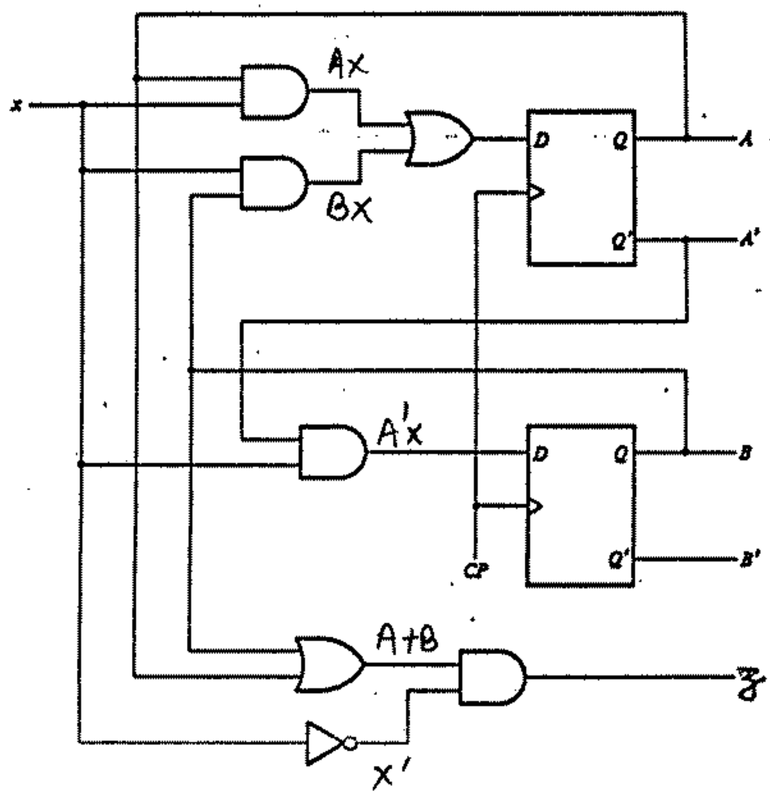
Section 4.4

ANALYSIS OF SYNCHRONOUS SEQUENTIAL CIRCUITS

GIVEN A SYNCHRONOUS SEQUENTIAL CIRCUIT:

e.g.,



Example of a sequential circuit

EXPRESS ITS BEHAVIOR BY

A) OUTPUT FUNCTIONS AND FF INPUT FUNCTIONS

(USE THE INFO IN THE CC'S FEEDING OUTPUTS AND FF INPUTS)

e.g.,

$$\left.\begin{aligned} z &= (A+B)x' \\ D_A &= Ax + Bx \\ D_B &= A'x \end{aligned}\right\} \text{ each is } f(\underbrace{A(t), B(t)}_{\text{Present State}}, \underbrace{x}_{\text{External input}})$$

B) STATE TRANSITION TABLE

FOR EACH POSSIBLE (PRESENT) STATE OF THE CIRCUIT AND
FOR EACH POSSIBLE COMBINATION OF VALUES OF INPUT VARIABLES,

1) USE THE FF INPUT FUNCTIONS AND THE CHARACTERISTIC ~~TABLES~~ EQUATIONS OF THE FF'S TO DETERMINE THE NEXT STATE OF THE CIRCUIT
2) USE THE OUTPUT FUNCTIONS TO DETERMINE THE OUTPUT VALUES

e.g., $A(t+1) = D_A = Ax + Bx$; $B(t+1) = D_B = A'x$; $z = (A+B)x'$

Present State		Input	Next State		Output
A(t)	B(t)	x	A(t+1)	B(t+1)	z
0	0	0	0	0	0
0	0	1	0	1	0
0	1	0	0	0	1
0	1	1	1	1	0
1	0	0	0	0	1
1	0	1	1	0	0
1	1	0	0	0	1
1	1	1	1	0	0

