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Problem 1. Solution

$$f = x\cdot(y'(w'z)')' + wxz + w' =$$
$$= x(y + w'z) + wxz + w' =$$
$$= xy + xw'z + wxz + w' =$$
$$= xy + w'(xz+1) + wxz =$$
$$= xy + w' + wxz =$$
$$= xy + w' + xz \qquad (\text{since } a' + ab = a' + b)$$

$$g = wx(y \oplus z \oplus yz) \oplus w \oplus 1 =$$
$$= wx(y+z) \oplus w \oplus 1 \quad \leftarrow \quad (\text{since } a \oplus b \oplus ab =$$
$$= a(1 \oplus b) \oplus b = ab' \oplus b =$$
$$= (ab')'b + ab'b' =$$
$$= (a'+b)b + ab' =$$
$$= a'b + b + ab' = b + ab' =$$
$$= a + b)$$
$$= w(x(y+z) \oplus 1) \oplus 1 =$$
$$= (w(x(y+z))')' =$$
$$(\text{since } a \oplus 1 = a')$$
$$= w' + x(y+z) =$$
$$= w' + xy + xz$$

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Problem 2.

(a) $f = \Sigma m(0,1,2,6,8,10,11,12)$

$g = \Sigma m(0,1,2,6,7,8,10,11,12,13)$

f:

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

SOP: $f = a'b'c' + a'cd' + ab'c + ac'd'$

POS: $f = (a+c'+d')(a+b'+c)(a'+c+d')(a'+b'+c')$

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

g:

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

SOP: $g = b'd' + a'b'c' + a'bc + abc' + ab'c$

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

POS: $g = (a+b'+c)(a'+b'+c') *$
$* (a+b+c'+d')(a'+b+c+d')$

(b) NAND: $f = a'(b'c' + cd') + a(b'c + c'd') =$

$= a'\left((b'c')'(cd')'\right)' + a\left((b'c)'(c'd')'\right)' =$

$$= \underbrace{\Big[\underbrace{\big(a'\underbrace{(\underbrace{(b'c')'}_{1}\underbrace{(cd')'}_{2})'}_{3}\big)'}_{4} \cdot \underbrace{\big(a\underbrace{(\underbrace{(b'c)'}_{5}\underbrace{(c'd')'}_{6})'}_{7}\big)'}_{8}\Big]'}_{9}$$

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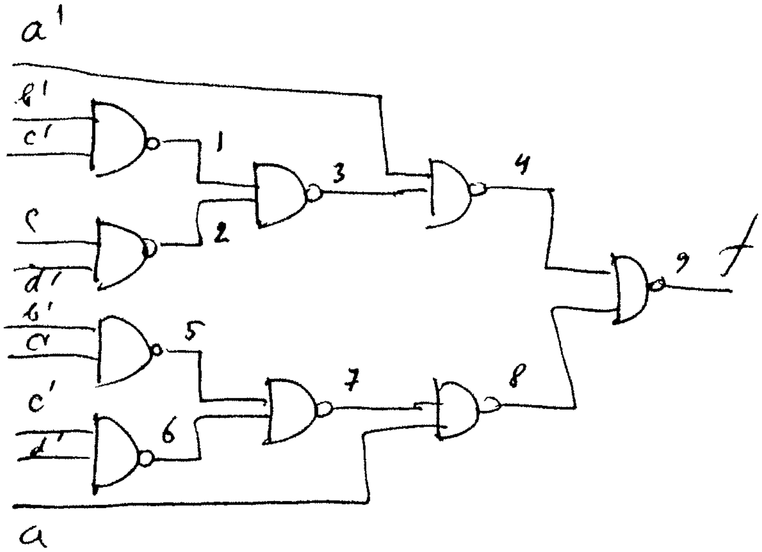
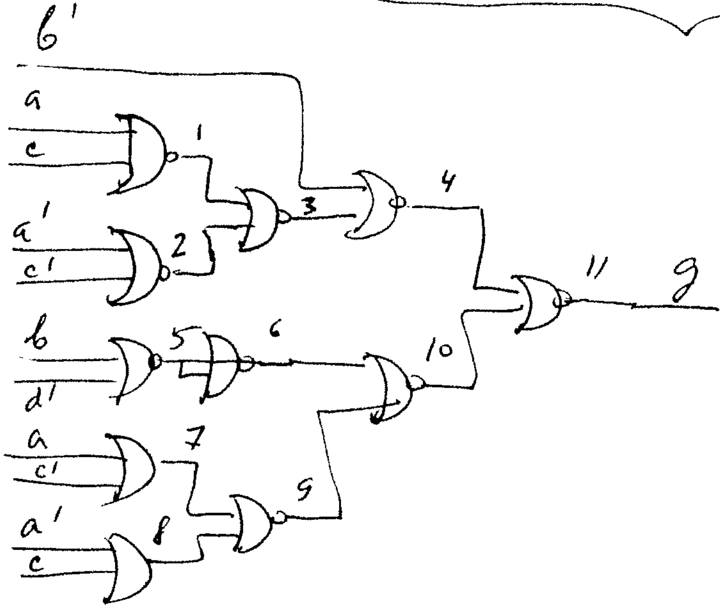


(c) NOR: $g = \left(b' + (a+c)(a'+c')\right)\left((b+d') + (a+c')(a'+c)\right) =$

$$= \Big[\underbrace{\Big(b' + \underbrace{\big(\underbrace{(a+c)'}_{1} + \underbrace{(a'+c')'}_{2} \big)'}_{3} \Big)'}_{4} + \underbrace{\Big(\underbrace{(b+d')''}_{5,6} + \underbrace{\big(\underbrace{(a+c')'}_{7} + \underbrace{(a'+c)'}_{8} \big)'}_{9} \Big)'}_{10} \Big]'_{11}$$



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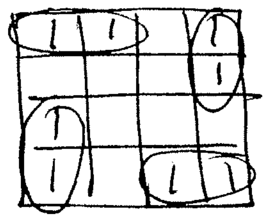
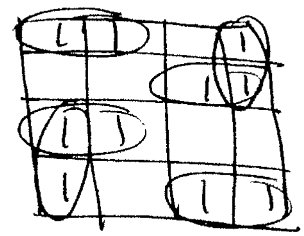
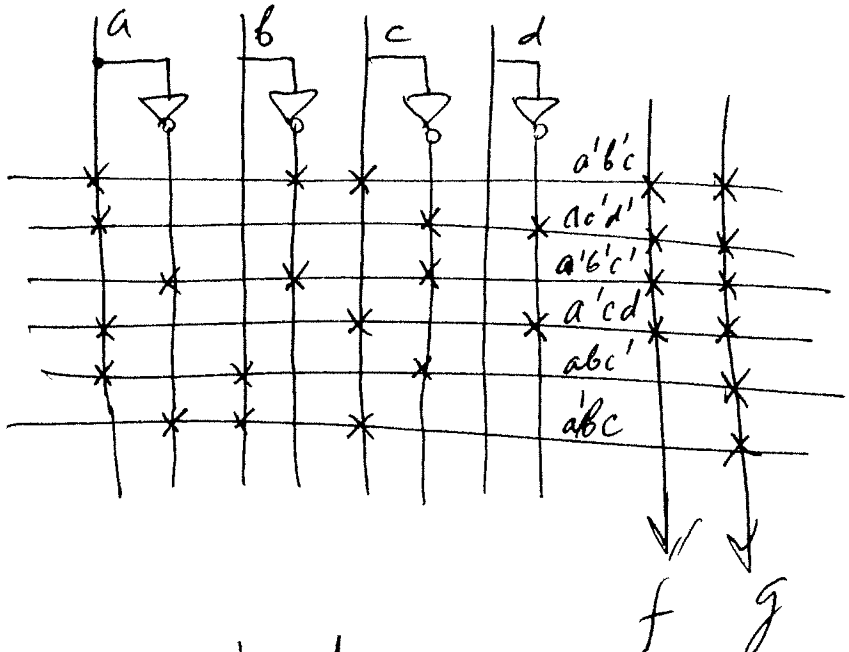
(d) Joint minimization of f and g:



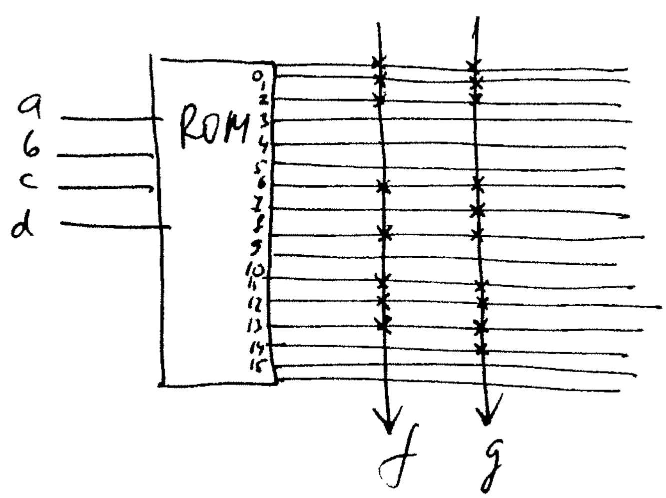


$f = ab'c + ac'd' + a'b'c' + a'cd'$

$g = a'b'c' + ab'c + a'cd' + ac'd' + abc' + a'bc$



(e) ROM



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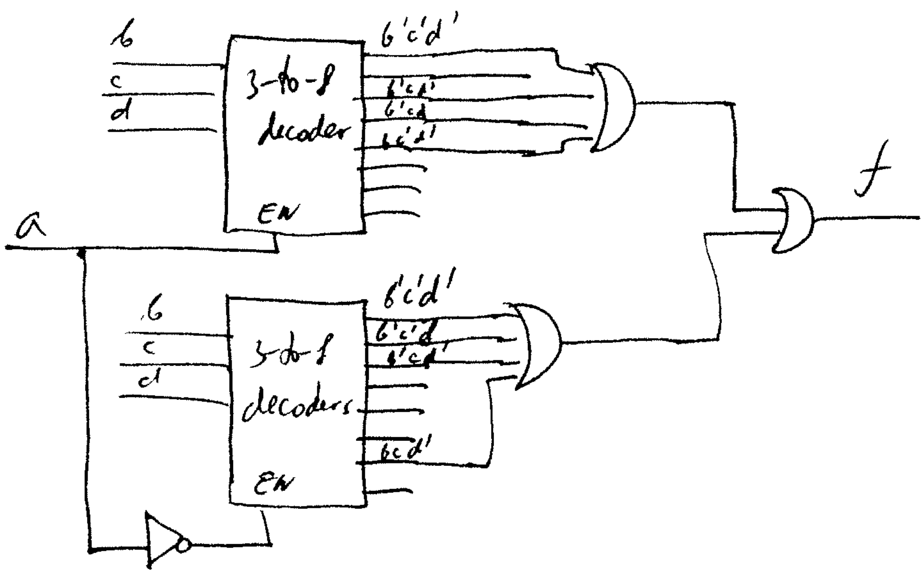
(f) $f = ab'c + ac'd' + a'b'c' + a'cd' =$

$= a(b'c + c'd') + a'(b'c' + cd') =$

$= a(b'cd' + b'cd + b'c'd' + bc'd') + a'(b'c'd' + b'c'd + b'cd' + bcd')$



(g)

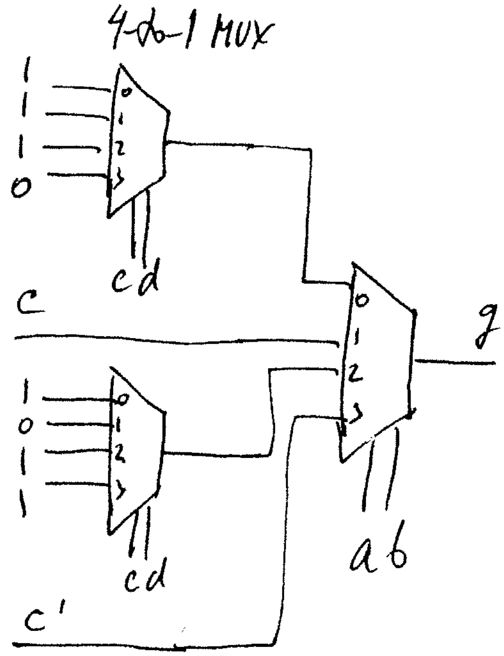
a	b	c	d	g
0	0	0	0	1
0	0	0	1	1
0	0	1	0	1
0	0	1	1	0
0	1	0	0	0
0	1	0	1	0
0	1	1	0	1
0	1	1	1	1
1	0	0	0	1
1	0	0	1	0
1	0	1	0	1
1	0	1	1	1
1	1	0	0	1
1	1	0	1	1
1	1	1	0	0
1	1	1	1	0

$(cd)' = c' + d'$ $\Rightarrow$

c $\Rightarrow$

$(c'd)' = c + d'$ $\Rightarrow$

c' $\Rightarrow$



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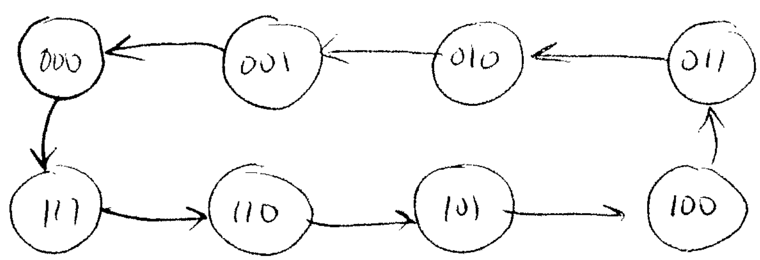
Problem 3. Solution

(a) STATE-TABLE : derived from $T_0 = 1$, $T_1 = Q_0'$, $T_2 = Q_0'Q_1'$

Q_2	Q_1	Q_0	Q_2^*	Q_1^*	Q_0^*	T_2	T_1	T_0
0	0	0	1	1	1	1	1	1
0	0	1	0	0	0	0	0	1
0	1	0	0	0	1	0	1	1
0	1	1	0	1	0	0	0	1
1	0	0	0	1	1	1	1	1
1	0	1	1	0	0	0	0	1
1	1	0	1	0	1	0	1	1
1	1	1	1	1	0	0	0	1

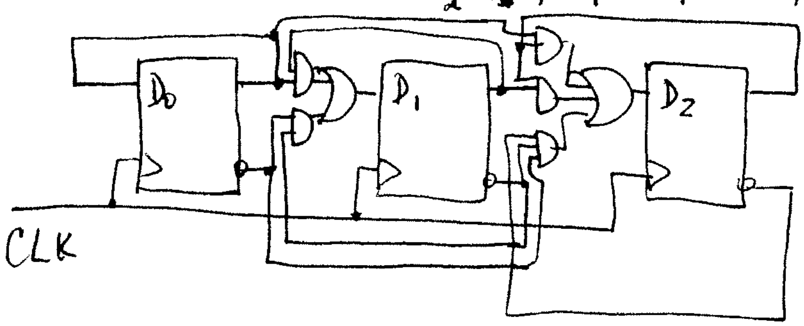
Note:
$Q_2^* = Q_2 \oplus T_2$
$Q_1^* = Q_1 \oplus T_1$
$Q_0^* = Q_0 \oplus T_0$

State diagram:



The counter counts down!

(b) For D flip-flops, $Q_2^* = D_2$, $Q_1^* = D_1$, $Q_0^* = D_0$,
$D_2 = Q_2'Q_1'Q_0' + Q_2Q_0 + Q_2Q_1$, $D_1 = Q_1'Q_0' + Q_1Q_0$, $D_0 = Q_0'$



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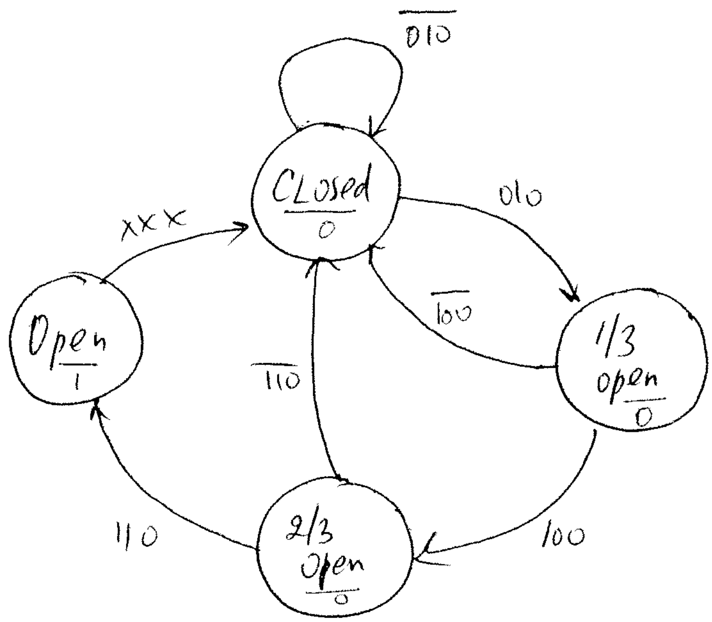
Problem 4

(a)



(b) STATES:

CLOSED = 00
1/3 OPEN = 01
2/3 OPEN = 10
OPEN = 11

STATE TABLE

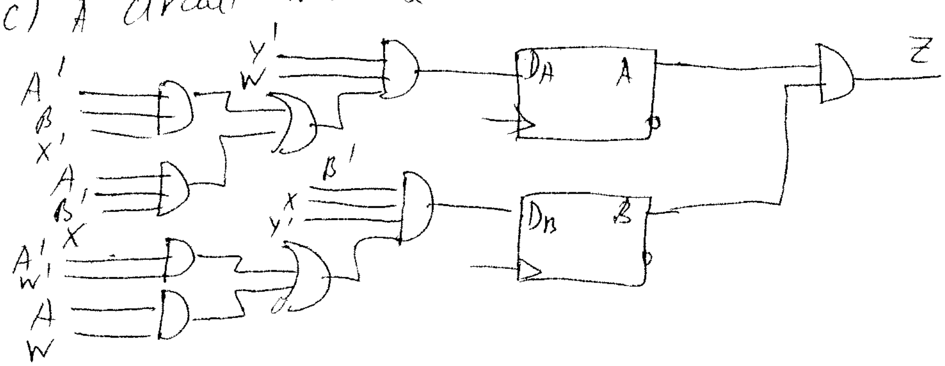
CURR. STATE A B	INPUTS W X Y	NEXT STATE A^* B^*	OUT Z
0 0	0 1 0	0 1	0
	X X X	0 0	
0 1	1 0 0	1 0	0
	X X X	0 0	
1 0	1 1 0	1 1	0
	X X X	0 0	
1 1	X X X	0 0	1

$A^* = A'BWX'Y' + AB'WXY' = WY'(A'BX' + AB'X)$

$B^* = A'B'W'XY' + AB'WXY' = B'XY'(A'W' + AW)$

$Z = AB$

(c) A circuit with 2 FLIP-FLOPS is needed; $D_A = A^*$, $D_B = B^*$



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(d) Using JK FFs.

A B	W X Y	A^* B^*	J_A K_A	J_B K_B	Z
0 0	0 1 0	0 1	0 X	1 X	0
	X X X	0 0	0 X	0 X	
0 1	1 0 0	1 0	1 X	X 1	0
	X X X	0 0	0 X	X 1	
1 0	1 1 0	1 1	X 0	1 X	0
	X X X	0 0	X 1	0 X	
1 1	X X X	0 0	X 1	X 1	1

Use the table for JK

Q Q^*	J K
0 0	0 X
0 1	1 X
1 0	X 1
1 1	X 0

FROM table:

$J_A = A'BWX'Y + A = BWX'Y + A$

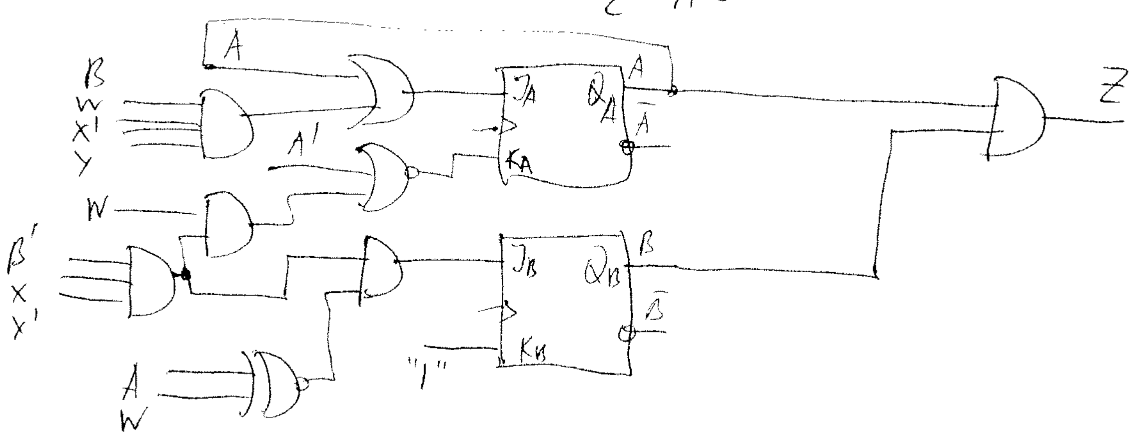
$K_A = (A' + AB'WXY')' = (A' + B'WXY')'$

$J_B = A'B'W'XY' + AB'WXY' = B'XY'(A'W' + AW) =$

$= B'XY'(\overline{A \oplus W})$

$K_B = 1$

$Z = AB$



(e)