Exam Solutions IE1204 Digital Design 2018-10-22 (corrected 4)

Part 1

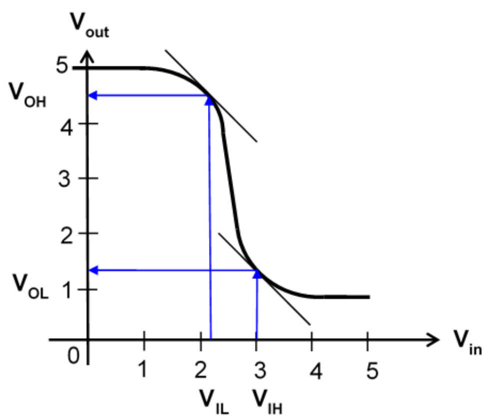
1.
Solution:
(a) (2p)
Z= (1) 0111 0111, overflow
(b) (2p)
W=0000 1100 1101 0110 = 0x0CD6 (-106 x -31 = 3286)
Not correct: (1000-0011-1101-0110): 83D6
The signs must be removed before the bitwise multiplication is performed

2. (2p)
Solution: $Y = \overline{A + B}$
A B Y
0 0 1
0 1 0
1 0 0
1 1 0

3. (2p)
Solution: f

a	b	c	f
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

4. (2p)
Solution: YES it can be an inverter



$V_{IL} = 2.2$; $V_{IH} = 3$; $V_{OL} = 1.2$; $V_{OH} = 4.5$; $NM_L = V_{IL} – V_{OL} = 1$; $NM_H = V_{OH} - V_{IH} = 1.5$

Part 2

5.

Solution:

(a) (1p)

BCD $q_3\,q_2\,q_1\,q_0$	A	B	C	D	E	F	G
0 0 0 0	0	0	0	0	0	0	1
0 0 0 1	1	0	0	1	1	1	1
0 0 1 0	0	0	1	0	0	1	0
0 0 1 1	0	0	0	0	1	1	0
0 1 0 0	1	0	0	1	1	0	0
0 1 0 1	0	1	0	0	1	0	0
0 1 1 0	0	1	0	0	0	0	0
0 1 1 1	0	0	0	1	1	1	1
1 0 0 0	0	0	0	0	0	0	0
1 0 0 1	0	0	0	0	1	0	0
1 0 1 0	0	0	0	1	0	0	0
1 0 1 1	1	1	0	0	0	0	0
1 1 0 0	0	1	1	0	0	0	1
1 1 0 1	1	0	0	0	0	1	0
1 1 1 0	0	1	1	0	0	0	0
1 1 1 1	0	1	1	1	0	0	0

(b) (2p)

E

q_1q_0 \ q_3q_2	00	01	11	10
00	0	1	0	0
01	1	1	0	1
11	1	1	0	0
10	0	0	0	0

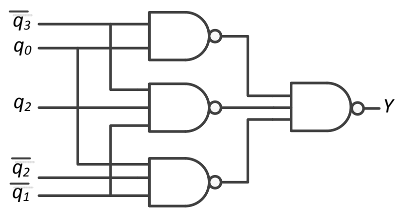
G

q_1q_0 \ q_3q_2	00	01	11	10
00	1	0	1	0
01	1	0	0	0
11	0	1	0	0
10	0	0	0	0

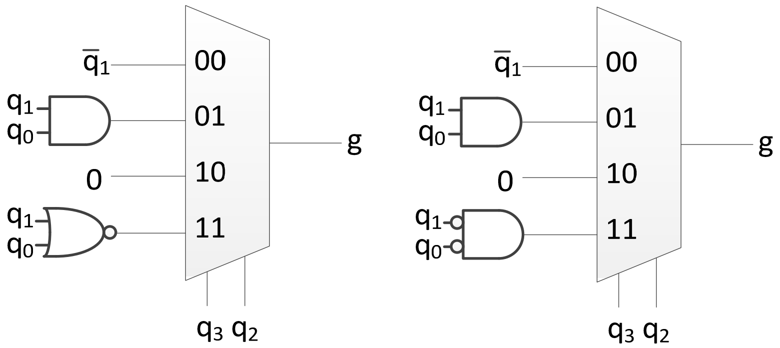
$$E = \bar{q}_3 q_0 + \bar{q}_3 q_2 \bar{q}_1 + \bar{q}_2 \bar{q}_1 q_0$$
$$G = \bar{q}_3 \bar{q}_2 \bar{q}_1 + \bar{q}_3 q_2 q_1 q_0 + q_3 q_2 \bar{q}_1 \bar{q}_0$$

(c) (1p)

$$E = \bar{q}_3 q_0 + \bar{q}_3 q_2 \bar{q}_1 + \bar{q}_2 \bar{q}_1 q_0 = \overline{\overline{\bar{q}_3 q_0 + \bar{q}_3 q_2 \bar{q}_1 + \bar{q}_2 \bar{q}_1 q_0}} = \overline{\overline{\bar{q}_3 q_0}.\overline{\bar{q}_3 q_2 \bar{q}_1}.\overline{\bar{q}_2 \bar{q}_1 q_0}}$$



(d) (1p)



6.