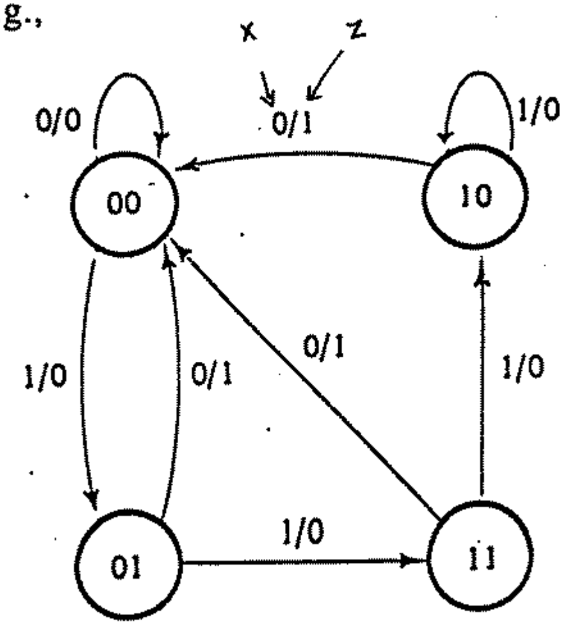
Present State	Next State		Output	
	$x = 0$	$x = 1$	$x = 0$	$x = 1$
AB	AB	AB	z	z
00	00	01	0	0
01	00	11	1	0
10	00	10	1	0
11	00	10	1	0

C) STATE TRANSITION DIAGRAM

FOR EACH POSSIBLE (PRESENT) STATE OF THE CIRCUIT AND
FOR EACH POSSIBLE COMBINATION OF VALUES OF INPUT VARIABLES,

1) USE THE FF INPUT FUNCTIONS AND THE CHARACTERISTIC ~~TABLES~~ EQUATIONS OF THE FF'S TO DETERMINE THE NEXT STATE OF THE CIRCUIT
2) USE THE OUTPUT FUNCTIONS TO DETERMINE THE OUTPUT VALUES

e.g.,



Note: If there are more than one input or output then use

$x_1, \ldots, x_n / z_1, \ldots, z_m$

where

$n \geq 2$ & $m \geq 1$

Finite State Machine (FSM)

D) OUTPUT FUNCTIONS AND STATE EQUATIONS

FOR OUTPUT FUNCTIONS,
USE THE INFO IN THE CC'S FEEDING OUTPUTS
FOR STATE EQUATION OF EACH FF,
EITHER
USE THE STATE TRANSITION TABLE/DIAGRAM AND IDENTIFY THE INPUT AND PRESENT STATE FOR WHICH THE NEXT STATE OF EACH FF IS 1
OR
SUBSTITUTE FF INPUT FUNCTIONS INTO FF CHARACTERISTIC EQUATION

e.g.,

$z = (A+B)x'$

Since $Q(t+1) = D$ for D-Flip Flop

$A(t+1) = D_A = Ax + Bx$

$B(t+1) = D_B = A'x$

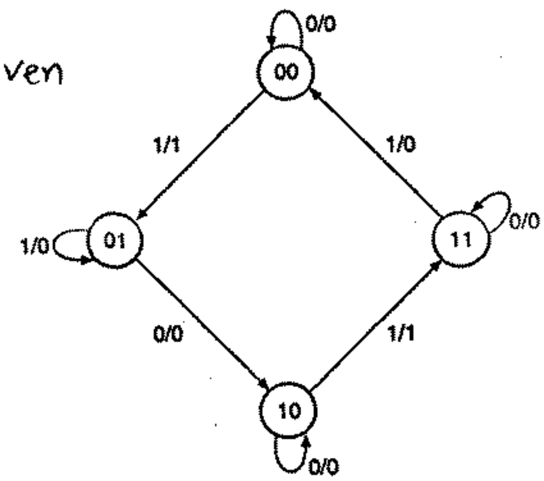
DESIGN OF SYNCHRONOUS SEQUENTIAL CIRCUITS

1. The word description of the circuit behavior is stated. This may be accompanied by a state diagram, a timing diagram, or other pertinent information.
2. From the given information about the circuit, ~~obtain the state table.~~ state transition diagram
3. The number of states may be reduced by state-reduction methods if the sequential circuit can be characterized by input–output relationships independent of the number of states.
4. Assign binary values to each state if the state table obtained in step 2 or 3 contains letter symbols.
5. Determine the number of flip-flops needed and assign a letter symbol to each.
6. Choose the type of flip-flop to be used.
7. From the state table, derive the circuit excitation and output tables.
8. Using the map or any other simplification method, derive the circuit output functions and the flip-flop input functions.
9. Draw the logic diagram.

