

Name of student to your left _____

Name of student to your right _____

Please read the following instructions carefully: If you are unclear about any of the questions on the exam, make the most plausible assumption to answer the question. Instructors and proctors will not answer questions on the exam material. Please write your name on the top of each page. Write the names of the students to your left and right in the space provided. **All the Best!**

1 CMOS Circuits

Design a CMOS gate with function $y(a,b,c,d) = [a + bcd]'$. Draw the schematic diagram using NMOS and PMOS transistors as the basic elements.

- 10 points for correct design
- 5 points deducted for wrong PMOS/NMOS logic
- 1 or 2 points deducted for minor mistakes
- no points for illogical design

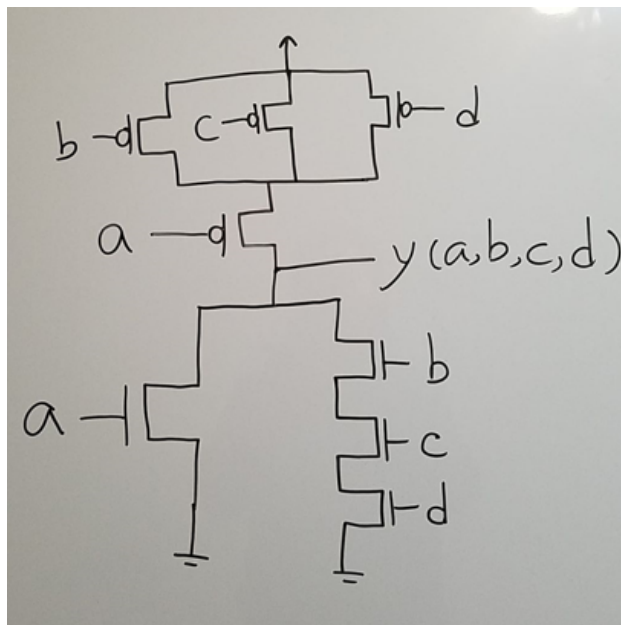


Figure 1: CMOS

2 Consensus Theorem Application

Rubrics

- 8 points for 2.1
- 12 points for 2.2
- 1 point deducted for each wrong, missing, or extra term

2.1 List all consensuses between the pair(s) of product terms in the following sum of products expressions.

1. $ab' + a'c + b'c$: Consensus(es) _____.

- $b'c$

2. $acd + abd'e' + a'bd'$: Consensus(es) _____.

- $bd'e'$
- $abce'$

3. $abc + a'de + bc'e'g$: Consensus(es) _____.

- $bcde$
- $abe'g$
- $a'bc'dg$

4. $ade + a'bcde + b'de'$: Consensus(es) _____.

- $bcde$
- $ab'd$

2.2 List all consensuses of the pair(s) of sum terms in the following product of sums expressions.

1. $(a + b')(a' + c')(b + c')$: Consensus(es) _____.

- $b' + c'$
- $a + c'$

2. $(a + b + c)(a + b' + e)(a' + c + d)$: Consensus(es) _____.

- $b + c + d$
- $b' + c + d + e$

- $a + c + e$

3. $(a + b' + d)(c + d' + e)(a' + c + d)$: Consensus(es) _____.

- $b' + c + d$
- $a + b' + c + e$
- $a' + c + e$

4. $(a + b + c)(a' + d)(a + c' + e)(a' + c + e)$: Consensus(es) _____.

- $b + c + d$
- $c' + d + e$
- $b + c + e$
- $a + b + e$

3 Circuit Specification: Priority Encoder

A priority encoder reads a vector of four binary bits (a_3, a_2, a_1, a_0) and produces a binary number (d_1, d_0) that presents the **highest** index of the input bit which is true. For example, when $(a_3, a_2, a_1, a_0) = (1, 0, 1, 1)$, the output $(d_1, d_0) = (1, 1)$; $(a_3, a_2, a_1, a_0) = (0, 1, 1, 0)$, the output $(d_1, d_0) = (1, 0)$; and when $(a_3, a_2, a_1, a_0) = (0, 0, 0, 1)$, the output $(d_1, d_0) = (0, 0)$. However, when none of the input bits asserts a true value, i.e. $(a_3, a_2, a_1, a_0) = (0, 0, 0, 0)$, the output remains to be $(d_1, d_0) = (0, 0)$.

1. Write the truth tables and K-maps of the two output functions. List all **essential** prime implicants.

Rubrics

- 16 points for 3.1
- 4 points for 3.2
- 4 points for the truth table; 1 point deducted for each wrong entry
- 4 points for each K-map; 1 point deducted for each wrong cell
- 4 points for correct essential prime implicants; 1 point deducted for each wrong, missing, or extra term
- 1 point deducted for mislabeled variables or unexplained blanks in K-maps
- 1 point deducted for wrongly formatted essential prime implicants (but we can tell you know the correct answer from your wrongly formatted answer)
- For 3.2, 4 points for correct answers; 1 point deducted for each wrong, missing, or extra term
- For 3.2, if the expression is not minimal, 1 point deducted for each output

a_3	a_2	a_1	a_0	d_1	d_0
0	0	0	0	0	0
0	0	0	1	0	0
0	0	1	0	0	1
0	0	1	1	0	1
0	1	0	0	1	0
0	1	0	1	1	0
0	1	1	0	1	0
0	1	1	1	1	0
1	0	0	0	1	1
1	0	0	1	1	1
1	0	1	0	1	1
1	0	1	1	1	1
1	1	0	0	1	1
1	1	0	1	1	1
1	1	1	0	1	1
1	1	1	1	1	1

Essential Prime Implicants (d_1): a_2, a_3

Essential Prime Implicants (d_0): a_3, a'_2a_1

2. Write a minimal sum of products expression for each of the two output bits.

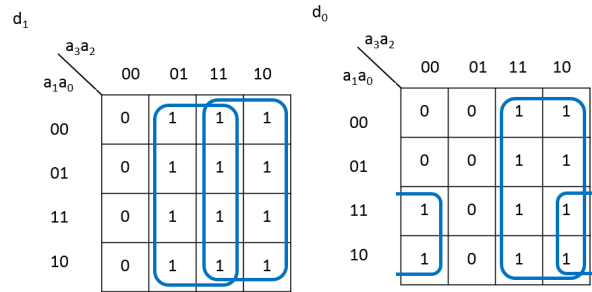


Figure 2: K-map of Priority Encoder

- $d_1 = a_2 + a_3$
- $d_0 = a'_2a_1 + a_3$

4 Karnaugh Map

Rubrics

- 5 points for each K-map; 1 point deducted for each wrong cell
- 6 points for minimal expressions in 4.1
- 4 points for minimal expressions in 4.2
- 1 point deducted for each wrong, missing, or extra expression

4.1 Sum of Products Expressions

Use Karnaugh map to simplify function

$$f(a,b,c) = \sum m(1,2,5,7) + \sum d(0,6).$$

Write the K-map and list all possible minimal sum of products expressions. No need for the logic diagram.

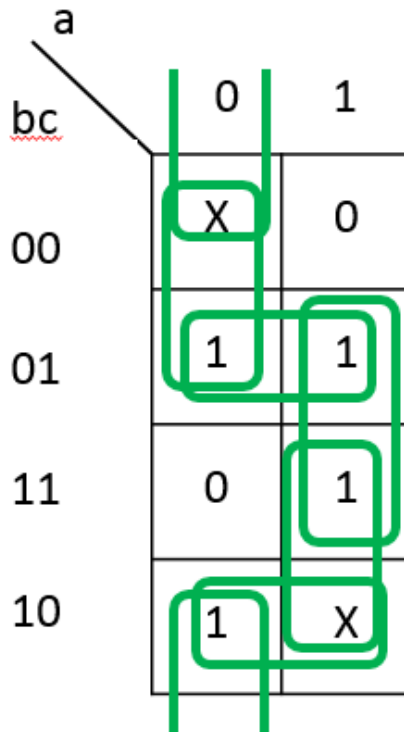


Figure 3: K-map of 4.1

- $f(a,b,c) = b'c + ac + bc'$
- $f(a,b,c) = b'c + ac + a'c'$
- $f(a,b,c) = b'c + ab + bc'$
- $f(a,b,c) = b'c + ab + a'c'$

