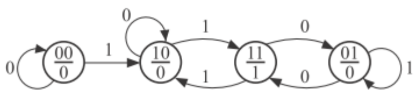
13.3 (a) $A^+ = AK_A' + A'J_A = A(B' + X) + A'(BX' + B'X)$
$B^+ = B'J_B + BK_B' = AB'X + B(A' + X')$
$Z = AB$

A^+: AB \ X	0	1
00	0	1
01	1	0
11	0	1
10	1	1

B^+: AB \ X	0	1
00	0	0
01	1	1
11	1	0
10	0	1

Present State AB	Next State A^+B^+ $X = 0$	$X = 1$	Z
00	00	10	0
01	11	01	0
11	01	10	1
10	10	11	0

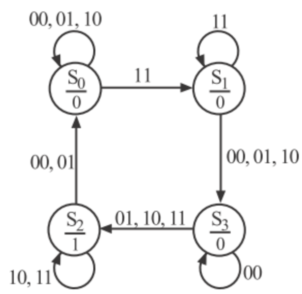


13.3 (b) $X =$ 0 1 1 0 0
$AB =$ 00 00 10 11 01 11
$Z =$ (0) 0 0 1 0 1

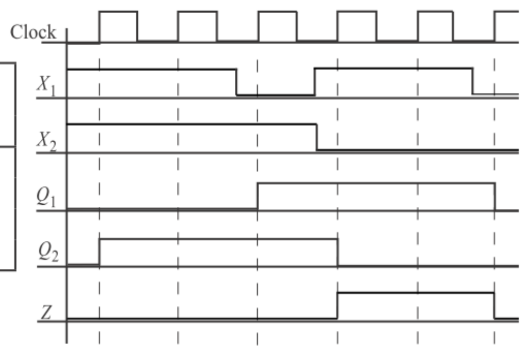
13.3 (c) *See FLD p. 758 for solution.*

13.9 (a) $Q_1^+ = D_1 = (X_1' + X_2' + Q_1)(Q_1 + Q_2)(X_1' + Q_2)$
$Q_2^+ = D_2 = (X_1'X_2' + Q_1')(X_1X_2 + Q_2)$
$Z = Q_1Q_2'$

State	Present State Q_1Q_2	Next State X_1X_2 00	01	11	10	Z
S_0	00	00	01	01	00	0
S_1	01	11	11	01	11	0
S_3	11	11	10	10	10	0
S_2	10	10	10	00	00	1

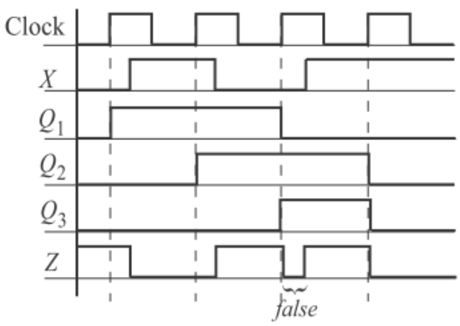


13.9 (b)



