IE1204 Exam 20191021 Answers version 2

Part 1

1

$A = 93_{10} = 01011101_2 = 5D_{16}$
$B = -42_{10} = 11010110_2 = D6_{16}$
$A + B = 00110011_2 = 51_{10}$

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$C = 01011010_2 = 90_{10} = 5A_{16}$
$D = 00110011_2 = 51_{10} = 33_{16}$
$-D = 11001101_2 = -51_{10} = CD_{16}$
$C - D = 00100111_2 = 39_{10}$

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

$$\overline{A}\,\overline{C} + CD + ABC$$

Can't be further simplified!

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$Z = \overline{A}\cdot\overline{B}\cdot\overline{C} = \overline{A + B + C}$ Three input NOR →

$Z = \overline{A}\cdot\overline{B}\cdot\overline{C} = \overline{\overline{\overline{A}\cdot\overline{B}\cdot\overline{C}}}$ (three input NAND also ok)

Part 2

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

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

$$Y = (B + \overline{C})(A + \overline{B} + C)(\overline{A} + \overline{B} + D) = \overline{\overline{\overline{B \cdot C} \cdot \overline{\overline{A} \cdot B \cdot \overline{C}} \cdot \overline{A \cdot B \cdot C}}}$$
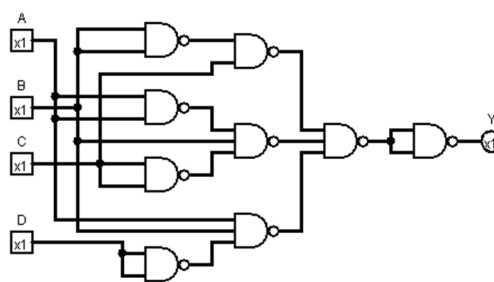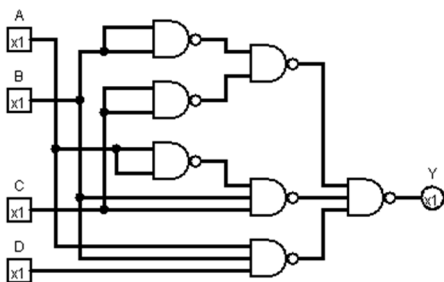
One point was deducted if the expression was not simplest possible. $\overline{A} \cdot \overline{D}$ should not be included.

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Format: Sum of products ∨

C, D

	00	01	11	10
00	0	0	0	0
01	1	1	0	0
11	1	1	1	1
10	0	1	0	1

A, B (row label)

$B\overline{C} + A\overline{C}D + AC\overline{D} + AB$

Format: Product of sums ∨

C, D

	00	01	11	10
00	0	0	0	0
01	1	1	0	0
11	1	1	1	1
10	0	1	0	1

A, B (row label)

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

Left MUX inputs:
- 00: 0
- 01: $\overline{C}$
- 10: $C \oplus D$ (XOR of C, D)
- 11: 1

Output Y, select lines $A\ B$

Right MUX inputs:
- 00: B
- 01: $A + B$ (OR of A, B)
- 10: A
- 11: $A \cdot B$ (AND of A, B)

Output Y, select lines $C\ D$
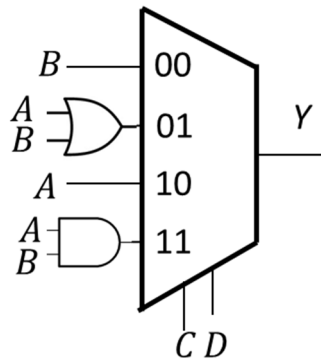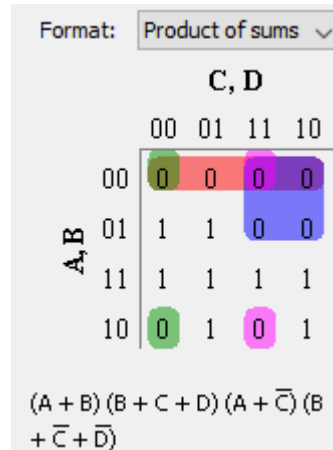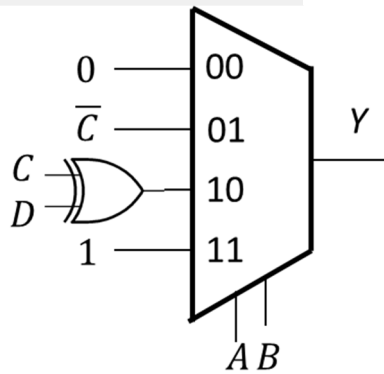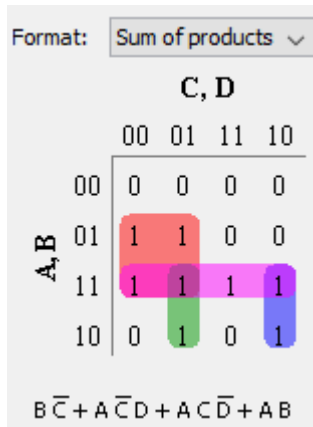
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q3	q2	q1	q0	B4	B3	B2	B1	B0
0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	1
0	0	1	0	0	0	0	1	0
0	0	1	1	0	0	0	1	1
0	1	0	0	0	0	1	0	0
0	1	0	1	0	0	1	0	1
0	1	1	0	0	0	1	1	0
0	1	1	1	0	0	1	1	1
1	0	0	0	0	1	0	0	0
1	0	0	1	0	1	0	0	1
1	0	1	0	1	0	0	0	0
1	0	1	1	1	0	0	0	1
1	1	0	0	1	0	0	1	0
1	1	0	1	1	0	0	1	1
1	1	1	0	1	0	1	0	0
1	1	1	1	1	0	1	0	1

Gate: q3, q2, q1 into AND (with q2⊕q1) → B4

ADD block inputs: q3, q2, q1, q0, 0, B4, 0; outputs B3, B2, B1, B0
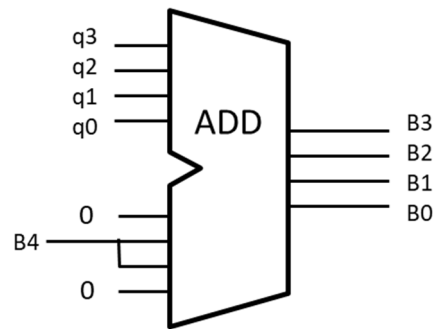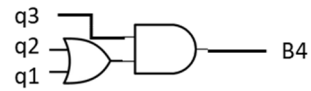
$B4 = q3 \cdot q2 + q3 \cdot q1 = q3(q2 + q1)$

$B3 = q3 \cdot \overline{B4}$ or $B3 = q3 \cdot \overline{q2} \cdot \overline{q1}$

$B2 = q2 \cdot \overline{B4} + q3 \cdot q2 \cdot q1$ or $B2 = \overline{q3} \cdot q2 + q2 \cdot q1$

$B1 = q1 \oplus B4$ or $B1 = \overline{q3} \cdot q1 + q3 \cdot q2 \cdot \overline{q1}$

$B0 = q0$

The expressions can be derived from examination, or K-maps (next page).
Variations with MUX (5 x 16:1 or 3 x 2:1 and others are also possible)
Or use the first expression (B4) plus an ADDER: add 6 if the value is 10 or higher.
(has the same effect as subtracting 10 when the carry is not used, see above)

Output: B4
Format: Sum of products

Q1, Q0

Q3, Q2 \ Q1, Q0	00	01	11	10
00	0	0	0	0
01	0	0	0	0
11	1	1	1	1
10	0	0	1	1

$Q_3 Q_1 + Q_3 Q_2$

Output: B3
Format: Sum of products

Q1, Q0

Q3, Q2 \ Q1, Q0	00	01	11	10
00	0	0	0	0
01	0	0	0	0
11	0	0	0	0
10	1	1	0	0

$Q_3 \overline{Q_2}\, \overline{Q_1}$

Output: B2
Format: Sum of products

Q1, Q0

Q3, Q2 \ Q1, Q0	00	01	11	10
00	0	0	0	0
01	1	1	1	1
11	0	0	1	1
10	0	0	0	0

$\overline{Q_3}\, Q_2 + Q_2 Q_1$

Output: B1
Format: Sum of products

Q1, Q0

Q3, Q2 \ Q1, Q0	00	01	11	10
00	0	0	1	1
01	0	0	1	1
11	1	1	0	0
10	0	0	0	0

$\overline{Q_3}\, Q_1 + Q_3 Q_2 \overline{Q_1}$

Output: B0
Format: Sum of products

Q1, Q0

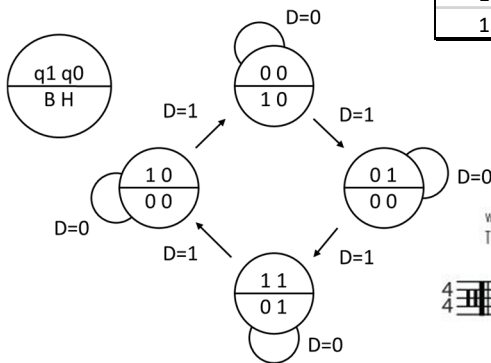| Q3, Q2 \ Q1, Q0	00	01	11	10
00	0	1	1	0
01	0	1	1	0
11	0	1	1	0
10	0	1	1	0

Q_0

Part 3

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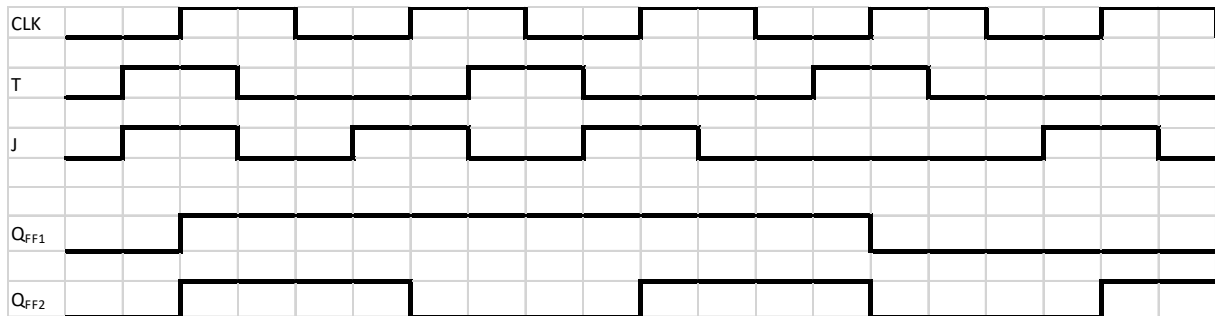
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$$q_1^+ = D \cdot q_0 + \overline{D} \cdot q_1$$
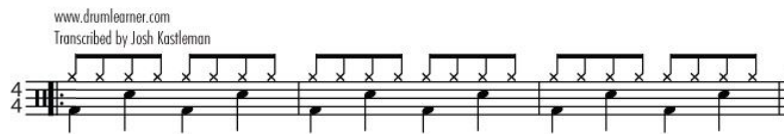$$q_0^+ = D \cdot \overline{q_1} + \overline{D} \cdot q_0$$

$$B = \overline{q_1 + q_0} = \overline{q_1} \cdot \overline{q_0}$$
$$H = q_1 \cdot q_0$$

Present state		Next state				Out	
		D=0		D=1			
q1	q0	q1+	q0+	q1+	q0+	B	H
0	0	0	0	0	1	1	0
0	1	0	1	1	1	0	0
1	1	1	1	1	0	0	1
1	0	1	0	0	0	0	0

The FSM can be used as a drum machine: B = Base, H = Hi-hat, clk = Snare, D=1 drum, D=0 pause

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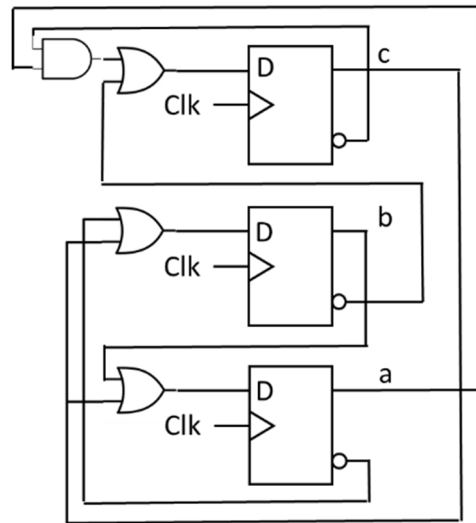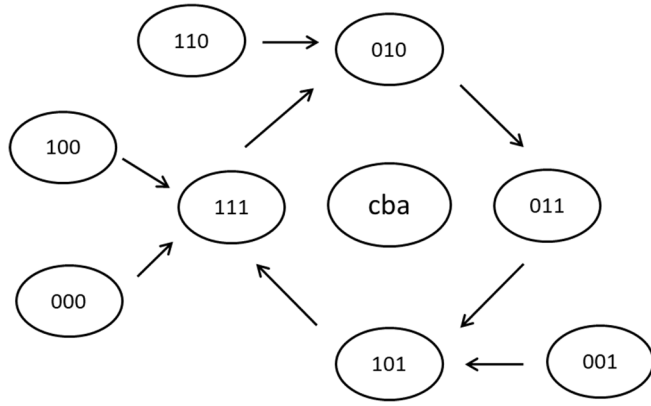| Present state			Next state		
c	b	a	c+	b+	a+
0	0	0			
0	0	1			
0	1	0	0	1	1
0	1	1	1	0	1
1	0	0			
1	0	1	1	1	1
1	1	0			
1	1	1	0	1	0

$$c^+ = \overline{b} + \overline{c} \cdot a$$
$$b^+ = c + \overline{a}$$
$$a^+ = \overline{c} + \overline{b}$$

Present state			Next state		
c	b	a	c+	b+	a+
0	0	0	1	1	1
0	0	1	1	0	1
0	1	0	0	1	1
0	1	1	1	0	1
1	0	0	1	1	1
1	0	1	1	1	1
1	1	0	0	1	0
1	1	1	0	1	0

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		Next state							
Present state		a b = 0 0		a b = 0 1		a b = 1 1		a b = 1 0	
q2	q1	q2+	q1+	q2+	q1+	q2+	q1+	q2+	q1+
0	0	0	0	1	0	—	—	0	1
0	1	0	0	0	1	1	1	0	1
1	1	—	—	0	1	1	1	0	1
1	0	0	0	1	0	1	1	—	—

q2+ \\ a b =	00	01	11	10
q2q1 = 00	0	1	X	0
01	0	0	1	0
11	X	0	1	0
10	0	1	1	X

q1+ \\ a b =	00	01	11	10
q2q1 = 00	0	0	X	1
01	0	1	1	1
11	X	1	1	1
10	0	0	1	X

$$q_2^+ = a \cdot b + \overline{q_1} \cdot b$$

$$q_1^+ = q_1 \cdot b + a$$

Part 4

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Ripple carry critical path is 2 x 4 = 8 gates. t_{pd} = 8 x 40 = 320 ps
74hc283 critical path is 6 gates. t_{pd} = 6 x 40 = 240 ps (even though the carry-chain has 5)
$T_c \geq t_{pcq} + t_{pd} + t_{setup}$ = 40 + 320 + 50 = 410 ps. f_{clock} = 1 / T_c = 2,5 GHz
$T_c \geq t_{pcq} + t_{pd} + t_{setup}$ = 40 + 240 + 50 = 330 ps. f_{clock} = 1 / T_c = 3,0 GHz
Hold time does not affect max clock speed.

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E = 01010101_2 = 85_{10}
F = 00101010_2 = 42_{10}
G = 00010001_2 = 17_{10}
P = E x F = $0000\ 1101\ 1111\ 0010_2$ = 3570_{10} = 85 x 42
K = E / G = 00000101_2 = 5_{10} = 85 / 17

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The opcodes for the ALU is as below (did not need to be shown).
First case A = 1010, B = 0011, S2 = 0, S1 = 1, S0 = 1: Y = A NOR B = 0100
Second case if S2 = 1: Y = A − B = 0111 (10 − 3 = 7, calculate decimal or binary with 2 complement)

S2	S1	S0	Operation
0	0	0	A AND B
0	0	1	A NAND B
0	1	0	A OR B
0	1	1	A NOR B
1	0	0	A + A = 2A
1	0	1	A - A = 0
1	1	0	A + B
1	1	1	A - B

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$A_4A_3A_2A_1A_0$ = 01001
$D_3D_2D_1D_0$ = 0101 (diodes are zero, no inverters on this ROM)