxterms) expression and complete the truth table.

A	B	C	F <sub>(A,B,C)</sub>
0	0	0	<b>0</b>
1	0	0	<b>1</b>
0	1	0	<b>0</b>
1	1	0	<b>0</b>
0	0	1	<b>1</b>
1	0	1	<b>1</b>
0	1	1	<b>1</b>
1	1	1	<b>1</b>

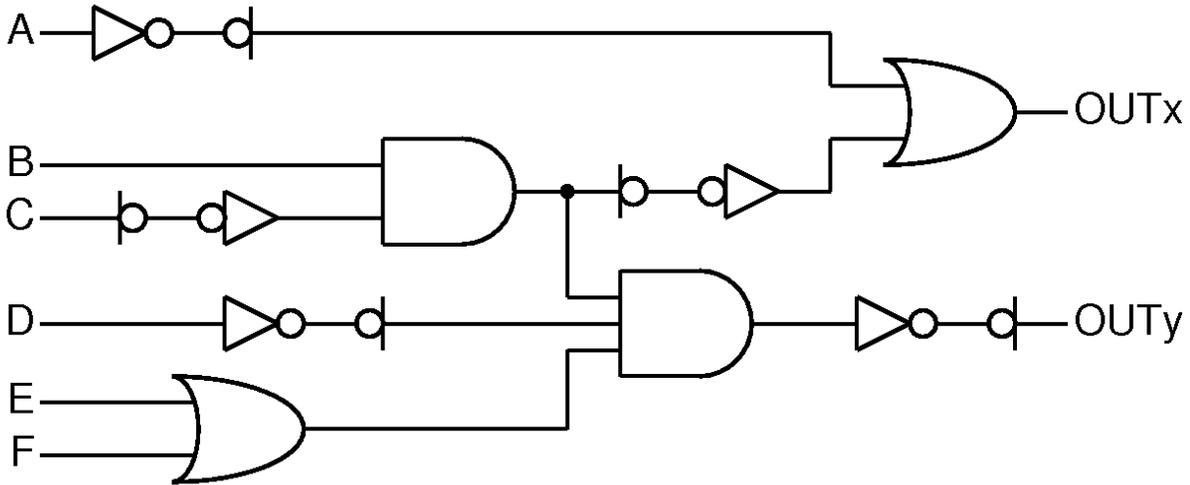
$$POS_{(MAXTERMS)} = (A + \overline{B} + C) \cdot (\overline{A} + \overline{B} + C) \cdot (A + B + C)$$


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Problem 3 (3 parts, 26 points)

Mixed Logic Design

Part A (12 points) The following design has no supporting documentation. Derive the desired Boolean expressions and the implementation cost (in CMOS transistors).

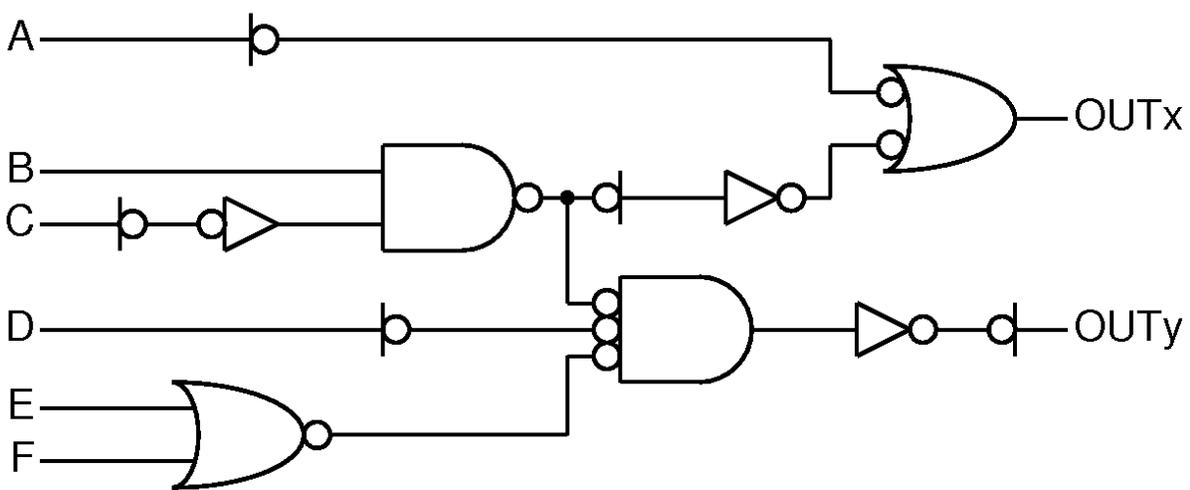


OUT<sub>x</sub> =  $\overline{A} + B \cdot \overline{C}$

OUT<sub>y</sub> =  $\overline{B \cdot \overline{C} \cdot D \cdot (E + F)}$

# transistors =  $1 \times 8 + 3 \times 6 + 5 \times 2 = 8 + 18 + 10 = 36T$

Part B (14 points) Now reimplement this expressions using NAND and NOR gates and inverters to minimize implementation cost. Use proper mixed logic notation. *Do not modify the expressions being implemented.* Determine the cost of this implementation (in transistors).



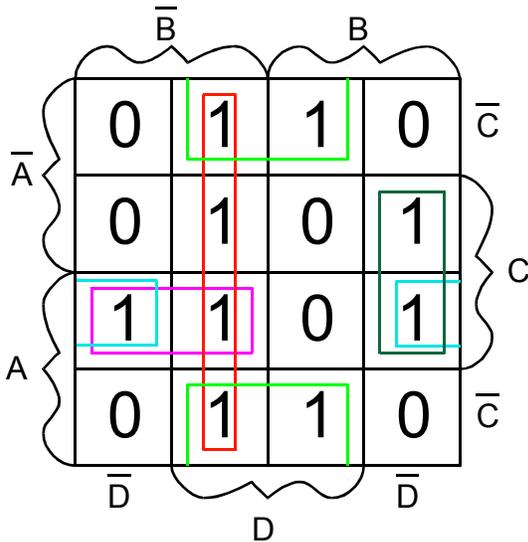
# transistors =  $1 \times 6 + 3 \times 4 + 3 \times 2 = 6 + 12 + 6 = 24T$

Problem 4 (3 parts, 24 points)

Karnaugh Maps

Part A (12 points) For the follow expression, derive a simplified **sum of products** expression using a Karnaugh Map. Circle and list *all* prime implicants, indicating which are essential.

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

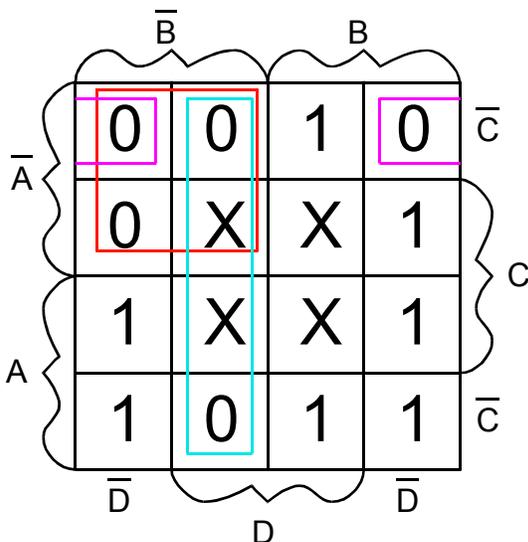


prime implicants	essential?	
	yes	no
$\bar{B}D$	<input checked="" type="checkbox"/>	<input type="checkbox"/>
$\bar{C}D$	<input checked="" type="checkbox"/>	<input type="checkbox"/>
$A\bar{B}C$	<input type="checkbox"/>	<input checked="" type="checkbox"/>
$AC\bar{D}$	<input type="checkbox"/>	<input checked="" type="checkbox"/>
$BC\bar{D}$	<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"/>

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

Part A (12 points) For the follow expression, derive a simplified **product of sums** expression using a Karnaugh Map. The output is X when both C and D are high. Circle and list all prime implicants, indicating which are essential.

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



prime implicants	essential?	
	yes	no
$A + B$	<input checked="" type="checkbox"/>	<input type="checkbox"/>
$B + \bar{D}$	<input checked="" type="checkbox"/>	<input type="checkbox"/>
$A + C + D$	<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"/>

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