Assume

Example:

Step 2: Given



← State transition diagram

or

state transition table

Present State		Next State x = 0		Next State x = 1		Output X=0	Output X=1
A	B	A	B	A	B	Z	Z
0	0	0	0	0	1	0	1
0	1	1	0	0	1	0	0
1	0	1	0	1	1	0	1
1	1	1	1	0	0	0	0

Step 5: 4 states ⇒ Need 2 flip-flops.
Let's call them A & B.

Step 6: Let's use D-flipflops.

Step 7:

Expand to 8 combinations

Present State A	Present State B	Input X	Next State A	Next State B	Output Z
0	0	0	0	0	0
0	0	1	0	1	1
0	1	0	1	0	0
0	1	1	0	1	0
1	0	0	1	0	0
1	0	1	1	1	1
1	1	0	1	1	0
1	1	1	0	0	0

D Flip-Flop

$Q(t)$	$Q(t+1)$	D
0	0	0
0	1	1
1	0	0
1	1	1

$\therefore Q(t+1) = D$

	Present State $A(t)$	Present State $B(t)$	Input X	Next State $A(t+1)$	Next State $B(t+1)$	Output Z	Flip-Flop Inputs D_A	Flip-Flop Inputs D_B
m_0	0	0	0	0	0	0	0	0
m_1	0	0	1	0	1	1	0	1
m_2	0	1	0	1	0	0	1	0
m_3	0	1	1	0	1	0	0	1
m_4	1	0	0	1	0	0	1	0
m_5	1	0	1	1	1	1	1	1
m_6	1	1	0	1	1	0	1	1
m_7	1	1	1	0	0	0	0	0

Step 8:

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

$D_A = A\bar{B} + B\bar{X}$

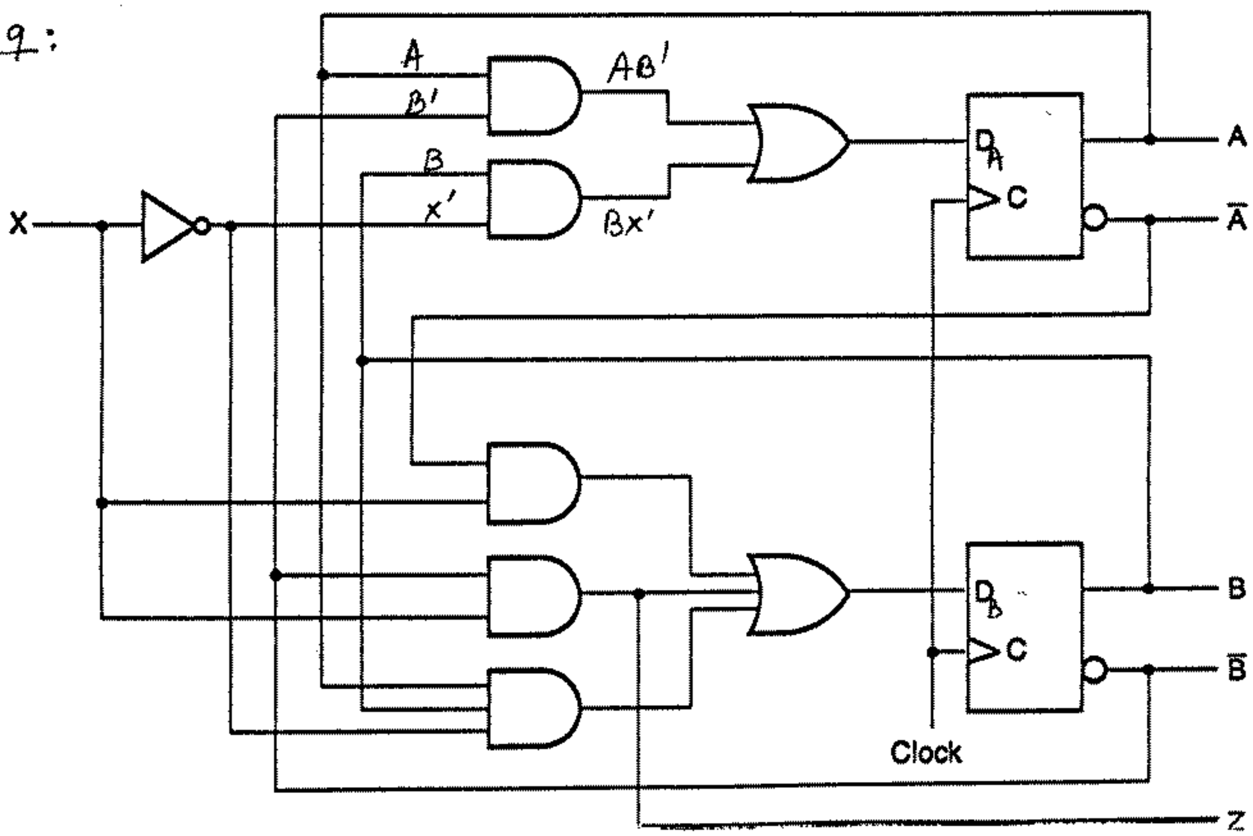
A \ BX	00	01	11	10
0		1	1	
1		1		1

$D_B = \bar{A}X + \bar{B}X + AB\bar{X}$

A \ BX	00	01	11	10
0		1		
1		1		

$Z = \bar{B}X$

Step 9:



Step 6: Let's use JK-FFs

Step 7:

Present State		Input	Next State		Output
A	B	X	A	B	Z
0	0	0	0	0	0
0	0	1	0	1	1
0	1	0	1	0	0
0	1	1	0	1	0
1	0	0	1	0	0
1	0	1	1	1	1
1	1	0	1	1	0
1	1	1	0	0	0

***JK* Flip-Flop**

$Q(t)$	$Q(t+1)$	J	K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0

Present State		Input	Next State		Output	Flip-Flop Inputs			
$A(t)$	$B(t)$	X	$A(t+1)$	$B(t+1)$	Z	J_A	K_A	J_B	K_B
0	0	0	0	0	0	0	X	0	X
0	0	1	0	1	1	0	X	1	X
0	1	0	1	0	0	1	X	X	1
0	1	1	0	1	0	0	X	X	0
1	0	0	1	0	0	X	0	0	X
1	0	1	1	1	1	X	0	1	X
1	1	0	1	1	0	X	0	X	0
1	1	1	0	0	0	X	1	X	1

Step 8:

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

$J_A = B\overline{X}$

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

$K_A = BX$

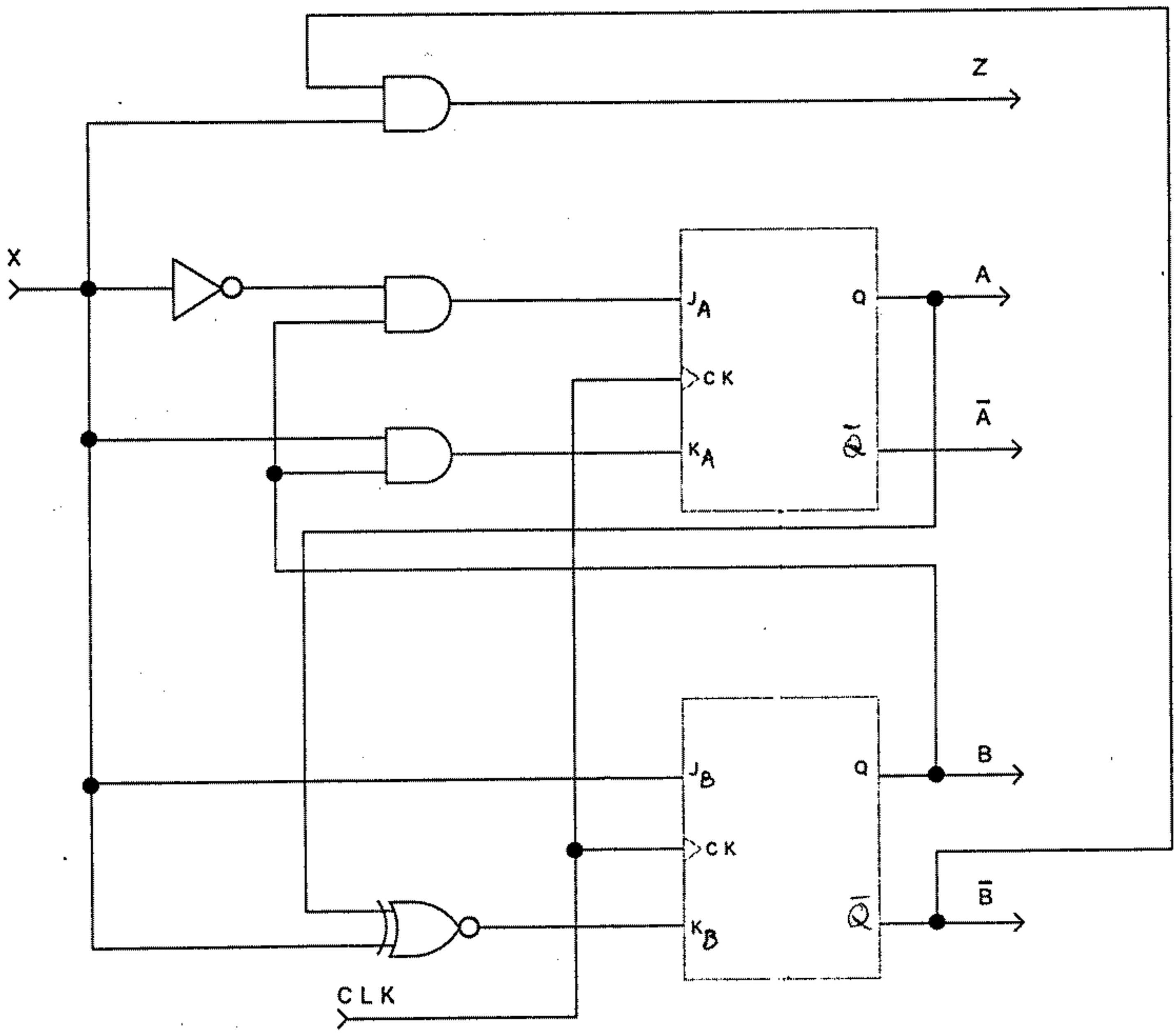
A \ BX	00	01	11	10
0		1	X	X
1		1	X	X

$J_B = X$

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

$K_B = AX + \overline{A}\overline{X}$
$= \overline{A \oplus X}$

Step 9:



Step 6: Let's use T - Flip flop

Step 7:

Present State		Input	Next State		Output
A	B	X	A	B	Z
0	0	0	0	0	0
0	0	1	0	1	1
0	1	0	1	0	0
0	1	1	0	1	0
1	0	0	1	0	0
1	0	1	1	1	1
1	1	0	1	1	0
1	1	1	0	0	0

T Flip-Flop

$Q(t)$	$Q(t+1)$	T
0	0	0
0	1	1
1	0	1
1	1	0

$Q(t+1) = Q'(t)$ when $T=1$.

Present State		Input	Next State		Output	Flip-Flop Inputs	
$A(t)$	$B(t)$	X	$A(t+1)$	$B(t+1)$	Z	T_A	T_B
0	0	0	0	0	0	0	0
0	0	1	0	1	1	0	1
0	1	0	1	0	0	1	1
0	1	1	0	1	0	0	0
1	0	0	1	0	0	0	0
1	0	1	1	1	1	0	1
1	1	0	1	1	0	0	0
1	1	1	0	0	0	1	1

Step 8:

A \ BX	00	01	11	10
0				1
1			1	

$T_A = \overline{A}B\overline{X} + ABX$

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

$T_B = \overline{A}B\overline{X} + ABX + \overline{B}X$

Step 9: