ShanghaiTech University

EE 115B: Digital Circuits

Fall 2024

Solution

Midterm Exam, November 14, 2024

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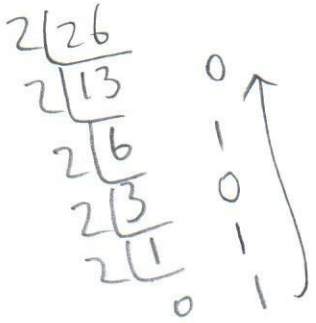
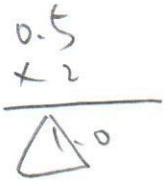
Student ID: _____ Name in Chinese: _____

1. Short questions. (10 points, 1 point each.)

(1) Convert $(26.5)_{10}$ to binary.



$(26)_{10} = (11010)_2$



$(0.5)_{10} = (0.1)_2$

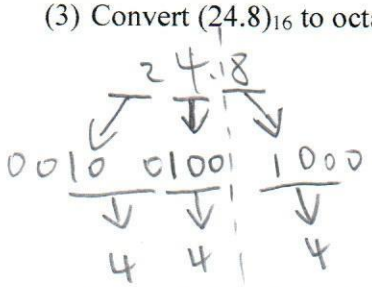
$(26.5)_{10} = (11010.1)_2$

(2) Convert $(10101.01)_2$ to decimal.

$(10101.01)_2 = 1\times2^4 + 1\times2^2 + 1\times2^0 + 1\times2^{-2}$

$= (21.25)_{10}$

(3) Convert $(24.8)_{16}$ to octal.



$(24.8)_{16} = (44.4)_8$

(4) Convert $(32)_8$ to BCD.

$(32)_8 = 3\times8^1 + 2\times8^0 = (26)_{10} = (0010\ 0110)_{BCD}$

(5) Convert $(01010011)_{BCD}$ to hexadecimal.

$(01010011)_{BCD} = (53)_{10}$

$= (35)_{16}$

16 | 53
16 | 3 ↑ 5
0 3 ↑

(6) Determine the odd parity bit for 100110101.

5 1's → odd parity bit is '0'.

(7) (True or False.) The XOR gate is also called the equivalence gate.

False

(8) What does "VHDL" stand for?

VHSIC (very High Speed Integrated Circuits)
Hardware Description Language

(9) What does "FPGA" stand for?

Field Programmable Gate Array

(10) Given the following VHDL code, write the logic function for F.

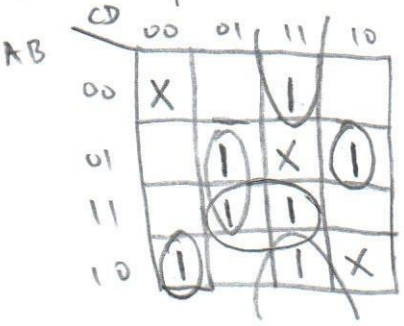
F <= A or B and C or D;

F= $(A+B)C+D$

2. Develop the minimum SOP and POS expressions with and without the don't cares using Karnaugh map. (20 points, 5 points each.) NOTE: In this exam, SOP means sum of products and POS means product of sums.

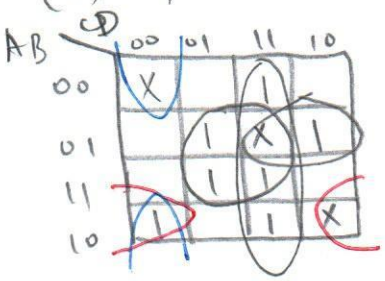
$$Y(A,B,C,D) = \sum m(3,5,6,8,11,13,15) + D(0,7,10)$$

(1) Sop without don't cares.



$Y = \bar{B}CD + B\bar{C}D + ABD + \bar{A}BC\bar{D} + A\bar{B}\bar{C}\bar{D}$

(2) SOP with don't cares

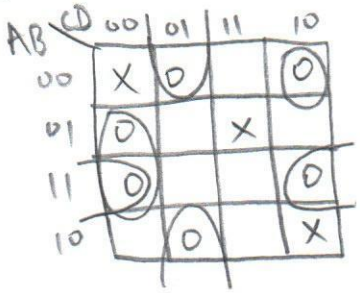


$Y = CD + BD + \bar{A}Bc + \underline{\bar{B}\bar{c}\bar{D}}$ blue

or

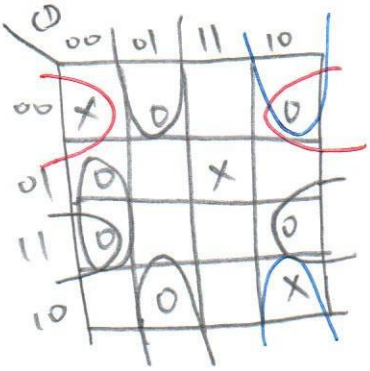
$Y = CD + BD + \bar{A}Bc + \underline{A\bar{B}\bar{D}}$ red

(3) POS without don't cares



$Y = (\bar{B}+c+D)(\bar{A}+\bar{B}+D)(B+c+\bar{D})(A+B+\bar{c}+D)$

(4) POS with don't cares



$Y = (\bar{B}+c+D)(\bar{A}+\bar{B}+D)(B+c+\bar{D})\underline{(B+\bar{c}+D)}$ blue

or

$Y = (\bar{B}+c+D)(\bar{A}+\bar{B}+D)(B+c+\bar{D})\underline{(A+B+D)}$ red

3. Develop the minimum POS expression (NOTE: NOT the minimum SOP expression) for the following function using the Quine-McCluskey method. (20 points.)

$$Y(A,B,C,D) = \sum m(2,3,4,6,8,10,11,14,15)$$

$Y = \Pi M(0,1,5,7,9,12,13)$

(1)

maxterms	0	1	5	7	9	12	13
	0000	0001	0101	0111	1001	1100	1101

This page is reserved for Problem 3.

grouping & combining (based on 1's)

group 0	0	0000 ✓	0,1	000−
group 1	1	0001 ✓	1,5	0−01 ✓
			1,9	−001 ✓
group 2	5	0101 ✓	5,7	01−1
	9	1001 ✓	5,13	−101 ✓
	12	1100 ✓	9,13	1−01 ✓
group 3	7	0111 ✓	12,13	110−
	13	1101 ✓		

1,5,9,13 −−01

1,9,5,13 −−01 redundant

PIs : 0,1 000− $A+B+C$; 5,7 01−1 $A+\bar{B}+\bar{D}$;

12,13 110− $\bar{A}+\bar{B}+C$; 1,5,9,13 −−01 $C+\bar{D}$.

(2) PI chart

maxterm	PI	0	1	5	7	9	12	13
0,1	$A+B+C$	(X)	X					
5,7	$A+\bar{B}+\bar{D}$			X	(X)			
12,13	$\bar{A}+\bar{B}+C$						(X)	X
1,5,9,13	$C+\bar{D}$		X	X		(X)		X

All PIs are EPIs.

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

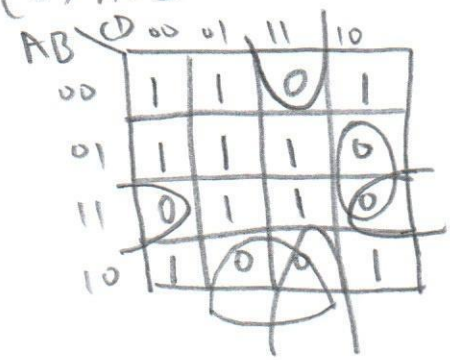
4. Convert the following AND-OR expression to NAND, AND-OR-Invert (AOI), and NOR expressions. (15 points, 5 points each.)

$$\boldsymbol{Y(A,B,C,D) = A'C' + B'D' + BD}$$

(1) NAND

$Y = \overline{\overline{AC} + \overline{BD} + BD} = \overline{\overline{AC} \cdot \overline{BD} \cdot \overline{BD}}$

(2) AOI



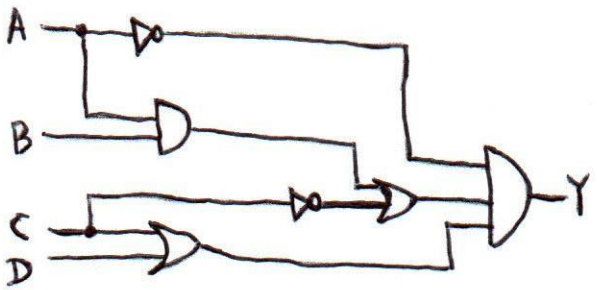
$Y = \overline{AB\bar{D} + A\bar{B}D + \bar{B}CD + BC\bar{D}}$

(3) NOR

$Y = \overline{\overline{AB\bar{D}} + \overline{A\bar{B}D} + \overline{\bar{B}CD} + \overline{BC\bar{D}}}$

$= \overline{\overline{A+\bar{B}+D} + \overline{A+B+\bar{D}} + \overline{B+\bar{C}+\bar{D}} + \overline{\bar{B}+\bar{C}+D}}$

5. Convert the following circuit to NAND-only and NOR-only circuits. You need to use the standard NAND and NOR symbols to draw your final circuits. (20 points, 10 points each.)