13.9 (c) Z = (0)000110

13.13



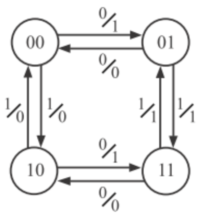
Correct output: $Z = 1011$

13.21

Clock Cycle	Information Gathered
1	$Q_1Q_2 = 00, X = 0 \Rightarrow Z = 1, Q_1^+Q_2^+ = 01$
2	$Q_1Q_2 = 01, X = 0 \Rightarrow Z = 0; X = 1 \Rightarrow Z = 1, Q_1^+Q_2^+ = 11$
3	$Q_1Q_2 = 11, X = 1 \Rightarrow Z = 1; X = 0 \Rightarrow Z = 0, Q_1^+Q_2^+ = 10$
4	$Q_1Q_2 = 10, X = 0 \Rightarrow Z = 1; X = 1 \Rightarrow Z = 0, Q_1^+Q_2^+ = 00$
5	$Q_1Q_2 = 00, X = 1 \Rightarrow Z = 0, Q_1^+Q_2^+ = 10$
6	$Q_1Q_2 = 10, X = 1 \Rightarrow (Z = 0); X = 0 \Rightarrow (Z = 1), Q_1^+Q_2^+ = 11$
7	$Q_1Q_2 = 11, X = 0 \Rightarrow (Z = 0); X = 1 \Rightarrow (Z = 1), Q_1^+Q_2^+ = 01$
8	$Q_1Q_2 = 01, X = 1 \Rightarrow (Z = 1); X = 0 \Rightarrow (Z = 0), Q_1^+Q_2^+ = 00$
9	$Q_1Q_2 = 00, X = 0 \Rightarrow (Z = 1)$

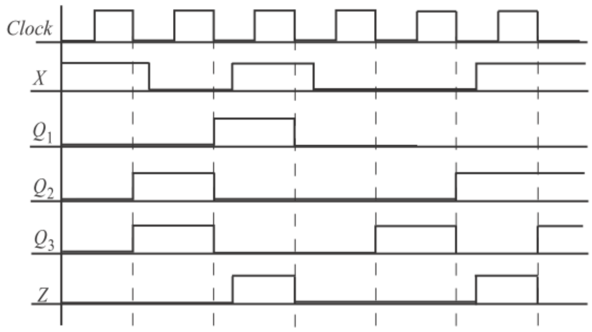
Note: Information inside parentheses was already obtained in a previous clock cycle.

Present State	Next State $Q_1^+Q_2^+$		Z	
Q_1Q_2	$X = 0$	$X = 1$	$X = 0$	$X = 1$
00	01	10	1	0
01	00	11	0	1
10	11	00	1	0
11	10	01	0	1



13.27 Transition table using a straight binary state assignment:

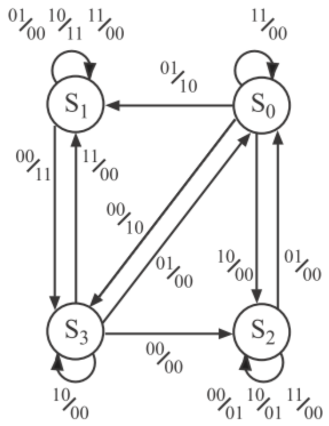
State	Present State	Next State $Q_1^+Q_2^+Q_3^+$		Z	
	$Q_1Q_2Q_3$	$X = 0$	$X = 1$	$X = 0$	$X = 1$
S_0	000	001	011	0	0
S_1	001	010	011	0	0
S_2	010	001	011	0	1
S_3	011	100	000	0	0
S_4	100	011	000	0	1



Correct output: $Z = 0, 0, 1, 0, 0, 1$

13.30 (cont.)

State	Present State	A^+B^+ $X_1X_2=$				Z_1Z_2 $X_1X_2=$			
	AB	00	01	10	11	00	01	10	11
S_0	00	11	01	10	00	10	10	00	00
S_1	01	11	01	01	01	11	00	11	00
S_2	10	10	00	10	10	01	00	01	00
S_3	11	10	00	11	01	00	00	00	00



14.6 This should be solved in the same way as Example 3 on FLD p. 471-472. Assign a state to each possible input (00, 01, 11, 10) with an output of 0, and another state to each input with an output of 1. This gives eight states.
See FLD p. 762 for the state table.

State	$Z = 0$
S_0	Last input was 00
S_1	Last input was 01
S_2	Last input was 11
S_3	Last input was 10

State	$Z = 1$
S_4	Last input was 00
S_5	Last input was 01
S_6	Last input was 11
S_7	Last input was 10

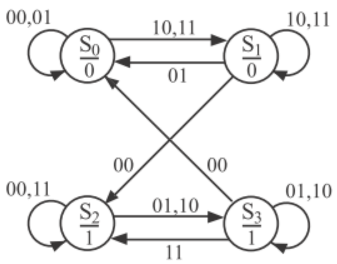
Each input takes you to the state defined by that input (e.g. an input of 01 takes you to either S_1 or S_5). The only thing in question is whether the output is 0 or 1. Determine the output by checking whether the last two inputs correspond to the three input sequences.

Alternate Solution: Notice that when $Z = 0$, "causes the output to become 0" is the same as remaining constant, and "causes the output to become 1" is the same as toggling the output. The situation is similar when $Z = 1$. So we can use only four states, as follows:

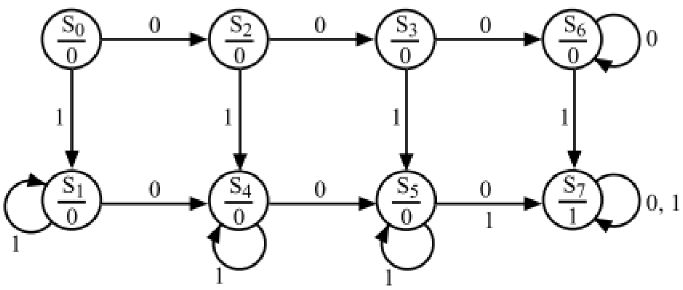
State	Meaning
S_0	$Z = 0$ and last input was either 00 or 01
S_1	$Z = 0$ and last input was either 10 or 11
S_2	$Z = 1$ and last input was either 00 or 11
S_3	$Z = 1$ and last input was either 01 or 10

State	Next State $X_1X_2 = 00$	01	10	11	Z
S_0	S_0	S_0	S_1	S_1	0
S_1	S_2	S_0	S_1	S_1	0
S_2	S_2	S_3	S_3	S_2	1
S_3	S_0	S_3	S_3	S_2	1

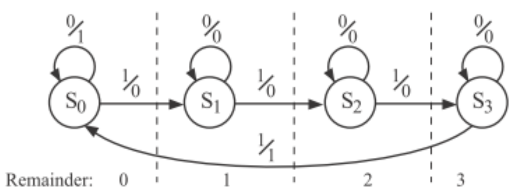
Note: The state table with 8 states reduces to this 4-state table using methods in Unit 15.



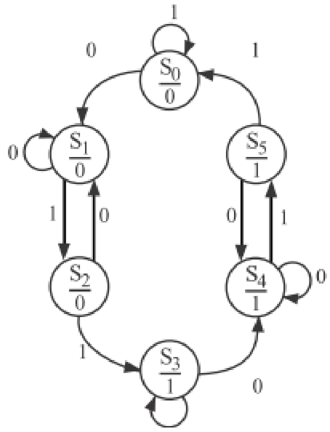
14.21 Plot 0's horizontally. Plot 1's vertically. Receiving a 0 takes us one state to the right. Receiving a 1 takes us one state down. The output is a 1 only in the "three 0's or more, one 1 or more" state:



14.24 (a) We need four states to describe the 1's received, as there are four possible remainders when dividing by four. An input of 1 takes us to the next state in cyclic fashion. An input of zero leaves us in the same state.

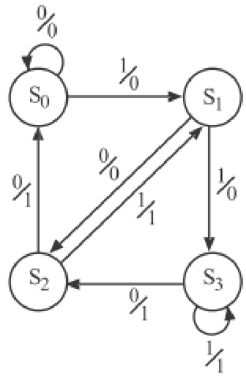


4.26 There are two identical parts: one with an output of 0 and one with an output of 1.



State	Meaning
S_1, S_4	Previous input was 0
S_2, S_5	Previous inputs were 01
S_3, S_0	Previous input was 1 / Reset (S_0)

14.34 To delay by two clock periods, we need to remember the previous two inputs. So we have four states, one for each combination of two inputs:



State	Next State $X=0$	Next State $X=1$	Z $X=0$	Z $X=1$
S_0	S_0	S_1	0	0
S_1	S_2	S_3	0	0
S_2	S_0	S_1	1	1
S_3	S_2	S_3	1	1

State	Meaning
S_0	Previous two inputs were 00
S_1	Previous two inputs were 01
S_2	Previous two inputs were 10
S_3	Previous two inputs were 11

Note: Just go to the state that represents the last two inputs.

14.45

Present State	Next State 00	01	10	11	Z_1Z_2 00	01	10	11
S_0	S_1	S_0	S_2	S_2	01	10	01	01
S_1	S_1	S_2	S_0	S_0	00	11	00	00
S_2	S_2	S_1	S_0	S_0	00	00	00	00

15.3

S_0	$S_5 - a$ $S_1 - b$	$\cancel{S_5 - a}$ $\cancel{S_1 - c}$	
S_1	$\cancel{S_5 - a}$ $\cancel{S_6 - b}$	$S_5 - a$ $S_6 - c$	
S_2	$\cancel{S_2 - a}$ $\cancel{S_6 - b}$	$\cancel{S_2 - a}$ $\cancel{S_6 - c}$	
S_3			$S_0 - a$ $S_1 - b$
S_4	$\cancel{S_4 - a}$ $\cancel{S_3 - b}$	$\cancel{S_4 - a}$ $\cancel{S_3 - c}$	
S_5	$S_0 - a$ $S_1 - b$	$\cancel{S_0 - a}$ $\cancel{S_1 - c}$	
S_6			$S_5 - a$ $S_1 - b$
	a	b	c

$S_0 \equiv a$
$S_1 \equiv b$
$S_3 \equiv c$
$S_5 \equiv a$
$S_6 \equiv c$
S_2 and S_4 have no equivalent states.

15.3 (a) $a \equiv S_0, S_5$
$b \equiv S_1$
$c \equiv S_3, S_6$

Since S_2 and S_4 do not have corresponding states, the circuits are *not* equivalent.

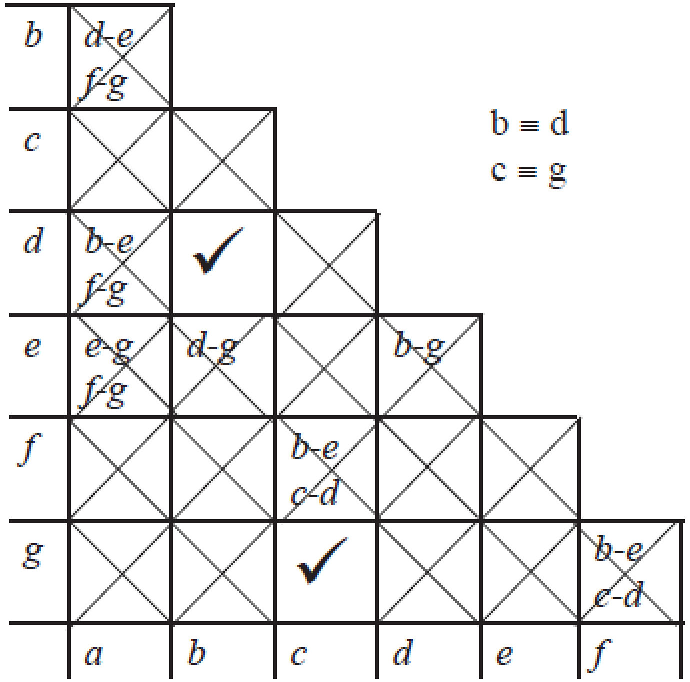
15.3 (b) Starting from S_0, it is not possible to reach S_2 or S_4. So then the circuits would perform the same.

15.9

		Q_1	Q_2	Q_3
Assign	S_0	1	0	0
	S_1	0	1	0

$$D_1 = X'Q_1 + XY'Q_3$$
$$D_2 = XQ_1 + YQ_3 + X'Q_2$$
$$D_3 = XQ_2 + X'Y'Q_3$$
$$P = XQ_1 + Y'Q_3 + XQ_2$$
$$S = X'Q_1 + XY'Q_3$$

15.11 (a)



b ≡ d
c ≡ g

State	Next State $X=0$	Next State $X=1$	Output $X=0$	Output $X=1$
a	e	c	0	1
b	b	f	0	1
c	e	c	1	0
e	c	f	0	1
f	b	b	1	0

15.11 (b) Input: 000

Output starting in state a:

001 (state $a \xrightarrow{0}$ state $e \xrightarrow{0}$ state $g \xrightarrow{0}$ state e)

Output starting in state b:

000 (state $b \xrightarrow{0}$ state $d \xrightarrow{0}$ state $b \xrightarrow{0}$ state d)

15.20 (a) Invert all three columns of assignment (*iv*), and then swap the first and last columns. Then (*iii*) and (*iv*) are the same, therefore, Assignment (*iii*) ≡ Assignment (*iv*).

15.20 (b) Equivalent assignments to each column having 000 as the starting state. Invert any column with 1 in the first row.

	(*ii*) - (c_2')	*iii* - c_1'	*iv* - $c_1'c_2'$	*v* - c_3'
S_0	000	000	000	000
S_1	101	001	100	110
S_2	011	100	001	100
S_3	100	101	101	010
S_4	010	011	110	001
S_5	110	010	010	011

15.20 (c) Many state assignments are not equivalent to (i) through (v), for example:

101	or	011
000		101
011		000
100		100
010		010
110		110

15.24 (a) Equations for one-hot state assignment:

$D_A = X(A + B + D + E)$, $D_B = X'(A + D)$,

$D_C = X'B$, $D_D = XC$, $D_E = X'(C + E)$, $z = D$

15.24 (b) Guidelines:

1. $(A, D)\text{x}2\ (C, E)\ (A, B, D, E)$
2. $(A, B)\text{x}2\ (A, C)\ (D, E)\ (A, E)$

The following assignment satisfies all but (A, E), (A, C) and (B, D):

$Q_2 Q_3 \backslash Q_1$	0	1
00	A	-
01	B	-
11	E	C
10	D	-

$Q_1Q_2Q_3$	$Q_1^+Q_2^+Q_3^+$ $X = 0$	1	z
000	001	000	0
010	111	000	0
011	011	000	0
010	001	000	1
110	---	---	-
111	011	010	0
101	---	---	-
100	---	---	-

$D_1 = X'Q_2'Q_3$, $D_2 = X'Q_3 + Q_1$, $D_3 = X'$,

$z = Q_2Q_3'$

15.35 By inspecting incoming arrows, we get:

$$Q_0^+ = D_0 = X'YQ_0 + Y'Q_1 + X'YQ_2$$
$$Q_1^+ = D_1 = XY'Q_0 + XYQ_1 + Y'Q_2$$
$$Q_2^+ = D_2 = XYQ_0 + X'Y'Q_0 + X'YQ_1 + XYQ_2$$
$$Z = X'YQ_1 + XYQ_2 + X'YQ_2 = X'YQ_1 + YQ_2$$

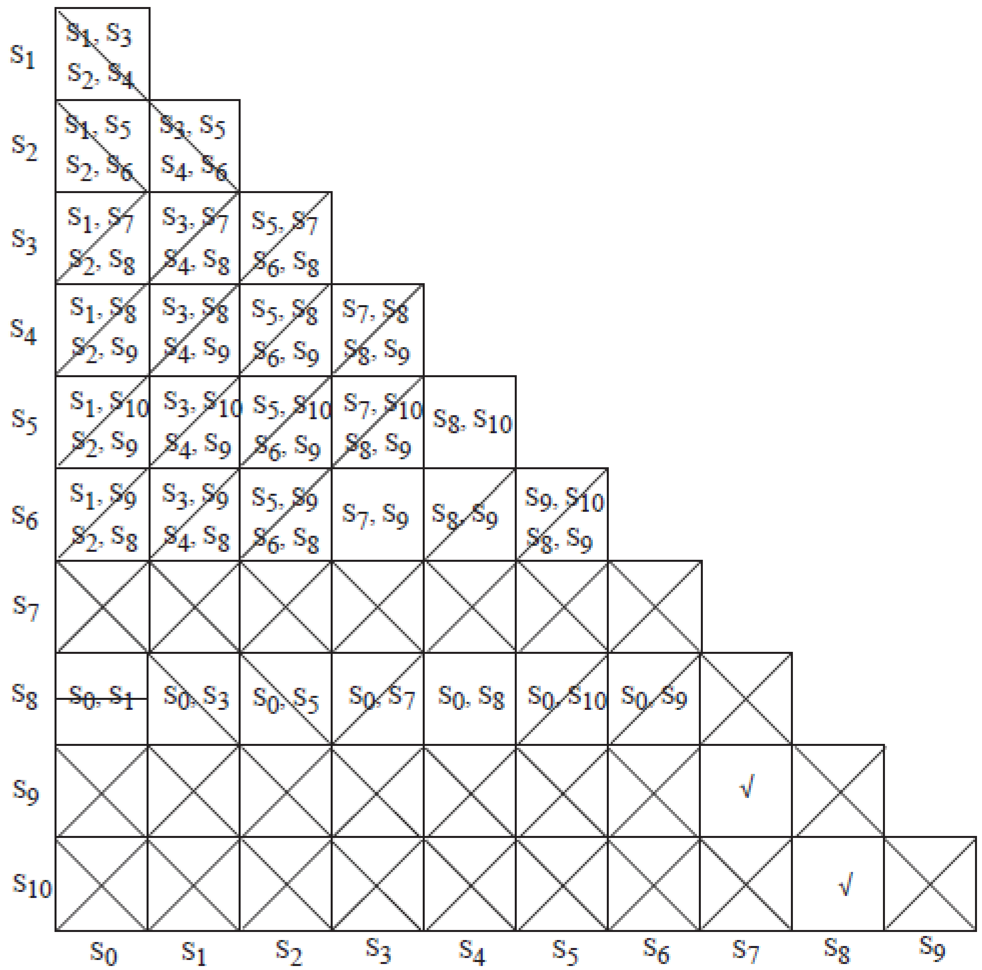
15.40 $S_7 \sim S_9$ and $S_8 \sim S_{10}$ so the table reduces to

Present State	Next State $X=0$	Next State $X=1$	Output (Z) $X=0$	Output (Z) $X=1$
S_0	S_1	S_2	0	0
S_1	S_3	S_4	0	0
S_2	S_5	S_6	0	0
S_3	S_7	S_8	0	0
S_4	S_8	S_7	0	0
S_5	S_8	S_7	0	0
S_6	S_7	S_8	0	0
S_7	S_0	S_0	1	0
S_8	S_0	S_0	0	1

Now $S_3 \sim S_6$ and $S_4 \sim S_5$ so the table reduces to

Present State	Next State $X=0$	Next State $X=1$	Output (Z) $X=0$	Output (Z) $X=1$
S_0	S_1	S_2	0	0
S_1	S_3	S_4	0	0
S_2	S_4	S_3	0	0
S_3	S_7	S_8	0	0
S_4	S_8	S_7	0	0
S_7	S_0	S_0	1	0
S_8	S_0	S_0	0	1

The implication chart verifies the answer.



Maximal Compatibles: $(S_3\ S_6)$, $(S_4\ S_5)$, $(S_7\ S_9)$, $(S_8\ S_{10})$