- $f(a,b,c) = a'b' + ac + a'c'$
- $f(a,b,c) = a'b' + ac + bc'$

4.2 Product of Sums Expressions

Use Karnaugh map to simplify function

$$f(a,b,c) = \sum m(0,7) + \sum d(4).$$

Write the K-map and list all possible minimal product of sums expressions. No need for the logic diagram.

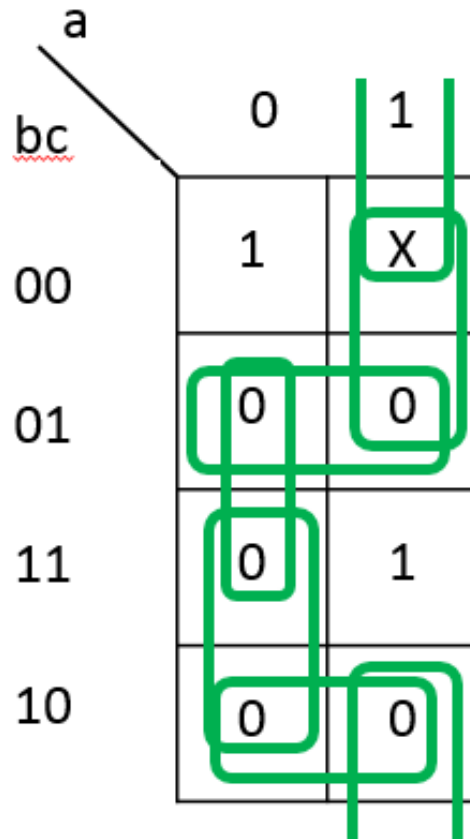


Figure 4: K-map of 4.2

- $f(a,b,c) = (b + c')(a + b')(b' + c)$
- $f(a,b,c) = (b + c')(a + b')(a' + c)$
- $f(a,b,c) = (a + c')(b' + c)(a' + b)$
- $f(a,b,c) = (a + c')(b' + c)(b + c')$

5 Other Types of Gates

5.1 Universal Set of Gates

Circle the following items which are universal sets of gates

A. {NAND}; B. {AND, NOT}; C. $\{f(x, y, z) = xy + xz + yz\}$; D. $\{f(x, y) = x + y'\}$; E. $\{f(x, y) = xy + x'y'\}$.

Rubrics

- 3 points for each choice

ABD

5.2 XOR gates

Consider the function $f(x, y)$ where $\oplus$ is an Exclusive OR operator and the priority of the operators is AND (first), Exclusive OR and OR (last):

$$f(x, y) = x \oplus (x + y) \oplus (x' + y) \oplus x'y' \oplus y \oplus x'y.$$

Simplify the function into a minimal sum of products expression using switching function techniques e.g. Shannon's expansion. Show your derivation.

Rubrics

- 15 points for correct answer
- 3 points deducted for using Shannon's expansion but arriving at a wrong answer
- 7 points for making derivation but arriving at a wrong answer
- no points for any wrong answer without the derivation

$$\begin{aligned} f(x, y) &= xf(1, y) + x'f(0, y) \quad \text{Shannon's Expansion} \\ &= x[1 \oplus 1 \oplus y \oplus 0 \oplus y \oplus 0] + x'[0 \oplus y \oplus 1 \oplus y' \oplus y \oplus y] \\ &= x[0] + x'[0] \\ &= 0 \quad (\text{Distributive, Identity Laws}) \end{aligned}$$

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