Solution:

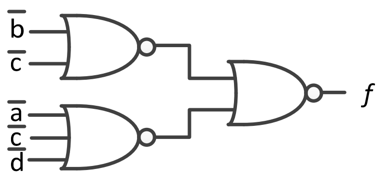
(a) (1p)

$$f = (\bar{b} + \bar{c})(\bar{a} + \bar{c} + \bar{d})$$

cd \ ab	00	01	11	10
00	1	1	1	1
01	1	1	1	1
11	1	0	0	0
10	1	0	0	1

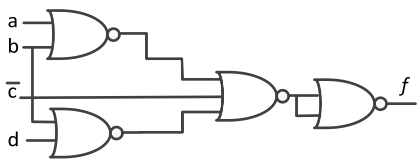
(b) (1p)

$$f = \left(\bar{b} + \bar{c}\right)\left(\bar{a} + \bar{c} + \bar{d}\right) = \overline{\left(\overline{\bar{b} + \bar{c}}\right) + \left(\overline{\bar{a} + \bar{c} + \bar{d}}\right)}$$



Grouping ones:

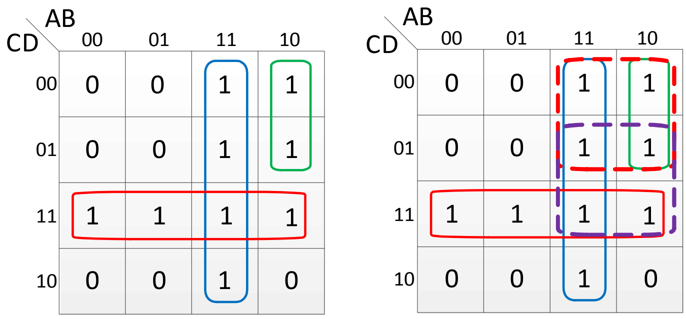
$$f = \bar{c} + \bar{a}\bar{b} + \bar{b}\bar{d} = \overline{\overline{\bar{c} + \bar{a}\bar{b} + \bar{b}\bar{d}}} = \overline{\overline{\bar{c} + (\overline{a + b}) + (\overline{b + d})}} =$$



7.

Solution:

(a) (1p) before: (b) after:



(b) (1p)

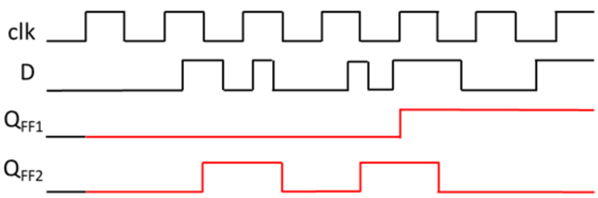
$Y = A \cdot B + C \cdot D + A \cdot \overline{C} + A \cdot D$ (the gate for $A \cdot \overline{B} \cdot \overline{C}$ is no longer needed)
Both terms needed for full points.

(c) (1p) for the circuit

Part 3

8.

Solution: (2p)



9.

(1p)

Present State			A=0			A=1		
q2	q1	q0	Q2	Q1	Q0	Q2	Q1	Q0
0	0	0	-	-	-	-	-	-
0	0	1	0	0	1	0	1	0
0	1	0	0	1	0	0	1	1
0	1	1	0	1	1	1	0	0
1	0	0	1	0	0	1	0	1
1	0	1	1	0	1	1	1	0
1	1	0	1	1	0	0	0	1
1	1	1	-	-	-	-	-	-

(2p)

