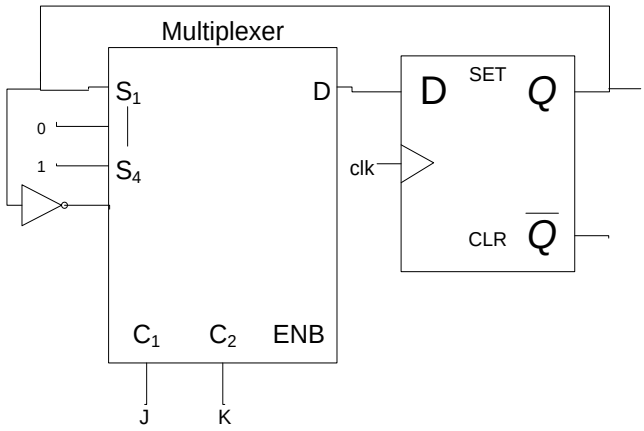
Chapter 5: Sequential Logic
Solutions to Problems: [2, 7, 9, 12, 13, 16, 18]

Problem 5-2:

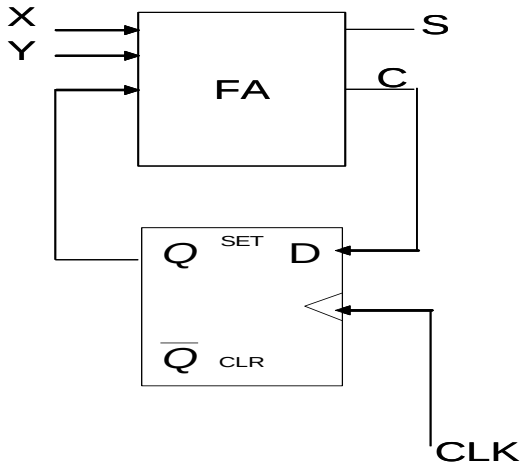
Construct a JK flip-flop using a D flip-flop, a 4-to-1-line multiplexer and an inverter.

Solution:



Problem 5-7:

A sequential circuit has one flip-flop Q, two inputs x and y, and one output S. It consists of a full-adder circuit connected to a D flip-flop, as shown. Derive the state table and state diagram of the sequential circuit.



Solution:

FA equations:

$S = X \oplus Y \oplus Q$

C = XY + XQ + YQ

Input equation:

D_Q = C

= XY + XQ + YQ (from the FA equations or from the K-map)

Characteristic equation:

Q(t+1) = D = XY + XQ + YQ

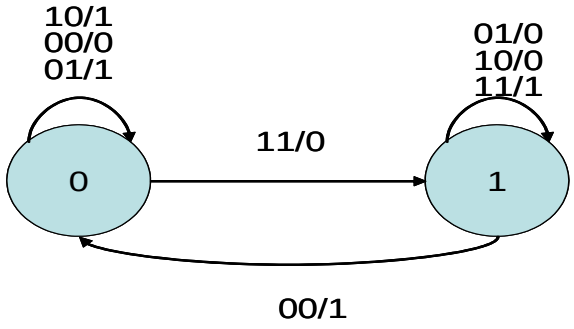
State equation:

Q(t+1) = C

State Table:

PRESENT STATE	INPUTS		NEXT STATE	OUTPUT
Q	*X*	Y	Q	S
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

State Diagram:



Problem 5-9:

A sequential circuit has two JK flip-flops A and B and one input x. The circuit is described by the following flip-flop input equations :

J_A = x K_A = B'

$J_B = x$ $K_B = A$

(a) Derive the state equation A(t+1) and B(t+1) by substituting the input equations for the J and K variables.
(b) Draw the state diagram of the circuit.

Solution:

State equation:

$$Q(t+1) = JQ' + K'Q$$

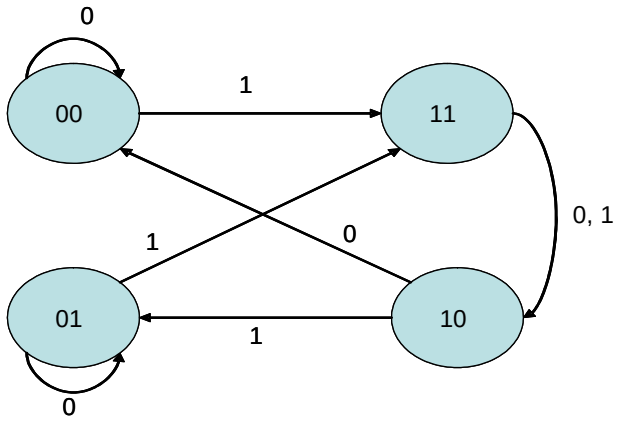
Characteristic equation:

$$A(t+1) = XA' + BA$$
$$B(t+1) = XB' + A'B$$

State Table:

PRESENT STATE		INPUT	NEXT STATE		FLIP-FLOP INPUTS			
A	***B***	**X**	**A**	***B***	J_A	K_A	J_B	K_B
0	0	0	0	0	0	1	0	0
0	0	1	1	1	1	1	1	0
0	1	0	0	1	0	0	0	0
0	1	1	1	1	1	0	1	0
1	0	0	0	0	0	1	0	1
1	0	1	0	1	1	1	1	1
1	1	0	1	0	0	0	0	1
1	1	1	1	0	1	0	1	1

State Diagram:



Problem 5-12:

Reduce the number of states in the following table and tabulate the reduced state table.

PRESENT STATE	NEXT STATE		OUTPUT	
	X=0	X=1	X=0	X=1
a	f	b	0	0
b	d	c	0	0
c	f	e	0	0
d	g	a	1	0
e	d	c	0	0
f	f	b	1	1
g	g	h	0	1
h	g	a	1	0

Solution:

States b,e are the same ,we will replace state e with state b .
States d,h are the same ,we will replace state h with state d .

PRESENT STATE	NEXT STATE		OUTPUT	
	X=0	X=1	X=0	X=1
a	f	b	0	0
b	d	c	0	0
c	f	b	0	0
d	g	a	1	0
f	f	b	1	1
g	g	d	0	1

States a,c are the same ,we will replace state c with state a .

PRESENT STATE	NEXT STATE		OUTPUT	
	X=0	X=1	X=0	X=1
a	f	b	0	0
b	d	a	0	0
d	g	a	1	0
f	f	b	1	1
g	g	d	0	1

Problem 5-13:

Starting from state a, and the input sequence 01110010011,determine the output sequence
for:

(a) the state table of the previous problem and
(b) the reduced state table from the previous problem. Show that the same output sequence is obtained for both.

Solution:

(a) using the state table of the problem 5-12 :

state	a	f	b	c	e	d	g	h	g	g	h	a
input	0	1	1	1	0	0	1	0	0	1	1	
output	0	1	0	0	0	1	1	1	0	1	0	

(b) using the reduced state table of the problem 5-12 :

state	a	f	b	a	b	d	g	d	g	g	d	a
input	0	1	1	1	0	0	1	0	0	1	1	
output	0	1	0	0	0	1	1	1	0	1	0	

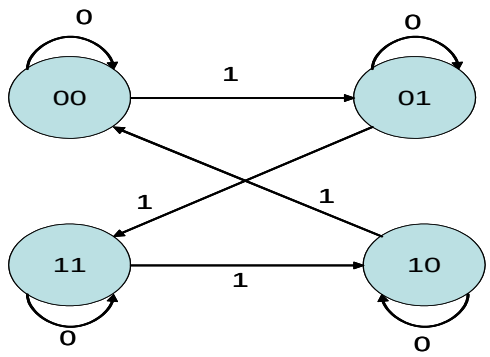
The same output sequence is obtained for both.

Problem 5-16:

Design a sequential circuit with two D flip-flops A and B, and one input x. When x=0, the state of the circuit remains the same. When x=1, the circuit goes through the state transitions from 00 to 01 to 11 to 10 back to 00, and repeats.

Solution:

State Diagram:



State Table:

PRESENT STATE		INPUT	NEXT STATE	
A	***B***	**X**	**A**	***B***
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	1
1	0	0	1	0
1	0	1	0	0
1	1	0	1	1
1	1	1	1	0

Characteristic equation:

$Q(t+1) = D$

Input equations or State equations :

$$A(t+1) = D_A\,(A,B,X) = \sum (3,4,6,7)$$
$$B(t+1) = D_B\,(A,B,X) = \sum (1,2,3,6)$$

K-maps :

D_A

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

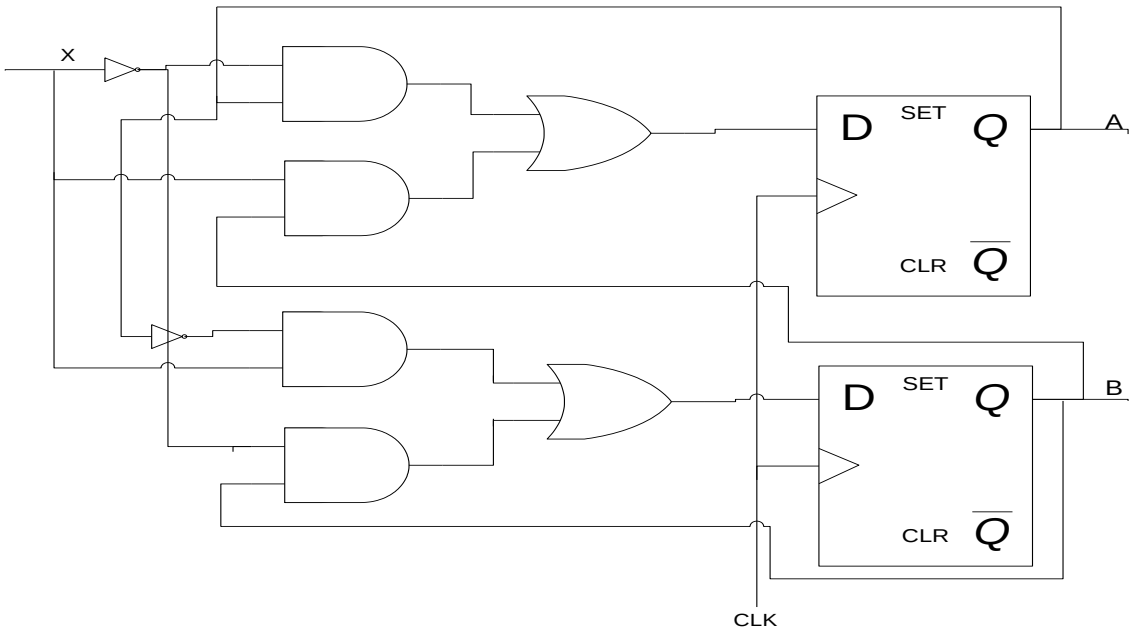
$D_A = BX + AX'$

D_B

A \ BX	0	1	11	10
0		1	1	1
1				1

$D_B = A'X + BX'$

Circuit Diagram :

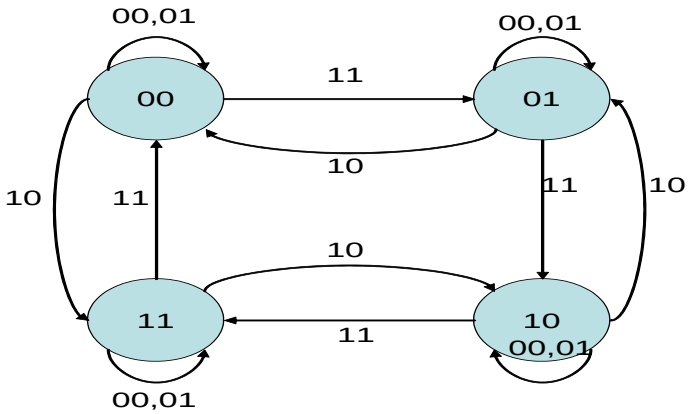


Problem 5-18:

Design a sequential circuit with two JK flip-flops A and B and two inputs E and x.If E =0 ,the circuit remains in the same state regardless of the value of x. When E =1 and x=1, the circuit goes through the state transitions from 00 to 01 to 10 to 11 back to 00,and repeats. When E =1 and x=0, the circuit goes through the state transitions from 00 to 11 to 10 to 01 back to 00,and repeats.

Solution:

State Diagram:



State Table:

PRESENT STATE		INPUT		NEXT STATE		FLIP-FLOP INPUTS			
A	B	E	X	A	B	J_A	K_A	J_B	K_B
0	0	0	0	0	0	0	X	0	X
0	0	0	1	0	0	0	X	0	X
0	0	1	0	1	1	1	X	1	X
0	0	1	1	0	1	0	X	1	X
0	1	0	0	0	1	0	X	X	0
0	1	0	1	0	1	0	X	X	0
0	1	1	0	0	0	0	X	X	1
0	1	1	1	1	0	1	X	X	1
1	0	0	0	1	0	X	0	0	X
1	0	0	1	1	0	X	0	0	X
1	0	1	0	0	1	X	1	1	X
1	0	1	1	1	1	X	0	1	X
1	1	0	0	1	1	X	0	X	0
1	1	0	1	1	1	X	0	X	0
1	1	1	0	1	0	X	0	X	1
1	1	1	1	0	0	X	1	X	1

K-maps :

J_A

	EX			
AB	00	01	11	10
0	0	0	0	1
1	0	0	1	0

$J_A = BEX + B'EX' = E\,(B \oplus X)'$

K_A

AB \ EX	0	1	11	10
0	X	X	X	X
1	X	X	X	X
11	0	0	1	0
10	0	0	0	1

$K_A = BEX + B'EX' = E\,(B \oplus X)'$

J_B

AB \ EX	0	1	11	10
0	0	0	1	1
1	X	X	X	X
11	X	X	X	X
10	0	0	1	1

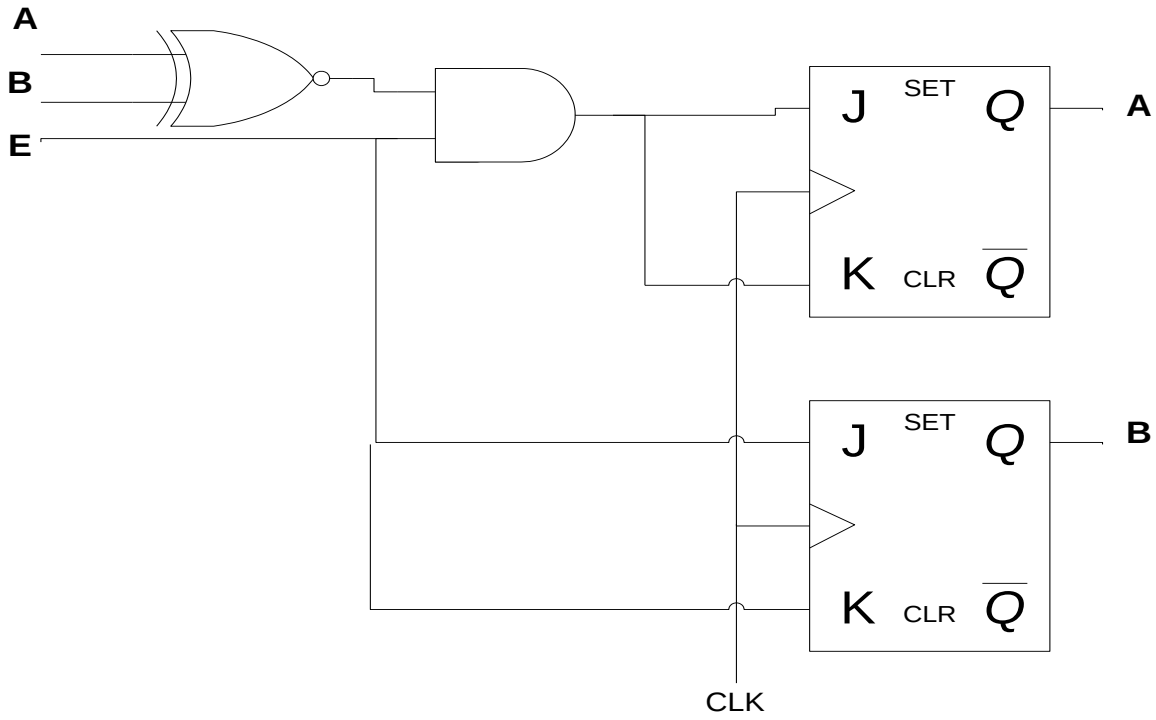
$J_B = E$

K_B

AB \ EX	0	1	11	10
0	X	X	X	X
1	0	0	1	1
11	0	0	1	1
10	X	X	X	X

$K_B = E$

Circuit Diagram :



This sequential circuit behaves like a 2-bit up-down-counter, with E the enable of the whole counter, and resets when it finishes counting , when X=1, it behaves like an up-counter, when X=0 ,it behaves like a down-counter.