COMPUTER BASICS 2018-2019
Exercises U1: Boolean Algebra and Logic design

U1_1. Perform the following conversions (Verify answers in decimal)

a) Convert to binary the decimal numbers 321, 1462, 205, 1023, 1024, 135, 45 y 967
b) Convert to decimal the following numbers (in binary) 111001, 101000, 100000001, 01111000, 0000011 y 10101
c) Convert to base 3 the following decimal numbers 76, 458 y 222

Solution:

a) 101000001, 10110110110, 11001101, 1111111111, 10000000000, 10000111, 101101, 1111000111
b) 57, 40, 257, 120, 3, 21
c) 2211, 121222, 22020

U1_2. Convert to Hexadecimal:

	Solution:		Solution:
1. 3167_{10}	C5F	**2.** 110_2	6
3. 219_{10}	DB	**4.** 1001011_2	4B
5. 6560_{10}	19A0	**6.** 728_{10}	2D8

U1_3. Convert to Decimal:

	Solution:		Solution:
1. $3AE_{16}$	942	**2.** $A2E_{16}$	2606
3. FFF_{16}	4095	**4.** 20_8	16
5. $6AF_{16}$	1711	**6.** 125_8	85
7. $C20_{16}$	3104		

U1_4. Convert to base 8:

	Solution:		Solution:
1. 3167_{10}	6137_8	**2.** 101_{10}	145_8
3. 219_{10}	333_8	**4.** 110_2	6_8
5. 304_{10}	460_8	**6.** 1001011_2	113_8
7. 256_{10}	400_8		

U1_5. Convert to decimal

	Solution:		Solution:
1. 318_8	208_{10}	**2.** 677_8	447_{10}
3. 13_8	11_{10}	**4.** 20_8	16_{10}
5. 7021_8	3601_{10}	**6.** 125_8	85_{10}

U1_6. Simplify the following expressions using the boolean Algebra basic Laws:

a) $A + A B + A \overline{B} C$

b) $(\overline{A} + B) C + A B C$

c) $A \overline{B} C (B D + CDE) + A \overline{C}$

Solution:

a) A;

b) $C (\overline{A} + B)$

c) $A (\overline{C} + \overline{B} D E)$

U1_7. Convert the following SOPs into the standard representation:

a) $A B + \overline{A} B D + \overline{A} C \overline{D}$

b) $A \overline{B} C + A \overline{C}$

Solution:

a) $ABCD + ABC \overline{D} + AB \overline{C} D + AB \overline{C} \, \overline{D} + \overline{A} BCD + \overline{A} B \overline{C} D + \overline{A} BC \overline{D} + \overline{A} \, \overline{B} C \overline{D}$

b) $\overline{A} B C + AB \overline{C} + A \overline{B} \, \overline{C}$

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U1_8. Convert the following POSs into the standard notation:

a) $(A + B + C)\ (A + \overline{B} + C)\ (A + B + \overline{C})$

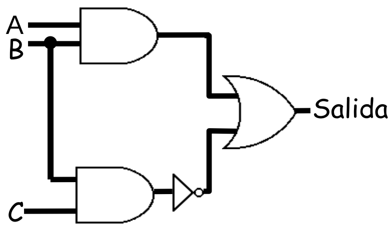
b) $A(A + \overline{C})\ (A + B)$

Solution:

a) $(A + B + C)\ (A + \overline{B} + C)\ (A + B + \overline{C})$

b) $(A + B + C)\ (A + B + \overline{C})\ (A + \overline{B} + C)\ (A + \overline{B} + \overline{C})$

U1_9. Obtain the truth table for the following circuit and its logic equation:

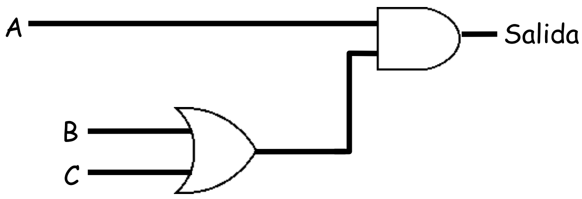


Solution:

a) $(A\ B) + \overline{B} + \overline{C}$

A	B	C	Salida
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

U1_10. Write the truth table and equation of the following circuit:



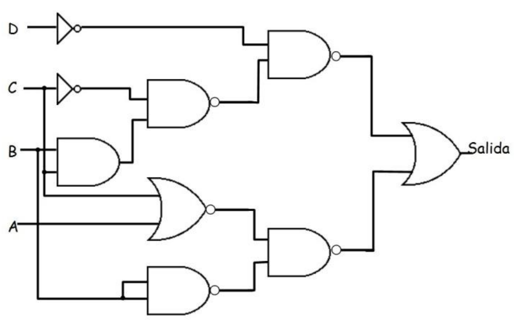
Solution:

a) $A\ (B + C)$

A	B	C	Salida		A	B	C	Salida
0	0	0	0		1	0	0	0
0	0	1	0		1	0	1	1
0	1	0	0		1	1	0	1
0	1	1	0		1	1	1	1

U1_11. Write the truth table of the following circuit :

Solution:



D	C	B	A	Salida		D	C	B	A	Salida
0	0	0	0	0		1	0	0	0	1
0	0	0	1	1		1	0	0	1	1
0	0	1	0	1		1	0	1	0	1
0	0	1	1	1		1	0	1	1	1
0	1	0	0	1		1	1	0	0	1
0	1	0	1	1		1	1	0	1	1
0	1	1	0	1		1	1	1	0	1
0	1	1	1	1		1	1	1	1	1

U1_12. Obtain the Logic equation (SOPs) of the folllowing boolean fucntion represented by a truth table:

A	B	C	D	F		A	B	C	D	F
0	0	0	0	0		1	0	0	0	0
0	0	0	1	0		1	0	0	1	1
0	0	1	0	0		1	0	1	0	0
0	0	1	1	1		1	0	1	1	1
0	1	0	0	0		1	1	0	0	0
0	1	0	1	1		1	1	0	1	1
0	1	1	0	0		1	1	1	0	1
0	1	1	1	1		1	1	1	1	1

Solution:

$$\bar{A}\,\bar{B}CD + \bar{A}B\bar{C}D + \bar{A}BCD + A\bar{B}\,\bar{C}D + A\bar{B}CD + AB\bar{C}D + ABC\bar{D} + ABCD$$

U1_13. Simplify the follwoing expressions

a) $F = A + \bar{A}B + (\overline{A+B}) + (\overline{A+B+C})D$

b) $F = \bar{A}B + AC + BCD + \bar{D}$

c) $F = A + \bar{A}\,\bar{B} + BC\bar{D} + B\bar{D}$

d) $F = (A + BC)(AB + A\bar{B} + BC + D)$

Solution:

a) $F = 1$

b) $F = \bar{A}B + AC + \bar{D}$

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

d) $F = A + BC$

U1_14. Use Karnaugh Maps to simplify the following functions

a) $F = AB + \bar{A}C + BC$

b) $F = A\bar{C}\,\bar{D} + AD + \bar{B}C + CD$

Solution:

a) $F = \bar{A}C + AB$

b) $F = A\bar{C} + CD + \bar{B}C$

U1_15. Find the simplified logic functions and design a circuit to implement the following expressions. Functions contains in all cases 4 variables (A, B,C,D) being A the most significant one and D the least significant one.

a) $F=\Sigma m(0,1,8,9,10)$
b) $F=\Sigma m(0,1,2,3,8,9,10,11)$
c) $F=\prod M(5,7,13,15)$
d) $F=\prod M(1,3,9,10,11,14,15)$
e) $F=\Sigma m(7,11,12,13,14,15)$
f) $F=\prod M(0,3,4,7,8,11,12,15)$

Solution:

a) $F = \bar{B}\,\bar{C} + A\bar{B}\,\bar{D}$

b) $F = \bar{B}$

c) $F = \bar{B} + \bar{D}$

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

e) $F = AB + ACD + BCD$

f) $F = C \oplus D$

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U1_16. Simplify the function F4 using the Karnaugh Method. F4=F1·F2+F3, with F1=Σm(1,2,3,5,7), F2=Σm(0,1) and F3= ∏M(5,6,7). Consider A as MSB and C as LSB.

Solution:

$$F4 = \overline{A} + \overline{B}\,\overline{C}$$

U1_17. Given the 4-variable functions F1 and F2. Obtain the Function F with F1=F2 XOR F, F1=Σm(3,4,7) and F2=Σm(0,1,3,6,7,9,10,13,14).

Solution:

$$F = \Sigma\, m(0,1,4,6,9,10,13,14)$$

a) Design the circuit using logic gates of any kind, but minimizing as much as possible.
b) Design the circuit using only NAND gates with two inputs.

U1_18. Four switches are available, A, B, C and D, which when open, provide a logical '0' and when closed a logical '1'. With them we want to generate a signal S that meets the following conditions: S will be '1' when A is closed when B is open; when D is closed with A and B open; or when A and B are closed with C and D open. In the rest of the cases S will be '0'. It is requested:

a) Design the circuit using logic gates of any kind, but minimizing as much as possible.
b) Design the circuit using only NAND gates with two inputs.

Solution:

a) $S = A\overline{B} + A\overline{C}\,\overline{D} + \overline{B}D$

b) $S = \overline{\overline{\overline{(\overline{A\overline{B}})\,(\overline{\overline{A\overline{C}}}\;\overline{D})}}\;(\overline{\overline{B}D})}$

U1_19. There is a terminal with a light Z_n active at low level. The switching on or off of the light is controlled by the following four input signals: turn on the light (ON), activate on high; enable the lighting on (EN_n), active on low; emergency (AL_n), active on low; and correct operation (OK), active high. The light comes on (is active) whenever the emergency signal is activated. It also lights up when the correct operation signal is activated, the signal that requests the lighting and enabling. It is requested to design the combinational circuit that performs the previous logic control function.

Solution:

$$Z\_n = AL\_n\,(EN\_n + \overline{OK} + \overline{ON})$$

U1_20. A digital circuit has a '1' in its output provided that at least three of its four inputs are at '1'. Perform the circuit using a maximum of 3 AND and 2 OR gates. Consider that each gate has a maximum of 3 entries.

Solution:

$$F = BC\,(A + D) + ABD + ACD$$

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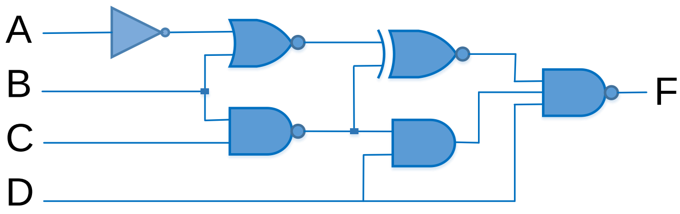
U1_21. Find the simplified expression of the following circuit:
- a) as SOPs
- b) Using only NAND gates with 2 inputs



Solution:

a) $F = \overline{A} + B + \overline{D}$

b) $F = \overline{\overline{\overline{AD}}\;\overline{B}}$

U1_22. Given the following truth table for functions F and G, calcualte the minimun expression as SOPs for F and as POS for G.

#	**A**	**B**	**C**	**D**	**F**	**G**
0	0	0	0	0	0	0
1	0	0	0	1	1	0
2	0	0	1	0	1	0
3	0	0	1	1	0	0
4	0	1	0	0	0	1
5	0	1	0	1	0	0
6	0	1	1	0	1	1
7	0	1	1	1	1	0

#	**A**	**B**	**C**	**D**	**F**	**G**
8	1	0	0	0	1	1
9	1	0	0	1	0	1
10	1	0	1	0	1	0
11	1	0	1	1	0	0
12	1	1	0	0	1	1
13	1	1	0	1	1	1
14	1	1	1	0	0	1
15	1	1	1	1	1	0

Solution:

$F = A\,\overline{C}\,\overline{D} + ABD + \overline{A}\,BC + \overline{B}\,C\,\overline{D} + \overline{A}\,\overline{B}\,\overline{C}\,D$

Also it would be possible: $F = A\,\overline{B}\,\overline{D} + AB\,\overline{C} + BCD + \overline{A}\,C\,\overline{D} + \overline{A}\,\overline{B}\,\overline{C}\,D$

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

U1_23. We have 2 logic functions, F1 y F2, of 4 variables: A, B, C y D, (A is MSB and D is LSB).
- **a)** if F1 = $\sum$ m (0,2,3,6,7,8,10,11), calculate the canonical expression for F1 as POSs.
- **b)** if F2 = $\prod$ M (4,6,9,11,12,13,14,15), calculate the canonical expression for F2 as SOPs.

Solution:

F1

CD / AB	**00**	**01**	**11**	**10**
00	1	0	1	1
01	0	0	1	1
11	0	0	0	0
10	1	0	1	1

F2

CD / AB	**00**	**01**	**11**	**10**
00	1	1	1	1
01	0	1	1	0
11	0	0	0	0
10	1	0	0	1

$F1 = (C + \overline{D})(\overline{A} + \overline{B})(\overline{B} + C)$

$F2 = \overline{B}\,\overline{D} + \overline{A}\,D$

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U1_24. In order to control a motor, we use 3 different switches named A, B y C:

i. If A, B and C are pressed the motor is activated.
ii. If only 2 switches are pressed, the motor is activated but an alarm light is also ON to indicate that we are in an emergency situation.
iii. If only a switch is pressed, the motor is not activated and the alarm light turns ON.
iv. If no switch is pressed neither the motor or the light are activated

Obtain:
a) The truth table of this system.
b) Simplified logic functions to control the motor (M) as the minimal POS and to control the light (L) as the minimal POS
c) Draw the function corresponding to the "M" function

Solution:

a)

A	B	C	M	L
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	1
1	0	0	0	1
1	0	1	1	1
1	1	0	1	1
1	1	1	1	0

b)

C AB	0	1	M
00	0	0	
01	0	1	
11	1	1	
10	0	1	

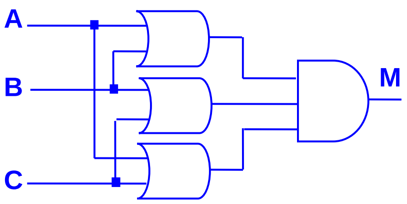
C AB	0	1	L
00	0	1	
01	1	1	
11	1	0	
10	1	1	

$$M = (A + B)\,(A + C)\,(B + C)$$

$$L = A\,\overline{B} + \overline{A}\,C + B\,\overline{C}$$

It is also possible: $L = A\,\overline{C} + \overline{A}\,B + B\,\overline{C}$

c)



U1_25. An electric motor can rotate in both directions by means of two contactors (electromechanical components that aim to establish or interrupt the passage of current): "D" for the right turn and "I" for the left turn. These two contactors are the outputs of a logic circuit controlled by two push buttons "A" (right) and "B" (left) and a selection switch L according to the following conditions:

i. If only one of the two rotation buttons is pressed, the motor rotates in the corresponding direction.
ii. If the two rotary buttons are pressed simultaneously, the direction of rotation depends on the state of the "L" switch so that:
iii. If "L" is activated, the motor turns to the right.
iv. If "L" is at rest, the motor turns to the left.

It is requested:

a) The truth table of the system.
b) The simplified logical functions "D" as the minimum sum of products (SOP) and "I" as the minimum product of sums (POS)
c) Draw the circuit for the "I" function

Solution:

a)

A	B	L	D	I
0	0	0	0	0
0	0	1	0	0
0	1	0	0	1
0	1	1	0	1
1	0	0	1	0
1	0	1	1	0
1	1	0	0	1
1	1	1	1	0

b)

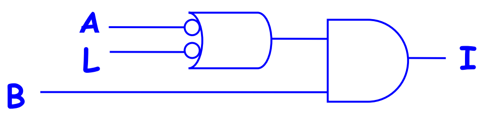
L / AB	0	1	D
00	0	0	
01	0	0	
11	0	1	
10	1	1	

$D = A\,\overline{B} + A\,L$

L / AB	0	1	I
00	0	0	
01	1	1	
11	1	0	
10	0	0	

$I = (\overline{A} + \overline{L})\,B$

c)



U1_26. Let the logical function F be 4 varaibles: A, B, C y D, (A is MSB and D is LSB). The equation of this function is $F = (\overline{B} + C + D)(B + \overline{D})(A + \overline{B} + C)$. What it is requested is the algebraic expression of F in canonical form as SOPs and a representation of the circuit with logic gates.

Solution:

CD / AB	00	01	11	10
00	1	0	0	1
01	0	0	1	1
11	0	1	1	1
10	1	0	0	1

The function is given as a product of sums, which using a Karnaugh diagram, points to all zeros of a function completely specified and given by its canonical function:

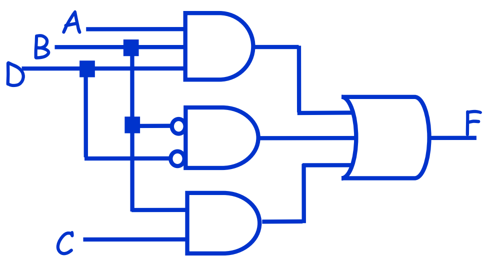
$F = \prod M(1, 3, 4, 5, 9, 11, 12)$

From the previous expression, it is posible to obtain the dual canonic function as sum of minterms (all the 1's of the function):

$F = \sum m(0, 2, 6, 7, 8, 10, 13, 14, 15)$

The simplification as SOPs is: $F = A\,B\,D + \overline{B}\,\overline{D} + B\,C$

The SOP circuit implementing this function is:



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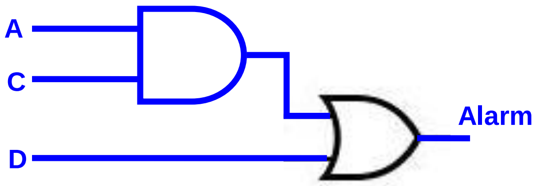
U1_27. An electronic alarm system consists of four detectors A, B, C and D. The alarm must be triggered when at least three of the four detectors are activated. If only two detectors are activated, their firing is indifferent. The alarm should never be triggered if one or no detector is activated. Finally, for safety reasons, it must also be activated if A = 0, B = 0, C = 0 and D = 1. Design and implement (draw) a control circuit for this alarm using as few logical gates as possible.

Solution:

AB \ CD	00	01	11	10
00	0	1	X	0
01	0	X	1	X
11	X	1	1	1
10	0	X	1	X



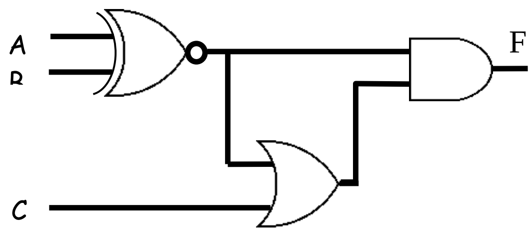
Alarm = D + A C

U1_28. Given the circuit in the figure:

a) Write the Truth table.

b) Obtain the expression for F in its canonical forms (SOPs and POSs).

c) Obtain the most simplified expression for the system using SOPs.



Solution:

a)

A	B	C	F	minterms	Maxterms
0	0	0	1	$\rightarrow \overline{A}\ \overline{B}\ \overline{C}$	
0	0	1	1	$\rightarrow \overline{A}\ \overline{B}\ C$	
0	1	0	0		$\rightarrow A + \overline{B} + C$
0	1	1	0		$\rightarrow A + \overline{B} + \overline{C}$
1	0	0	0		$\rightarrow \overline{A} + B + C$
1	0	1	0		$\rightarrow \overline{A} + B + \overline{C}$
1	1	0	1	$\rightarrow A\ B\ \overline{C}$	
1	1	1	1	$\rightarrow A\ B\ C$	

b)

SOP Canonical: $F = \overline{A}\ \overline{B}\ \overline{C} + \overline{A}\ \overline{B}\ C + A\ B\ \overline{C} + A\ B\ C = \Sigma\ m\ (0, 1, 6, 7)$

POS Canonical: $F = (A + \overline{B} + C).(A + \overline{B} + \overline{C}).(\overline{A} + B + C).(\overline{A} + B + \overline{C}) = \Pi\ M\ (2, 3, 4, 5)$

c)

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

$F = \overline{A}\ \overline{B} + A\ B = \overline{A \oplus B}$

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U1_29. It is desired to design an electronic equipment for the occupation control of a charming rural house that has four beautiful rooms, called A, B, C and D.In each room there is a device that tells us, with two bits, the number of people inside each moment, which will logically be from 0 to 3 people. The outputs of each of these devices will be the inputs to the circuit, which are called A_1, A_0, B_1, B_0, C_1, C_0, D_1 y D_0.

.

The outputs of the circuit are:

- F_1: It is activated ("1") when there is no people in any room.
- F_2: Activated when all the rooms are occupied by at least one person
- F_3: Activated when there are 3 persons in all the rooms
- F_4: Activated when, at least, there is an occupied room, by at least one person.

It is requested:

a) Obtain the expression of function F_1.
b) Obtain the expression of function F_2.
c) Obtain the expression of function F_3.
d) Obtain the expression of function F_4.

Solution:

a) $F_1 = \overline{A_1 + A_0 + B_1 + B_0 + C_1 + C_0 + D_1 + D_0}$

b) $F_2 = (A_1+A_0)\ (B_1+B_0)\ (C_1+C_0)\ (D_1+D_0)$

c) $F_3 = (A_1 \,.\, A_0 \,.\, B_1 \,.\, B_0 \,.\, C_1 \,.\, C_0 \,.\, D_1 \,.\, D_0)$

d) $F_4 = (A_1 + A_0 + B_1 + B_0 + C_1 + C_0 + D_1 + D_0)$

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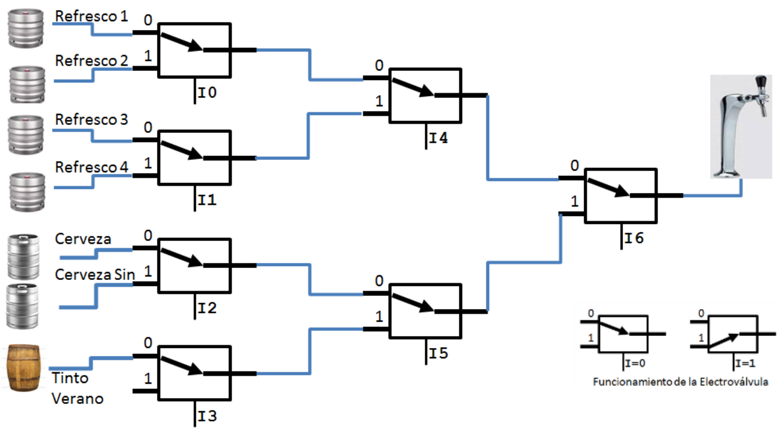
U1_30. It is intended to design the control of a bar drinks dispenser. Through a pushbutton with three buttons, a binary code is generated that allows you to select one drink or another, according to the attached table. To control the flow of beverages, a series of electro valves is available. These are electromechanical elements with two inputs and one output. They allow one of the inputs to be connected to the output as a function of an electrical signal (a logical "zero" connects the input 0 with the output and a logical "one" connects the input 1). The operating scheme is shown below:



Buttons A	B	C	Selection
0	0	0	Nothing
0	0	1	Refresco 1
0	1	0	Refresco 2
0	1	1	Refresco 3
1	0	0	Refresco 4
1	0	1	Cerveza
1	1	0	Cerveza Sin
1	1	1	Tinto de Verano

a. Fill the truth table of a circuit whose inputs are the signal of the three buttons (A, B and C) and the outputs are the activation of the control signals of the electrovalves. It will be valued that this table has the lowest number of variables possible.
b. Obtain the 2 canonical expressions for the signal which activates control signal I1.
c. Obtain as SOP, the simplified logic expression to actívate control signal I4.
d. Obtain as SOP, the simplified logic expression to actívate control signal I6.
e. With the proposed system, ¿would it be posible to provide “refresco 3” and “Cerveza” simultaneously? Justify your answer.

Solution:

a) A simple solution involves the control over the inputs that enable each of the seven solenoid valves. The truth table would be:

A	B	C	I_6	I_5	I_4	I_3	I_2	I_1	I_0
0	0	0	1	1	X	1	X	X	X
0	0	1	0	X	0	X	X	X	0
0	1	0	0	X	0	X	X	X	1
0	1	1	0	X	1	X	X	0	X
1	0	0	0	X	1	X	X	1	X
1	0	1	1	0	X	X	0	X	X
1	1	0	1	0	X	X	1	X	X
1	1	1	1	1	X	0	X	X	X

b) sum of products : $\mathbf{I1 = A \cdot \overline{B} \cdot \overline{C}}$

product of sums : $\mathbf{I_1 = A + \overline{B} + \overline{C}}$

c)

C / AB	0	1
00	**X**	**0**
01	**0**	**1**
11	**X**	**X**
10	**1**	**X**

Simplified SOPs:

$$I_4 = A + BC$$

d)

C / AB	0	1
00	**1**	**0**
01	**0**	**0**
11	**1**	**1**
10	**0**	**1**

Simplified POSs:

$$I_6 = (\overline{A} + B + C)(A + \overline{B})(A + \overline{C})$$

e) It is not possible because the "Refresco 3" and the "Cerveza" access the I6 valve through different inputs.

Most Efficient Solution:

A more efficient alternative solution in hardware considers the whole system of solenoid valves as a single multiplexer with 8 inputs and one output controlled by only three control lines, one for each level of solenoid valves, which is proposed by means of a truth table as The next:

A	B	C	X_2	X_1	X_0
0	0	0	1	1	1
0	0	1	0	0	0
0	1	0	0	0	1
0	1	1	0	1	0
1	0	0	0	1	1
1	0	1	1	0	0
1	1	0	1	0	1
1	1	1	1	1	0

b) Activate I_1 is equivalent to activate $X0 = \overline{C}$

c) Activate I_4 is equivalent to activate $X_1 = \overline{B}\,\overline{C} + BC$

d) Activate I_6 is equivalent to activate

$$X_2 = (\overline{A} + B + C)(A + \overline{B})(A + \overline{C})$$

COMPUTER BASICS 2018-2019
Exercises U1: Boolean Algebra and Logic design

U1_31.- Given the truth table, it is requested (justifying the answer):

a. Canonical expression of F1 as SOP.
b. Canonical expression of F2 as POS.

c. Simplified expression of F1 as SOP.
d. Simplified expression of F2 as POS.
e. The most simplified expression for F3.
f. Canonical expression of a function F with $F_2=\overline{F_1 \oplus F}$

A	B	C	D	F_1	F_2	F_3
0	0	0	0	1	0	1
0	0	0	1	1	0	1
0	0	1	0	0	1	1
0	0	1	1	1	0	1
0	1	0	0	1	1	1
0	1	0	1	1	0	X
0	1	1	0	0	1	1
0	1	1	1	0	0	X
1	0	0	0	0	0	X
1	0	0	1	1	0	X
1	0	1	0	0	1	X
1	0	1	1	1	1	X
1	1	0	0	1	1	X
1	1	0	1	1	0	X
1	1	1	0	0	0	X
1	1	1	1	1	1	X

a. $F_1(ABCD)=\sum m(0,1,3,4,5,9,11,12,13,15)$

b. $F_2(ABCD)=\prod M(0,1,3,5,6,7,8,13,14)$

c. Simplification using the Karnaugh method

AB \ CD	00	01	11	10
00	1	1	1	0
01	1	1	0	0
11	1	1	1	0
10	0	1	1	0

$$F_1 = \bar{A}\bar{C} + B\bar{C} + AD + \bar{B}D$$

d. Simplification using the Karnaugh method

AB \ CD	00	01	11	10
00	0	0	0	1
01	1	0	0	1
11	1	0	1	0
10	0	0	1	1

$$F_2 = (B+C)(C+\bar{D})(A+\bar{D})(\bar{A}+\bar{B}+\bar{C}+D)$$

e. To achieve maximum simplification, we consider all indeterminations as 1s, therefore the function remains $F_3 = 1$

f. Solving the equation for each case, the canonical form is $F(ABCD)=\sum m(4,7,8,11,12,14,15)$

Since XNOR function is

A	B	XNOR
0	0	1
0	1	0
1	0	0
1	1	1

F_1	F	XNOR	F_2
1	0	→	0
1	0	→	0
0	0	→	1
1	0	→	0
1	1	→	1
1	0	→	0
0	0	→	1
0	1	→	0
0	1	→	0
1	0	→	0
0	0	→	1
1	1	→	1
1	1	→	1
1	0	→	0
0	1	→	0
1	1	→	1