Q2

q_0A \ q_2q_1	00	01	11	10
00	0	0	1	1
01	0	0	0	1
11	0	1	1	1
10	0	0	1	1

Q1

q_0A \ q_2q_1	00	01	11	10
00	1	1	1	0
01	1	1	0	0
11	1	0	0	1
10	0	1	1	0

Q0

q_0A \ q_2q_1	00	01	11	10
00	0	0	0	0
01	1	1	1	1
11	0	0	0	0
10	1	1	1	1

Q2

q_2q_1 \ q_0A	00	01	11	10
00	d	d	0	0
01	0	0	1	0
11	1	0	d	d
10	1	1	1	1

Q1

q_2q_1 \ q_0A	00	01	11	10
00	d	d	1	0
01	1	1	0	1
11	1	0	d	d
10	0	0	1	0

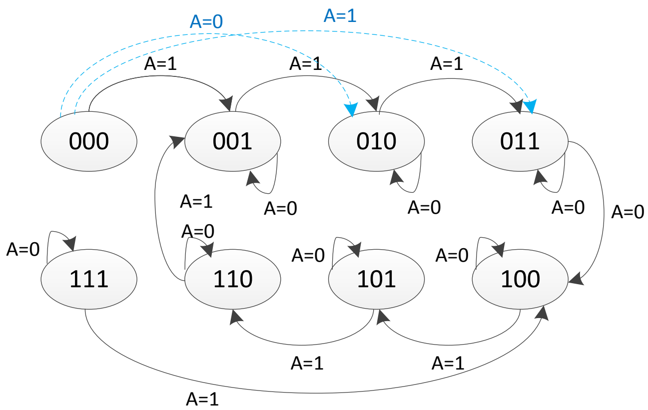
Q0

q_2q_1 \ q_0A	00	01	11	10
00	d	d	0	1
01	0	1	0	1
11	0	1	d	d
10	0	1	0	1

$$Q2 = q_2\overline{q}_1 + q_2\overline{A} + q_1q_0A$$
$$Q1 = q_1\overline{A} + \overline{q}_2\overline{q}_0 + \overline{q}_1q_0A$$
$$OR\ Q1 = q_1\overline{A} + \overline{q}_2\overline{q}_0A + \overline{q}_1q_0A$$
$$OR\ Q1 = q_1\overline{A} + \overline{q}_2q_1\overline{q}_0 + \overline{q}_1q_0A$$
$$Q0 = q_0\overline{A} + \overline{q}_0A$$

Present State			A=0			A=1		
q2	q1	q0	Q2	Q1	Q0	Q2	Q1	Q0
0	0	0	0	1	0	0	1	1
0	0	1	0	0	1	0	1	0
0	1	0	0	1	0	0	1	1
0	1	1	0	1	1	1	0	0
1	0	0	1	0	0	1	0	1
1	0	1	1	0	1	1	1	0
1	1	0	1	1	0	0	0	1
1	1	1	1	1	1	1	0	0

(1p)



10.

(a) (1p) Tc >= $t_{pcq} + t_{pdAND} + t_{pdAND} + t_{pdAND} + t_{pdXOR} + t_{setup} = 2 + 3 + 3 + 3 + 4 + 3 = 18$ ns

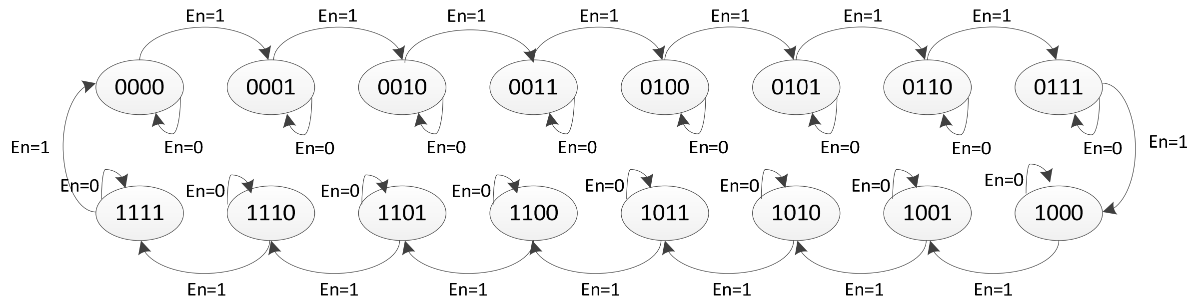
(b) (1p) $t_{hold} < t_{ccq} + t_{cdXOR}$: $2 < 1 + 2$

(c) (1p)

$$Q_0 = En \oplus q_0 = En.\overline{q_0} + \overline{En}.q_0$$
$$Q_1 = (En.q_0) \oplus q_1 = \overline{(En.q_0)}q_1 + (En.q_0)\overline{q_1}$$
$$Q_2 = (En.q_0.q_1) \oplus q_2$$
$$Q_3 = (En.q_0.q_1.q_2) \oplus q_3$$

Present state				Enable=0				Enable=1			
q3	q2	q1	q0	Q3	Q2	Q1	Q0	Q3	Q2	Q1	Q0
0	0	0	0	0	0	0	0	0	0	0	1
0	0	0	1	0	0	0	1	0	0	1	0
0	0	1	0	0	0	1	0	0	0	1	1
0	0	1	1	0	0	1	1	0	1	0	0
0	1	0	0	0	1	0	0	0	1	0	1
0	1	0	1	0	1	0	1	0	1	1	0
0	1	1	0	0	1	1	0	0	1	1	1
0	1	1	1	0	1	1	1	1	0	0	0
1	0	0	0	1	0	0	0	1	0	0	1
1	0	0	1	1	0	0	1	1	0	1	0
1	0	1	0	1	0	1	0	1	0	1	1
1	0	1	1	1	0	1	1	1	1	0	0
1	1	0	0	1	1	0	0	1	1	0	1
1	1	0	1	1	1	0	1	1	1	1	0
1	1	1	0	1	1	1	0	1	1	1	1
1	1	1	1	1	1	1	1	0	0	0	0

(d) (1p)



Part 4

11. (2p)

SRAM	DRAM
Volatile	Volatile
6 transistors	1 transistor 1 capacitor
Larger	Smaller
Slightly faster	Fast
No refresh	Capacitor needs refresh
Easily integrated in CPU	Needs extra mask layers for buried capacitor

12. (2p)
Solution:
Q=0011+Q(prev)

0000 → 0011 → 0110 → 1001 → 1100

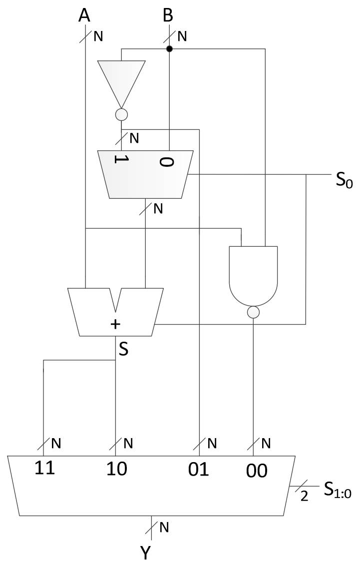
13.
Solution:
a) (1p) Seven gate delays. From pin 1, 18, 20 or 22 “B0”-“B3” to pin 14 “A = B”
b) (1p) NOT: 5, AND: 34, NAND: 4, NOR: 12, XOR: 8 (63)
5x2 + 34x6 + 18x2 + 4x4 + 5x2 + 12x4 + 9x2 + 8x8 = 406

Not gates: 5	2 transistors	
AND (1-input): 5	4	
AND (2-input): 12	6	
AND (3-input): 12	8	
AND (4-input): 4	10	
AND (5-input): 1	12	
NOR (2-input): 5	4	
NOR (3-input): 5	6	
NOR (4-input): 2	8	
NAND (2-input): 2	4	(one OR with inverted inputs counted as NAND)
NAND (4-input): 1	8	
NAND (5-input): 1	10	
XOR (2-input): 8	8	

5*2 + (5*4 + 12*6 + 12*8 + 4*10 + 1*12) + (5*4 + 5*6 + 2*8) + (2*4 + 1*8 + 1*10) +8*8 = 406

14.

Solution: (2p)



(The inverter can be replaced with an XOR between B and S_0)

One point was deducted for solutions with more than one full adder.

15.

Solution: (2p)

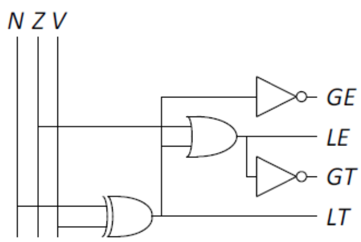
(a) $GE = \overline{N \oplus V}$

$LE = Z + (N \oplus V)$

$GT = \overline{LE} = \overline{Z}\,\overline{(N \oplus V)}$

$LT = \overline{GE} = N \oplus V$

(b)



GE

V \ NZ	00	01	11	10
0	1	1	d	0
1	0	d	d	1

LE

V \ NZ	00	01	11	10
0	0	1	d	1
1	1	d	d	0

GT

V \ NZ	00	01	11	10
0	1	0	d	0
1	0	d	d	1

LT

V \ NZ	00	01	11	10
0	0	0	d	1
1	1	d	d	0

Z and V cannot be “1” at the same time. Z and N cannot be “1” at the same time too, so they are “d” in the K-map.

Based on this K-map, the equations will be:

$$GE = \bar{V}\bar{N} + VN = \overline{V \oplus N}$$

$$LE = V\bar{N} + \bar{V}N + Z = Z + (V \oplus N)$$

$$GT = \bar{V}\bar{N}\bar{Z} + VN$$

$$LT = V\bar{N} + \bar{V}N = V \oplus N$$