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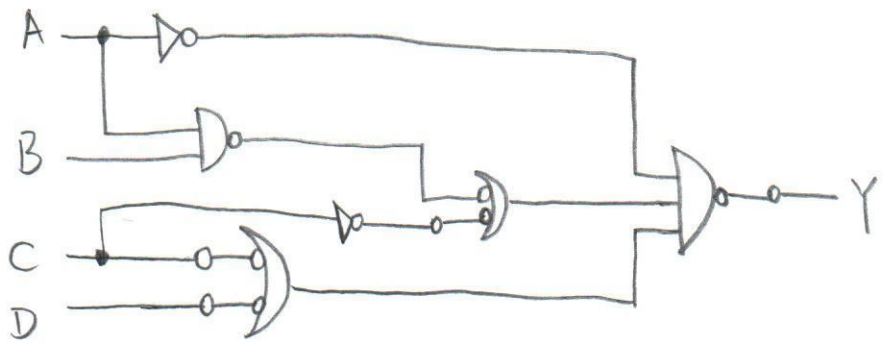
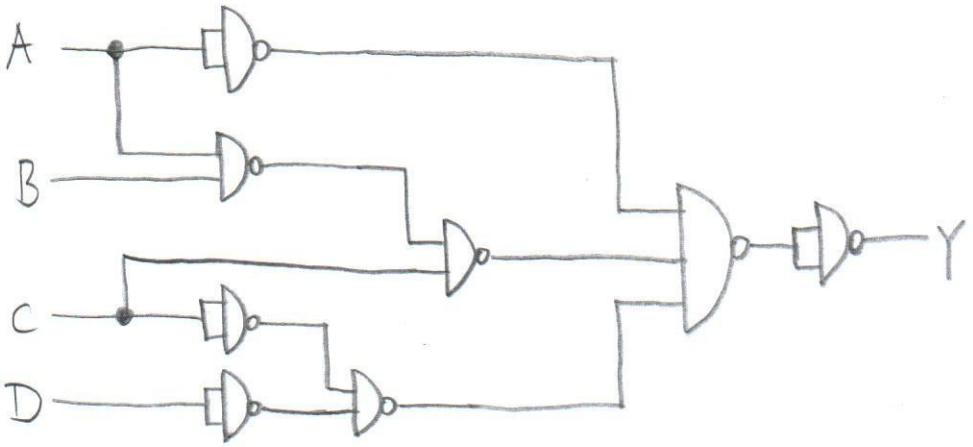
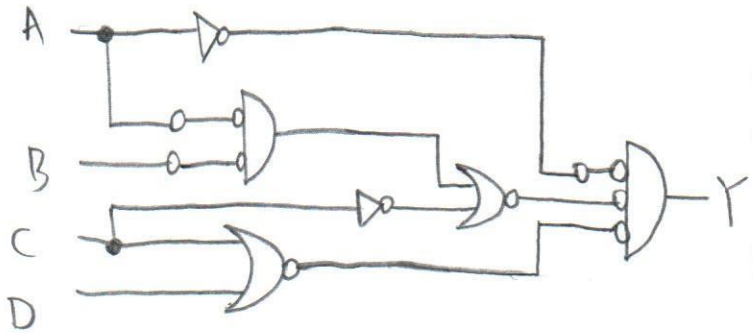
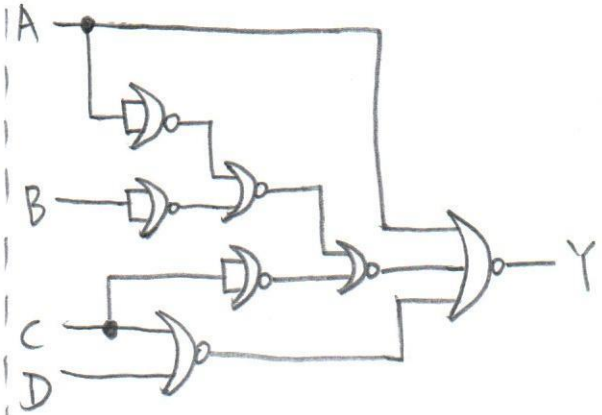
(1) NAND





(2) NOR





6. Design a circuit with three inputs and one output. The output is 1 if an odd number of inputs is(are) 1. You need to: (a) define the logic variables and build the truth table, (b) develop the minimum SOP expression for the output, and (c) draw the circuit diagram using AND, OR, and NOT gates based on the minimum SOP expression. (15 points, 5 points each.)

(a) Inputs: A, B, C. Output: Y.

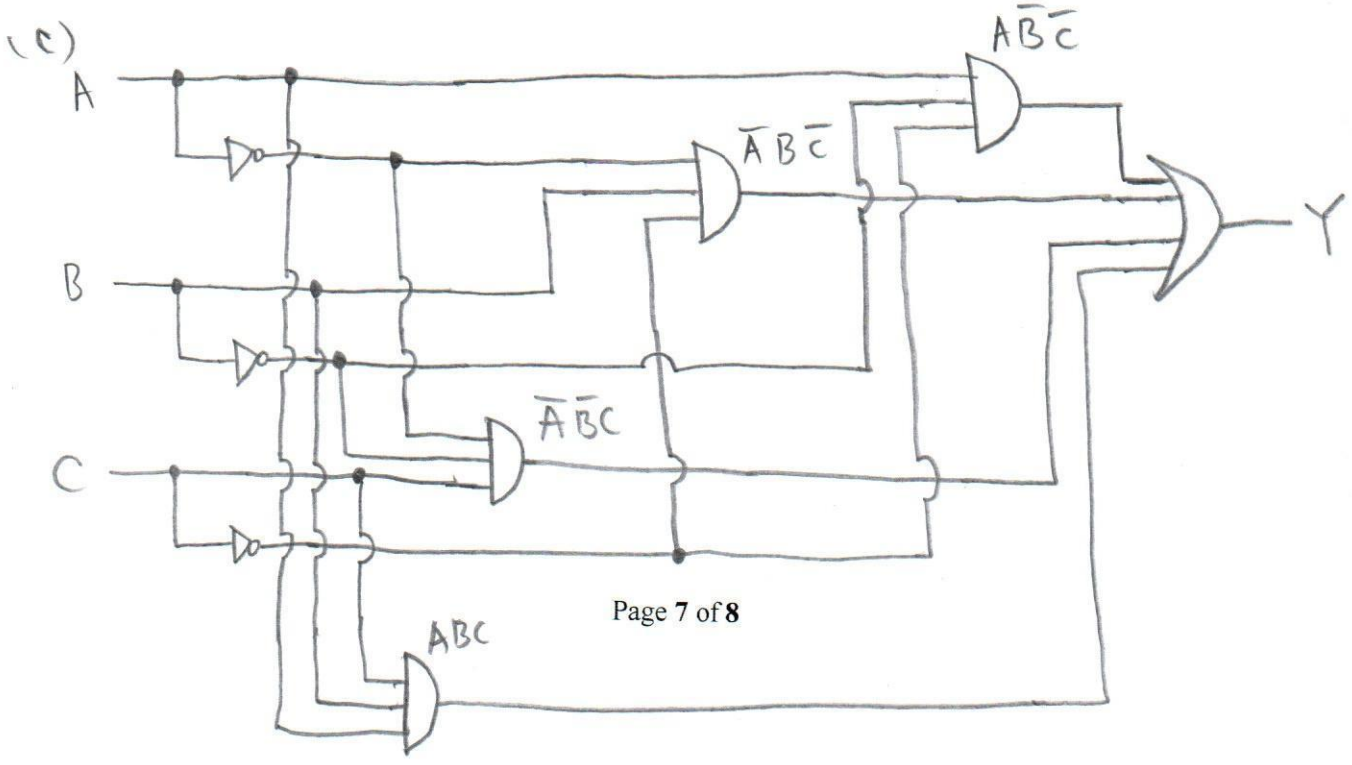
A	B	C	Y
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1

(b)

A \ BC	00	01	11	10
0	0	(1)	0	(1)
1	(1)	0	(1)	0

$Y = \bar{A}\bar{B}C + \bar{A}B\bar{C} + A\bar{B}\bar{C} + ABC$

(c)



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Do NOT use this page as an answer sheet.