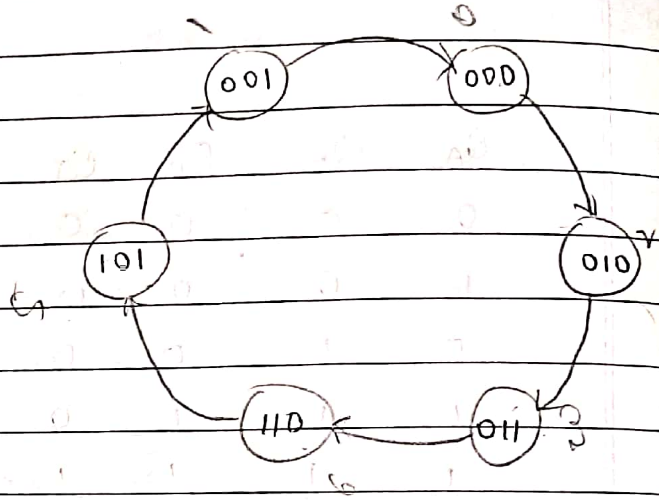
MODULE - 4
DESIGN OF SYNCHRONOUS COUNTERS
BY USING JK F/F OR D F/F OR T F/F OR SR F/F

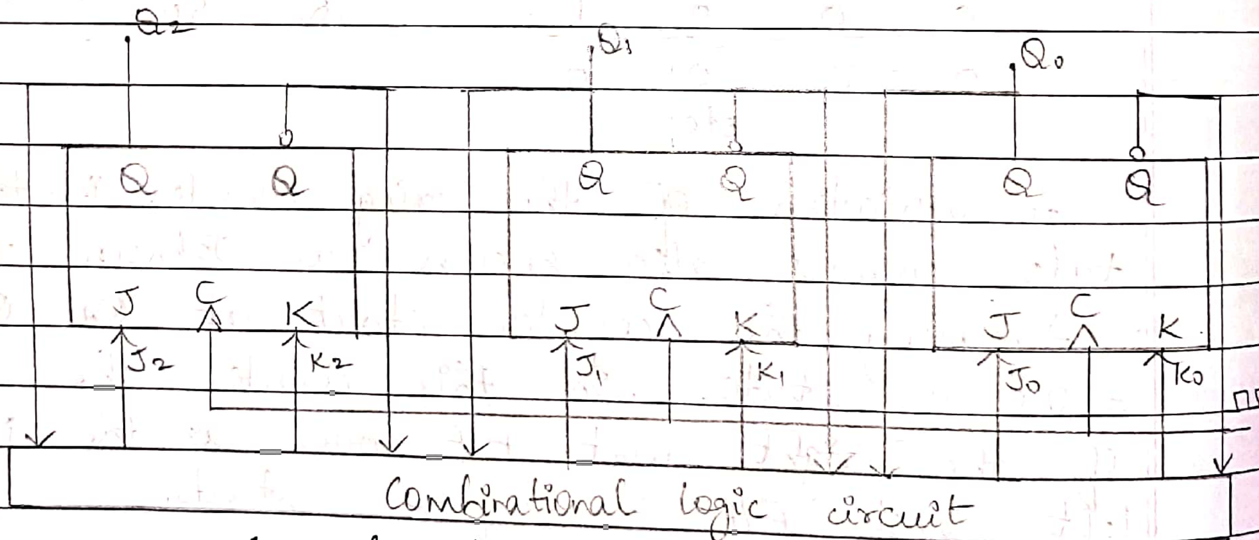
Design of a synchronous MOD 6 counter using clocked JK F/F.

Q_2	Q_1	Q_0
0	0	0
0	1	0
0	1	1
1	1	0
1	0	1
0	0	1
0	0	0 (repeat)

A Mod-6 sequence



State diagram of Mod-6 counter



General structure of Mod-6 counter

The counter we have seen so far ~~while~~ where characterisied by the count pulses being applied directly to the control inputs C of the clocked F/F's that compromise the counter. As a result all the F/F's change simultaneously & the new state of the counter is observed with less amount of time.

At that time emphasis was on the binary counter & the counters were based on shift register.

However depending upon the application other types of counters might be desireable for eg: one that counts according to the gray code.

The counting sequence of a counter produces various patterns. ∴ The use of counters as pattern generators. At this time a general procedure is developed for designing synchronous counters having a pre-specified output without any logic.

Application table for JK F/F:

Row no.	Q	$\rightarrow$ Q^+	J	K
0	0	0	0	–
1	0	1	1	–
2	1	0	–	1
3	1	1	–	0

Cell no.	Present state			Next state			Flip-flop inputs					
	Q_2	Q_1	Q_0	Q_2^+	Q_1^+	Q_0^+	J_2	K_2	J_1	K_1	J_0	K_0
0	0	0	0	0	1	0	0	–	1	–	0	–
1	0	0	1	0	0	0	0	–	0	–	–	1
2	0	1	0	0	1	1	0	–	–	0	1	–
3	0	1	1	1	1	0	1	–	–	0	–	1
4	1	0	0	–	–	–	–	–	–	–	–	–
5	1	0	1	0	0	1	–	1	0	–	–	0
6	1	1	0	1	0	1	–	0	–	1	1	–
7	1	1	1	–	–	–	–	–	–	–	–	–

K-map for J_2:

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	0	0	1	0
1	-	-	-	-

$$J_2 = \overline{Q_2} Q_1 Q_0 + Q_2 Q_1 Q_0$$

$$J_2 = Q_1 Q_0$$

K-map for K_2:

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	-	-	-	-
1	-	1	-	0

$$K_2 = \overline{Q_2}\,\overline{Q_1} Q_0 + Q_2 \overline{Q_1} Q_0 + \overline{Q_2} Q_1 Q_0 + Q_2 Q_1 Q_0$$

$$K_2 = \overline{Q_1} Q_0 + Q_1 Q_0$$

$$K_2 = Q_0$$

K-map for J_1:

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	1	0	-	-
1	-	0	-	-

$$J_1 = \overline{Q_2}\,\overline{Q_1}\,\overline{Q_0} + Q_2 \overline{Q_1}\,\overline{Q_0} + \overline{Q_2} Q_1 \overline{Q_0} + Q_2 Q_1 \overline{Q_0}$$

$$= \overline{Q_1}\,\overline{Q_0} + Q_1 \overline{Q_0}$$

$$J_1 = \overline{Q_0}$$

K-map for K_1:

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	-	-	0	0
1	-	-	-	1

$$K_1 = Q_2 \overline{Q_1}\,\overline{Q_0} + Q_2 \overline{Q_1} Q_0 + Q_2 Q_1 Q_0 + Q_2 Q_1 \overline{Q_0}$$

$$= Q_2 \overline{Q_1} + Q_2 Q_1$$

$$K_1 = Q_2$$

K-map for J_0:

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	0	-	-	1
1	-	-	-	1

$$J_0 = \overline{Q_2} Q_1 Q_0 + \overline{Q_2} Q_1 \overline{Q_0} + Q_2 Q_1 Q_0 + Q_2 Q_1 \overline{Q_0}$$

$$= \overline{Q_2} Q_1 + Q_2 Q_1$$

$$J_0 = Q_1$$

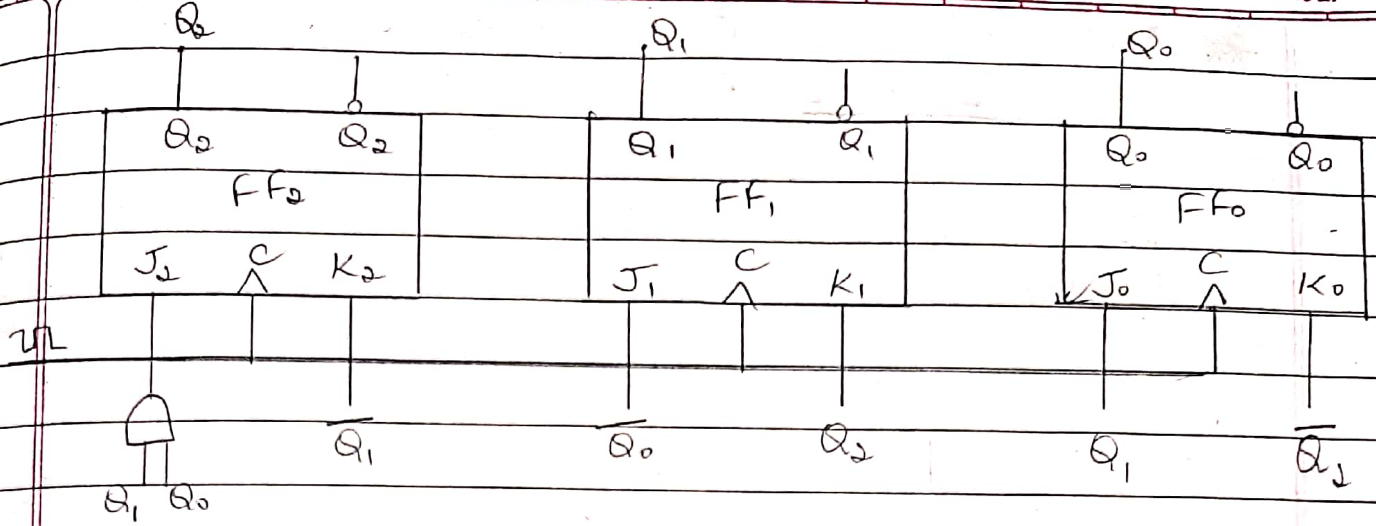
K-map for K_0:

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	-	1	1	-
1	-	0	-	-

$$K_0 = \overline{Q_2}\,\overline{Q_1}\,\overline{Q_0} + \overline{Q_2}\,\overline{Q_1} Q_0 + \overline{Q_2} Q_1 Q_0 + \overline{Q_2} Q_1 \overline{Q_0}$$

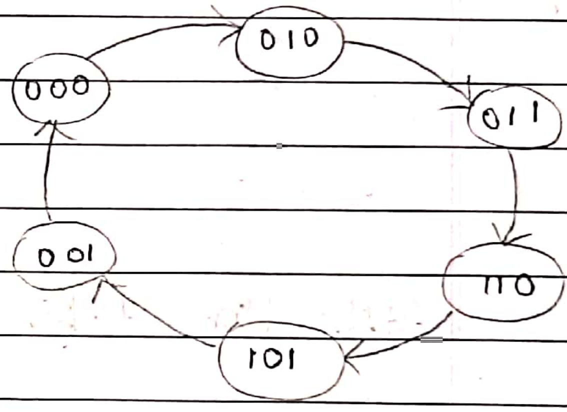
$$= \overline{Q_2}\,\overline{Q_1} + \overline{Q_2} Q_1$$

$$K_0 = \overline{Q_2}$$



Application table for D - F/F:

Row no.	Q	$\rightarrow Q^+$	D
0	0	0	0
1	0	1	1
2	1	0	0
3	1	1	1



Cell no.	Q_2	Q_1	Q_0	Q_2^+	Q_1^+	Q_0^+	D_2	D_1	D_0
0	0	0	0	0	1	0	0	1	0
1	0	0	1	0	0	0	0	0	1
2	0	1	0	0	1	1	0	1	1
3	0	1	1	1	1	0	1	1	0
4	1	0	0	–	–	–	–	–	–
5	1	0	1	0	0	1	0	0	1
6	1	1	0	1	0	1	1	0	1
7	1	1	1	–	–	–	–	–	–

for D_2:

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	0	0	1	0
1	–	0	–	1

for D_1:

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	1	0	1	1
1	–	0	–	0

$$D_2 = \bar{Q}_2Q_1Q_0 + Q_2Q_1Q_0 + Q_2Q_1Q_0 + Q_2Q_1\bar{Q}_0$$

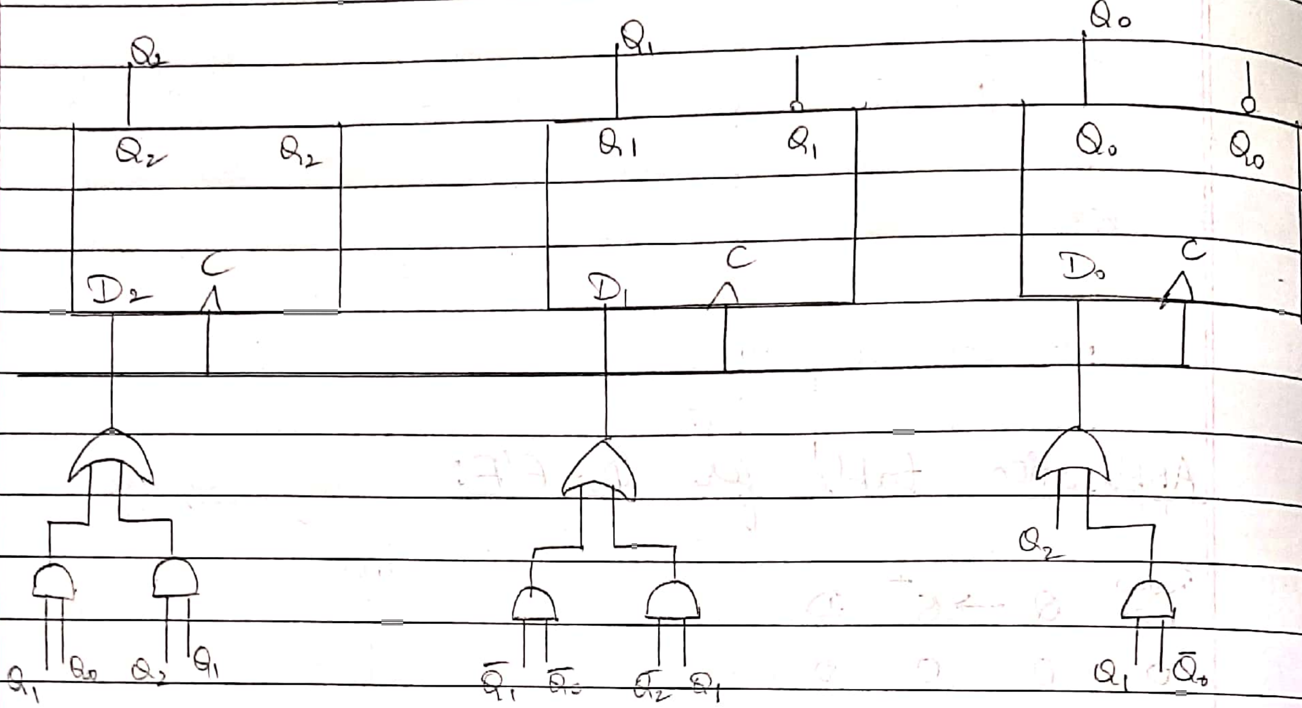
$$D_2 = Q_1Q_0 + Q_2Q_1$$

$$D_1 = \bar{Q}_2\bar{Q}_1\bar{Q}_0 + Q_2\bar{Q}_1\bar{Q}_0 + \bar{Q}_2Q_1Q_0 + \bar{Q}_2Q_1\bar{Q}_0$$

$$D_1 = \bar{Q}_1\bar{Q}_0 + \bar{Q}_2Q_1$$

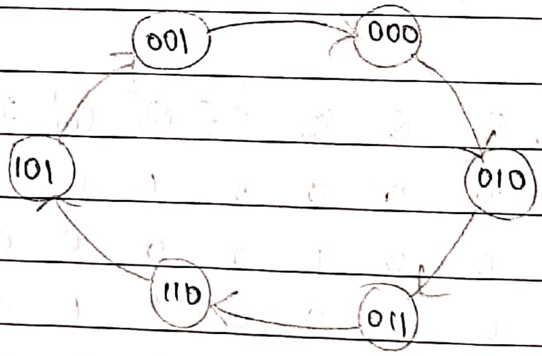
for D_0:

0	0	0	1
–	1	–	1



Application table for T-f/f:-

Q	Q^+	T
0	0	0
0	1	1
1	0	1
1	1	0



cell no.	Q_2	Q_1	Q_0	Q_2^+	Q_1^+	Q_0^+	T_2	T_1	T_0
0	0	0	0	0	1	0	0	1	0
1	0	0	1	0	0	0	0	0	1
2	0	1	0	0	1	1	0	0	1
3	0	1	1	1	1	0	1	0	1
4	1	0	0	–	–	–	–	–	–
5	1	0	1	0	0	1	1	0	0
6	1	1	0	1	0	1	0	1	1
7	1	1	1	–	–	–	–	–	–

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T_2:

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	0	0	1	0
1	–	1	–	0

$$T_2 = Q_1Q_0 + Q_2\overline{Q_1}$$

T_1:

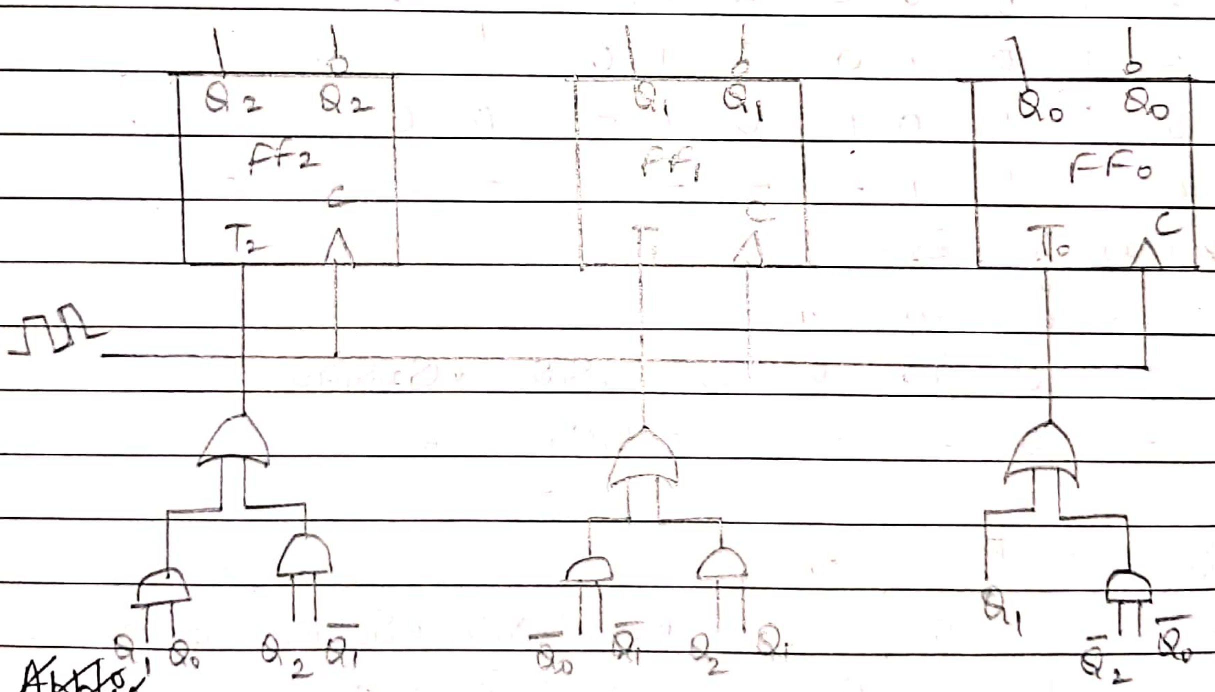
$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	1	0	0	0
1	–	0	–	1

$$T_1 = \overline{Q_1}\,\overline{Q_0} + Q_2Q_1$$

T_0:

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	0	1	1	1
1	–	0	–	1

$$T_0 = Q_1 + \overline{Q_2}\,\overline{Q_0}$$



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Application table for SR f/f:-

Q	Q^+	S	R
0	0	0	—
0	1	1	0
1	0	0	1
1	1	—	0

cell no.	Q_2	Q_1	Q_0	Q_2^+	Q_1^+	Q_0^+	S_2	R_2	S_1	R_1	S_0	R_0
0	0	0	0	0	1	0	0	—	1	0	0	—
1	0	0	1	0	0	0	0	—	0	—	0	1
2	0	1	0	0	1	1	0	—	—	0	1	0
3	0	1	1	1	1	0	1	0	—	0	0	1
4	1	0	0	—	—	—	—	—	—	—	—	—
5	1	0	1	0	0	1	0	1	0	—	—	0
6	1	1	0	1	0	1	—	0	0	1	1	0
7	1	1	1	—	—	—	—	—	—	—	—	—

K-map for S_2:

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	0 (0)	0 (1)	1 (3)	0 (2)
1	— (4)	0 (5)	— (7)	— (6)

$S_2 = \bar{Q}_2Q_1Q_0 + Q_2Q_1Q_0$

$S_2 = Q_1Q_0$

K-map for R_2

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	—	—	0	—
1	—	1	—	0

$R_2 = \bar{Q}_2\bar{Q}_1\bar{Q}_0 + \bar{Q}_2\bar{Q}_1Q_0 + Q_2\bar{Q}_1\bar{Q}_0 + Q_2\bar{Q}_1Q_0$

$= \bar{Q}_2\bar{Q}_1 + Q_2\bar{Q}_1$

$R_2 = \bar{Q}_1$

K-map for S_1:

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	1	0	—	—
1	—	0	—	0

$S_1 = \bar{Q}_2\bar{Q}_1\bar{Q}_0 + Q_2\bar{Q}_1\bar{Q}_0$

$S_1 = \bar{Q}_1\bar{Q}_0$

R_1:

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	0	—	0	0
1	—	—	—	1

$R_1 = Q_2\bar{Q}_1\bar{Q}_0 + Q_2\bar{Q}_1Q_0 + Q_2Q_1Q_0 + Q_2Q_1\bar{Q}_0$

$= Q_2\bar{Q}_1 + Q_2Q_1$

$R_1 = Q_2$

K-map for S_0

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	0	0	0	1
1	–	–	–	1

$S_0 = \cancel{\bar{Q}_2 Q_1 \bar{Q}_0 + \bar{Q}_2 \bar{Q}_1 \bar{Q}_0 + Q_2 \bar{Q}_1 \bar{Q}_0 + Q_2 Q_1 \bar{Q}_0} + \bar{Q}_2 Q_1 \bar{Q}_0$

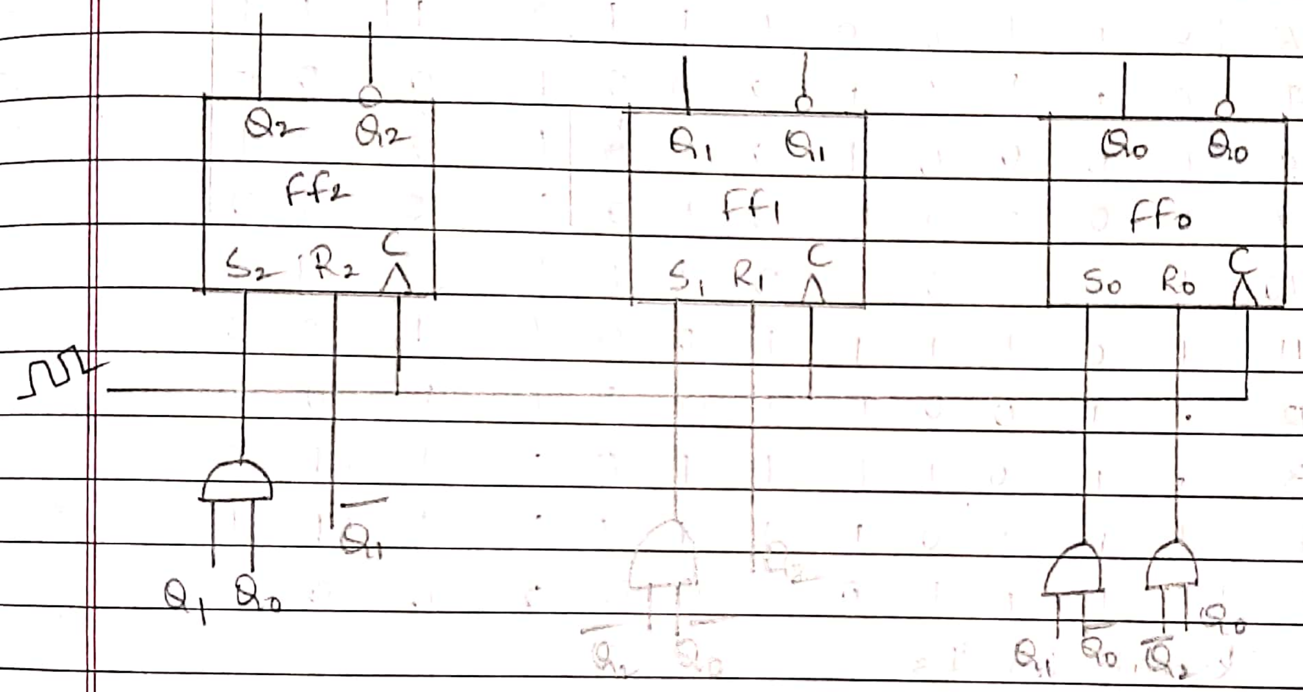
$S_0 = \cancel{Q_2 \bar{Q}_1 + Q_2 Q_1} + Q_1 \bar{Q}_0 + \bar{Q}_2 Q_1 \bar{Q}_0$

Kmap for R_0

$Q_2 \backslash Q_1Q_0$	00	01	11	10
0	–	1	1	0
1	–	0	–	0

$R_0 = \bar{Q}_2 \bar{Q}_1 Q_0 + \bar{Q}_2 Q_1 Q_0$

$R_0 = \bar{Q}_2 Q_0$



Design a synchronous MOD-16 counter using the edge triggered D f/f with minimal combination gate circuits.

Cell no.	Present state Q_3	Q_2	Q_1	Q_0	Next state Q_3^+	Q_2^+	Q_1^+	Q_0^+	Flip-flop i/p D_3	D_2	D_1	D_0
0	0	0	0	0	0	0	0	1	0	0	0	1
1	0	0	0	1	0	0	1	0	0	0	1	0
2	0	0	1	0	0	0	1	1	0	0	1	1
3	0	0	1	1	0	1	0	0	0	1	0	0
4	0	1	0	0	0	1	0	1	0	1	0	1
5	0	1	0	1	0	1	1	0	0	1	1	0
6	0	1	1	0	0	1	1	1	0	1	1	1
7	0	1	1	1	1	0	0	0	1	0	0	0
8	1	0	0	0	1	0	0	1	1	0	0	1
9	1	0	0	1	1	0	1	0	1	0	1	0
10	1	0	1	0	1	0	1	1	1	0	1	1
11	1	0	1	1	1	1	0	0	1	1	0	0
12	1	1	0	0	1	1	0	1	1	1	0	1
13	1	1	0	1	1	1	1	0	1	1	1	0
14	1	1	1	0	1	1	1	1	1	1	1	1
15	1	1	1	1	0	0	0	0	0	0	0	0

K-map for D_3

$Q_3Q_2 \backslash Q_1Q_0$	00	01	11	10
00	0 (0)	0 (1)	0 (3)	0 (2)
01	0 (4)	0 (5)	1 (7)	0 (6)
11	1 (12)	1 (13)	0 (15)	1 (14)
10	1 (8)	1 (9)	1 (11)	1 (10)

$$D_3 = \bar{Q}_3 Q_2 Q_1 Q_0 + Q_3 \bar{Q}_2 + Q_3 \bar{Q}_1 + Q_3 \bar{Q}_0$$

K-map for D_2

$Q_3Q_2 \backslash Q_1Q_0$	00	01	11	10
00	0 (0)	0 (1)	1 (3)	0 (2)
01	1 (4)	1 (5)	0 (7)	1 (6)
11	1 (12)	1 (13)	0 (15)	1 (14)
10	0 (8)	0 (9)	1 (11)	0 (10)

$$D_2 = \bar{Q}_3 \bar{Q}_2 Q_1 Q_0 + Q_3 \bar{Q}_2 Q_1 Q_0 + \bar{Q}_3 Q_2 \bar{Q}_1 \bar{Q}_0 + Q_3 Q_2 \bar{Q}_1 \bar{Q}_0$$
$$+ \bar{Q}_3 Q_2 \bar{Q}_1 Q_0 + Q_3 Q_2 \bar{Q}_1 Q_0 + \bar{Q}_3 Q_2 \bar{Q}_1 \bar{Q}_0$$
$$+ Q_3 Q_2 \bar{Q}_1 \bar{Q}_0 + \bar{Q}_3 Q_2 Q_1 \bar{Q}_0 + Q_3 Q_2 Q_1 \bar{Q}_0$$
$$= \bar{Q}_2 Q_1 Q_0 + Q_2 \bar{Q}_1 \cancel{Q_0} + Q_2 \bar{Q}_1 \cancel{Q_0} + Q_2 \bar{Q}_1 \bar{Q}_0$$
$$+ Q_2 Q_1 \bar{Q}_0$$

$$D_2 = \bar{Q}_2 Q_1 Q_0 + Q_2 \bar{Q}_1 + Q_2 \bar{Q}_0$$

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K-map for D_1

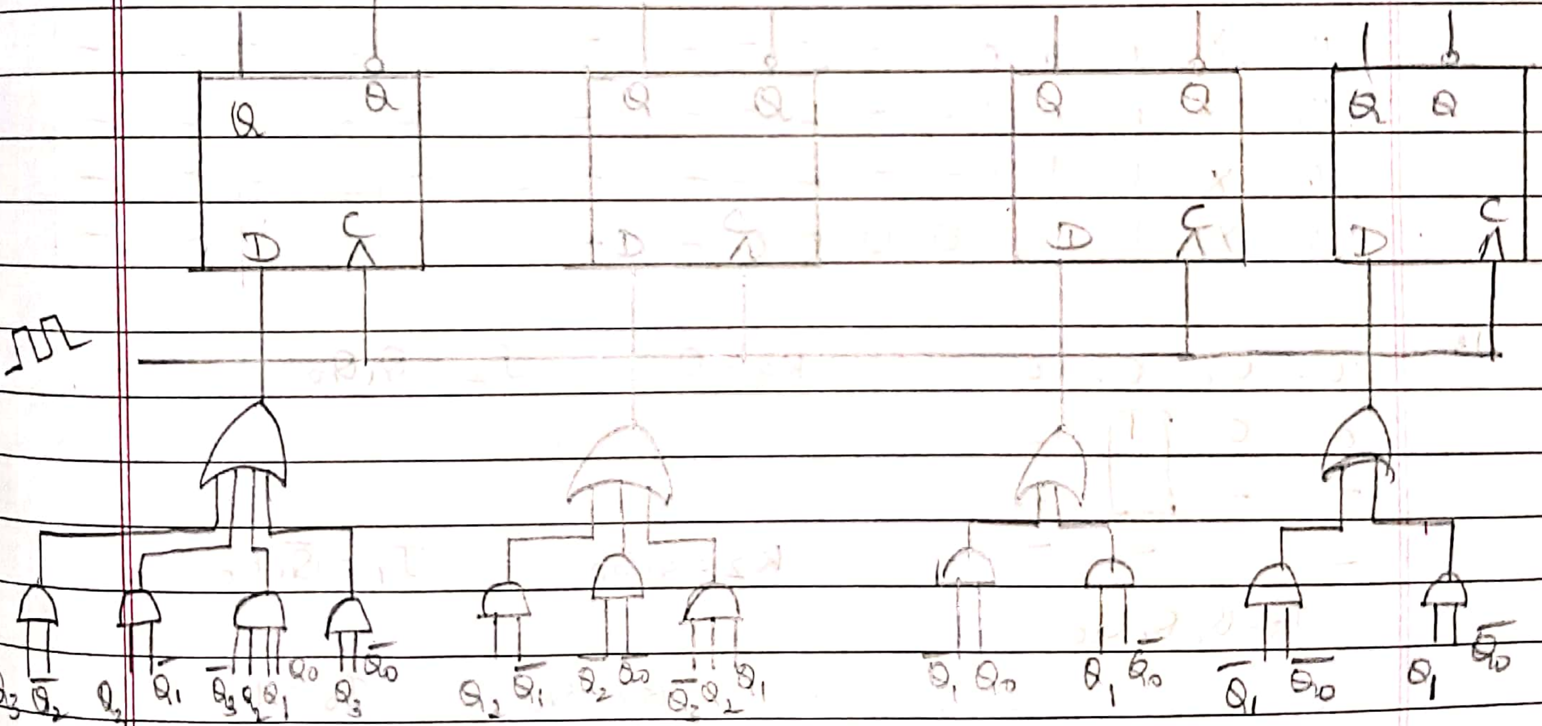
$Q_3Q_2 \backslash Q_1Q_0$	00	01	11	10
00	0	1	0	1
01	0	1	0	1
11	0	1	0	1
10	0	1	0	1

$$D_1 = \bar{Q}_1 Q_0 + Q_1 \bar{Q}_0$$

K-map for D_0:

$Q_3Q_2 \backslash Q_1Q_0$	00	01	11	10
00	1	0	0	1
01	1	0	0	1
11	1	0	0	1
10	1	0	0	1

$$D_0 = \cancel{\bar{Q}_2 Q_1 \bar{Q}_0} + \bar{Q}_1 \bar{Q}_0 + Q_1 \bar{Q}_0$$



Design a synchronous MOD-16 counter using +ve edge triggered JK f/f with minimal combinational gate ckts. count from (0-9)

Cell no	Q_3	Q_2	Q_1	Q_0	Q_3^+	Q_2^+	Q_1^+	Q_0^+	J_3	K_3	J_2	K_2	J_1	K_1	J_0	K_0
0	0	0	0	0	0	0	0	1	0	–	0	–	0	–	1	–
1	0	0	0	1	0	0	1	0	0	–	0	–	1	–	–	1
2	0	0	1	0	0	0	1	1	0	–	0	–	–	0	1	–
3	0	0	1	1	0	1	0	0	0	–	1	–	–	1	–	1
4	0	1	0	0	0	1	0	1	0	–	–	0	0	–	1	–
5	0	1	0	1	0	1	1	0	0	–	–	0	1	–	–	1
6	0	1	1	0	0	1	1	1	0	–	–	0	–	0	1	–
7	0	1	1	1	1	0	0	0	1	–	–	1	–	1	–	1
8	1	0	0	0	1	0	0	1	–	0	0	–	0	–	1	–
9	1	0	0	1	–	–	–	–	–	–	–	–	–	–	–	–
10	X	0	1	0	–	–	–	–	–	–	–	–	–	–	–	–
11	X	0	1	1	–	–	–	–	–	–	–	–	–	–	–	–
12	X	1	0	0	–	–	–	–	–	–	–	–	–	–	–	–
13	X	1	0	1	–	–	–	–	–	–	–	–	–	–	–	–
14	X	1	1	0	–	–	–	–	–	–	–	–	–	–	–	–
15	X	1	1	1	0	0	0	0	–	–	–	–	–	–	–	–

J_3

0	0	0	0
0	0	1	0
–	–	–	–
–	–	–	–

$K_3 = 0$

$J_2 = Q_1 Q_0$

$K_2 = Q_1 Q_0$

$J_1 = \bar{Q_1} Q_0$

$J_3 = Q_2 Q_1 Q_0$

$K_1 = Q_0$

$J_0 = 1$

$K_0 = 1$

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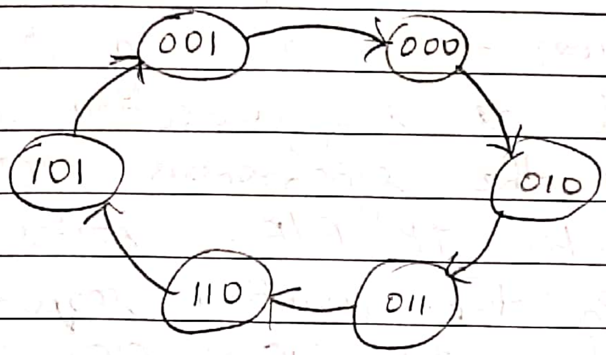
Self correcting counter:



As we see in the last case for a mod 6 counter, the counter did not include the states 100 & 111.

Once the counter is designed, definite next states results if either of these states should occur. When a system is initially started i.e., when power ~~in~~ is first applied to the network, the initial states of the F/F's are unpredicatable.

Consiquently either of the two states 100 & 111 can occur.

As a solⁿ to this problem the counter could be initalized prior to its use.

One way in which this can be done is by applying appropriate signals to the asynchronous input terminals of the F/F's to force them into the first state of the counting sequence. However noise signals can also cause the counter to enter one of its initially ~~unse~~ unused states.

A counter in which all the states not included in the original counting sequence eventually lead to the normal counting sequence that alters one or more count pulses that are applied to the control inputs.

The control input 'C' is said to be self correcting inorder to ~~avoid~~ having counter to enter into unused state (or) to avoid hang up, it shld always be designed as self correcting counters.

Again consider the synchronous MOD-6 counter previously designed by JK F/F's, states $Q_2 Q_1 Q_0 = 100$ was not included in the counting sequence. Now substituting these values into the F/F's input eq^n obtained wrt JK F/F's we get $J_2 = Q_1 Q_0$, $K_2 = Q_0$

$J_1 = \overline{Q_0}$, $K_1 = Q_2$, $J_0 = Q_1$, $K_0 = \overline{Q_2}$.

$\boxed{J_1 = Q_2 Q_3,\ K_1 = \overline{Q_2},\ J_2 = \overline{Q_3},\ K_2 = Q_1,\ J_3 = Q_2,\ K_3 = \overline{Q_1}}$

1) $Q_1 Q_2 Q_3 = 100$

$J_1 = 0$, $K_1 = 1$, $J_2 = 1$, $K_2 = 1$, $J_3 = 0$, $K_3 = 0$.

$Q_2\ Q_1\ Q_0$ $Q_1\ Q_2\ Q_3$ $Q_1^+\ Q_2^+\ Q_3^+$

$Q_1 Q_2 Q_3 = 100 \rightarrow 010$

2) $Q_1 Q_2 Q_3 = 111$

$\underbrace{J_1 = 1,\ K_1 = 0}_{\text{Set} = 1}$, $\underbrace{J_2 = 0,\ K_2 = 1}_{\text{reset} = 0}$, $\underbrace{J_3 = 1,\ K_3 = 0}_{\text{set} = 1}$.

$\therefore Q_1 Q_2 Q_3 = 111 \rightarrow \underset{Q_1^+ Q_2^+ Q_3^+}{101}$

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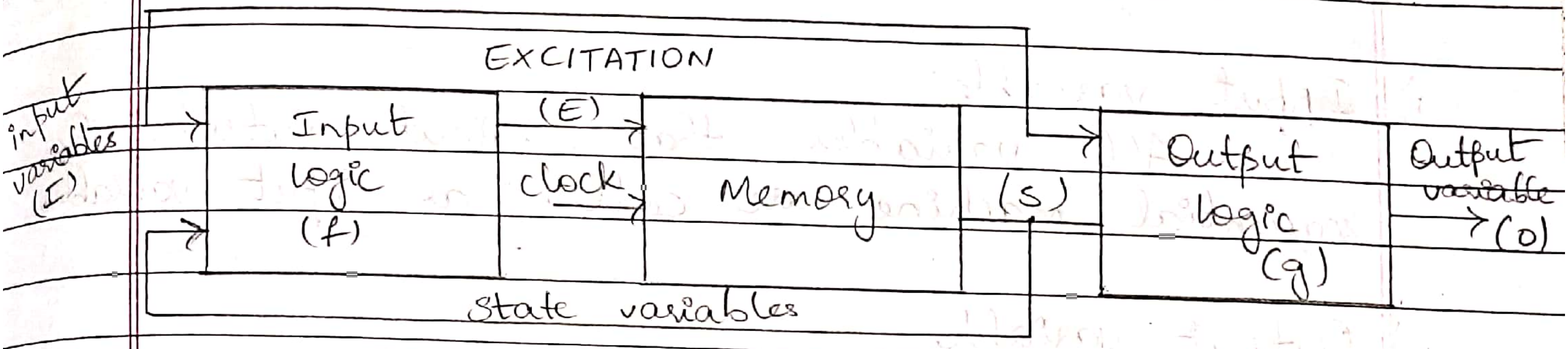
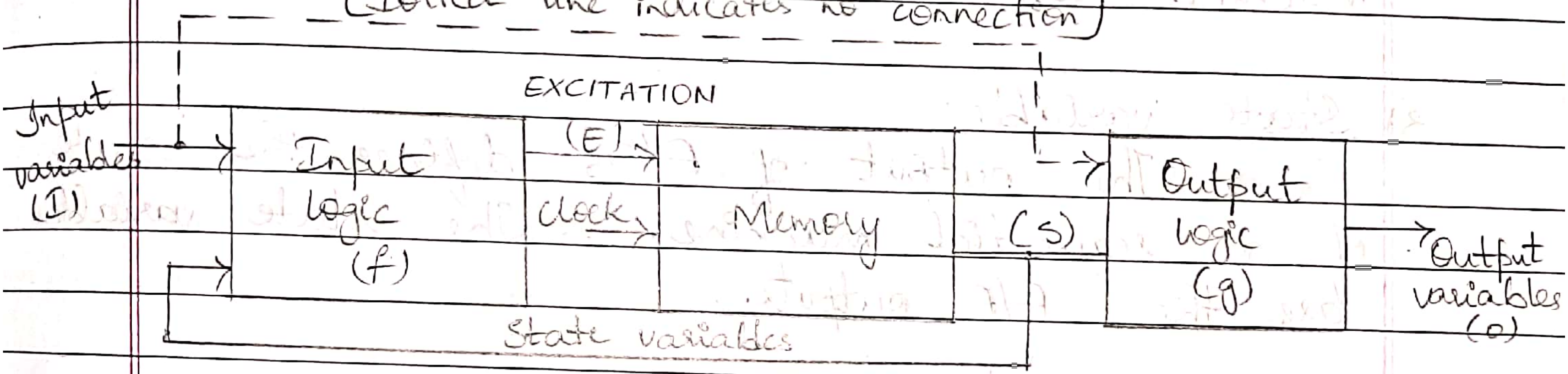
Mealy & Moore models:



Mealy sequential ckt model

[Dotted line indicates no connection]



Moore sequential circuit model

A mealy sequential ckt differs from a moore ckt in the variables used to generate the output functions.

In a mealy machine, the external i/p variables (I) & the state variables (S) are applied to the output logic function. where as a moore function is dependent only on the state variable(s). Thus the moore model output dependents only on the present state of the F/F's. where as a ~~moore~~ mealy model o/p depends both on the present state of the F/F as well as the output.

In moore model i/p changes doesnot effect the ~~of~~ output, in maealy model i/p ~~effects~~ ~~if~~ changes may affect the output.

State machine notation:

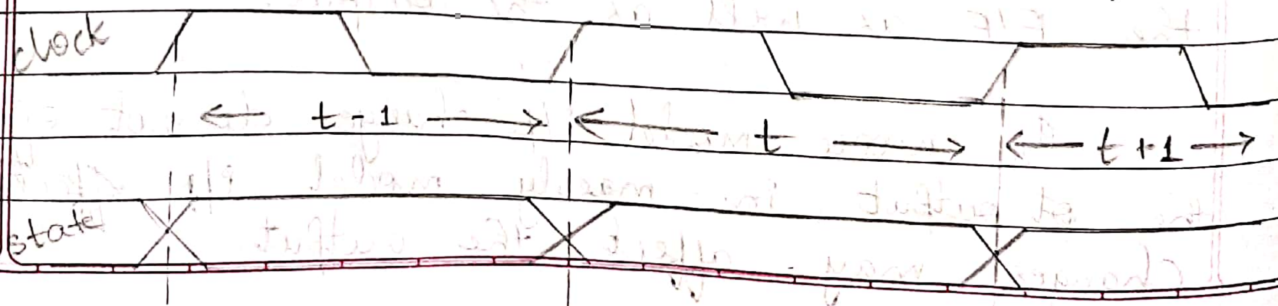
1) **Input variable:**
All variables that originate outside the sequential machine are called as input variables.

2) **Output variable:**
All variables that exist the sequential machine are called as output variables.

3) **State variable:**
The output of F/F's defines the state of a sequential machine. ∴ The state variables are the F/F outputs.

4) **Excitation variable:**
These are the variables that are inputs to the F/F's & are generated by the input combinational logic that is operating on the state variables & input variables.

State & State variables:
In state machine state variables & states are related by the exp. $2^x = y$ where x = no. of state variables & y = max. no. of possible states.
for eg: A 4 state variable can represent 16



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In a state machines it is necessary to distinguish state variables before & after the clock pulse with this we can get the idea of present state & next state.

Present state:

The status of all variables at some time 't' before the next clock edge represents the condition called as Present state.

Next state:

The status of all the state variables at some time t+1 represents the condition called as Next state.

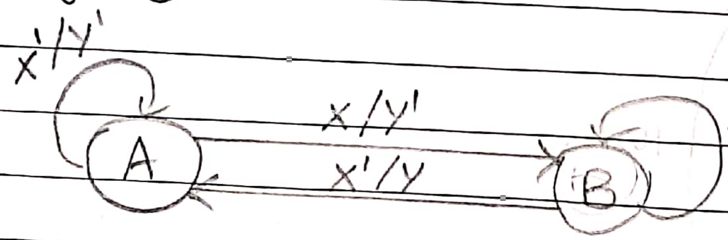
State diagram:

A state diagram is a graphical representation of a ~~sequention~~ sequential ckt where individual states are represented by a circle with an identifying symbol ~~tee~~ located inside.

Eg: (A)

Change from state to state are indicated by the directed arc.

Eg: (A) ⟶ (B)



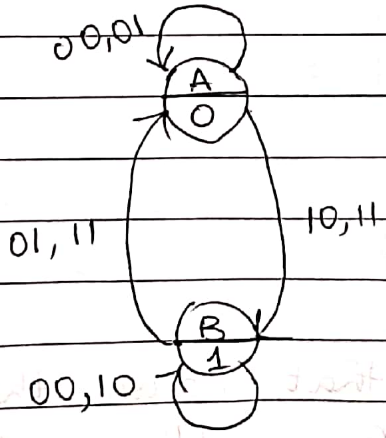
Input conditions that cause the state changes to occur & the resulting output signals are written ~~adjust~~ adjacent to the directed arc.

In the eg. state A is represented with a circle ~~A~~ with a letter A written inside. A directed arc connects state A with state B with this example the next state can be either A or B. depending upon the input variable 'x'. If an i/p variable $x=0$ then the machine remains in 'A'. If $x=1$, then the machine a transition to state B is made.

An i/o statement is written such that the input variables are to the left & the output variables to the right separated by a slash(/).

Note that the o/p in this scheme is a function of both the present state & the input variables & thus making it as Maely model.

In moore machine notation where the output depends on only the present state which represents the output variable inside the state circle or with an arc terminating in the output variable.



This represents the condition for a JK F/F.

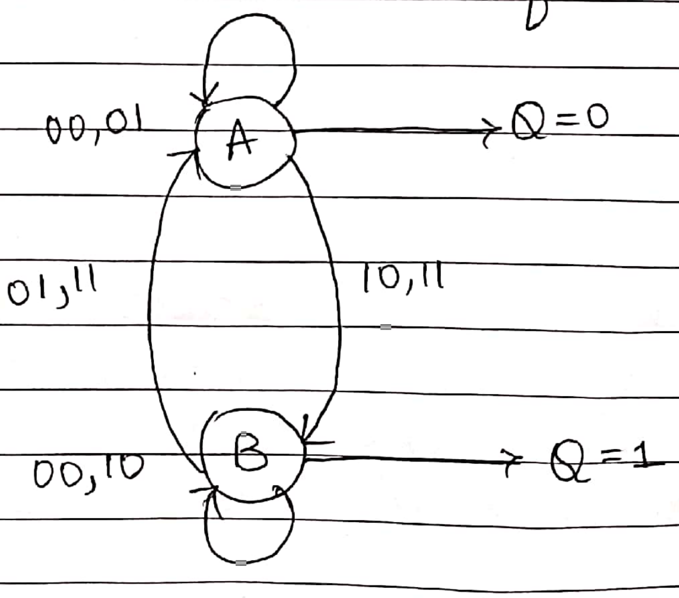
A JK F/F can be modeled by a state diagram as shown in the above fig. Each state in the state diagram represents a state of a F/F.

For this eg, J & K are both input & excitation variables whereas Q is both the output & state variable. State A represents where Q=0 whereas state B represents Q=1. & note that if A is the present state & JK = 10 then a transition is made from A to B & the o/p Q changes to 1.

When a transition from state A to state B is made when JK=10 or JK=11. The other two input combinations will ~~give~~ the remain machine in state A itself.

If B is the present state i.e., Q = 1 the two i/p conditions that causes a transition from B to A is 01 & 11.

~~The two input~~
When JK=00 or JK=10 the machine remains in state B itself.



Refer, 326 307 2 diagrams.

State tables:

State tables are tabular forms of the state diagrams.

A series of next state columns exist one for each input combination.

The purpose of the state table is to indicate the state transitions, A 2 input variable will have 4 states & with 1 output variable as shown in the state diagram.

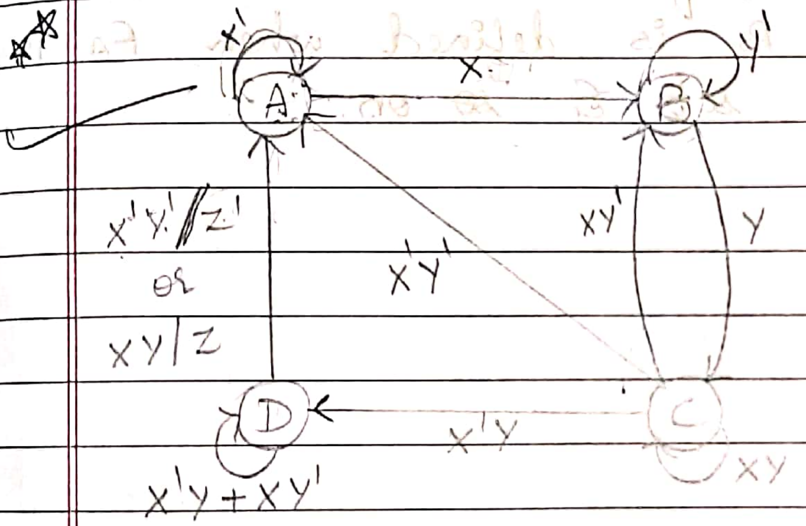


fig: State machine M_1

	Next state XY/Z							
Present state	00	Z	01	Z	11	Z	10	Z
A	A	0	A	0	B	0	B	0
B	B	0	C	0	C	0	B	0
C	A	0	D	0	C	0	B	0
D	A	0	D	0	A	1	D	0

Transition table:

A transition table takes the state table one step further where the state diagram & state table represents states using symbols or names.

Creation of a transition table requires that specific state variable values should be assigned to each state.

Consider a table below where 4 states labeled A B C & D requiring 2 state variables FA & FB let the state assignment be A→00 B→01, C→11, D→10.

Each state is assigned with a unique code where state A is defined when both the F/F's are reset. State B is defined when FA is reset & FB is set & so on.

F_A	F_B	State
0	0	A
0	1	B
1	1	C
1	0	D

Present state		00	Z	01	Z	11	Z	10	Z
F_A	F_B	F_AF_B		F_AF_B		F_AF_B		F_AF_B	
0	0	00	0	00	0	01	0	01	0
0	1	01	0	11	0	11	0	01	0
1	~~0~~ 1	00	0	10	0	11	0	01	0
1	0	00	0	10	0	00	1	10	0

Excitation table & Equations:

Once the changes in F/F outputs are known the next step is to determine the excitation inputs needed to cause the desired F/F output changes. This requires the info of type of the F/F used in releaizing the state machine.

D	Present Q_t	Next Q_{t+1}
0	0	0
1	0	1
0	1	0
1	1	1

$Q_{t+1} = D$

Present state	Next state 00	Z	01	Z	11	Z	10	Z
FA FB	DADB		DADB		DADB		DADB	
0 0	0 0	0	0 0	0	0 1	0	0 1	0
0 1	0 1	0	1 1	0	1 1	0	0 1	0
1 1	0 0	0	1 0	0	1 1	0	0 1	0
1 0	0 0	0	1 0	0	0 0	1	1 0	0

The excitation table for any state machine M, is exactly same as its transition table when D F/F are used.

Note that the next state value for a stable table using D F/F is same as the D input. This means that Q_{t+1} [Next state] values for FAFB are the same as the D values.

The excitation eq^s are derived directly from excitation table.

An eq^n is written for each F/F D input & for each o/p variable. For this example 2 excitation eq^n's & 1 o/p eq^s are needed. Here we have assigned FA as MSB & Y as LSB in every next state column.

Each term in the D_A eq^n is derived from the table as follows wrt min term exist for each logical 1 in every next state column.

Minterms of D_A

Min term	F_A	F_B	X	Y
	8	4	2	1
5	0	1	0	1
13	1	1	0	1
9	1	0	0	1
7	0	1	1	1
15	1	1	1	1
10	1	0	1	0

Minterms of D_B

Minterm	F_A	F_B	X	Y
	8	4	2	1
4	0	1	0	0
5	0	1	0	1
3	0	0	1	1
7	0	1	1	1
15	1	1	1	1
2	0	0	1	0
6	0	1	1	0
14	1	1	1	0

Now writing the decimal notation eq$^{n's}$ for each excitation variables gives,

$$D_A = f(F_A, F_B, X, Y) = \Sigma(5, 7, 9, 10, 13, 15)$$

$$D_B = f(F_A, F_B, X, Y) = \Sigma(2, 3, 4, 5, 6, 7, 14, 15)$$

F_AF_B \ XY	00	01	11	10
00	0_0	0_1	0_3	0_2
01	0_4	1_5	1_7	0_6
11	0_{12}	1_{13}	1_{15}	0_{14}
10	0_8	1_9	0_{11}	$\boxed{1}_{10}$

$$G_1 = \bar{F}_A F_B \bar{X} Y + \bar{F}_A F_B X Y + F_A F_B \bar{X} Y + F_A F_B X Y$$

$$= \bar{F}_A F_B Y + F_A F_B Y$$

$$G_1 = F_B Y$$

$$G_2 = F_A F_B \bar{X} Y + F_A \bar{F}_B \bar{X} Y = F_A \bar{X} Y$$

$$G_3 = F_A \bar{F}_B X \bar{Y}$$

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$D_A = F_B Y + F_A \bar{X} Y + F_A \bar{F_B} X \bar{Y}$

$F_A F_B$ \ XY	00	01	11	10
00	0_0	0_1	1_3	1_2
01	1_4	1_5	1_7	1_6
11	0_{12}	0_{13}	1_{15}	1_{14}
10	0_8	0_9	0_{11}	0_{10}

$D_B = \bar{F_A} F_B + F_B X + \bar{F_A} Y$

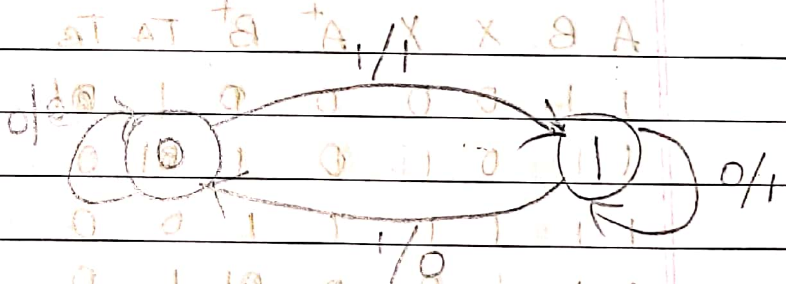
Z =

$F_A F_B$ \ XY	00	01	11	10
00	0	0	0	0
01	0	0	0	0
11	0	0	0	0
10	0	0	$\boxed{1}$	0

$Z = F_A \bar{F_B} X Y$

T F/F:

PS Q(t)	i/p to F/F T(t)	Next state Q(t+1)
0	0	0
0	1	1
1	0	1
1	1	0



Present state		00	Z	01	Z	11	Z	10	Z
F_A	F_B	$T_A T_B$		$T_A T_B$		$T_A T_B$		$T_A T_B$	
0	0	0 0	0	0 0		0 1		0 1	
0	1	0 0	0	1 0		1 0		0 0	
1	1	1 1	0	0 1		0 0		1 0	
1	0	1 0	0	0 0		1 0		0 0	

PS		i/P		N S		F/F i/p's		o/P
A	B	X	Y	A^+	B^+	T_A	T_B	Z
0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0
0	0	1	1	0	1	0	1	0
0	0	1	0	0	1	0	1	0

PS		i/p		NS		F/F i/p		o/p
A	B	X	Y	A^+	B^+	T_A	T_B	Z
0	1	0	0	0	1	0	0	0
0	1	0	1	1	1	1	0	0
0	1	1	1	1	1	1	0	0
0	1	1	0	0	1	0	0	0

A	B	X	Y	A^+	B^+	T_A	T_B	Z
1	1	0	0	0	0	1	1	0
1	1	0	1	0	1	1	0	0
1	1	1	1	1	1	0	0	0
1	1	1	0	0	1	1	0	0

A	B	X	Y	A^+	B^+	T_A	T_B	Z
1	0	0	0	0	0	1	0	0
1	0	0	1	1	0	0	0	0
1	0	1	1	0	0	1	0	0
1	0	1	0	1	0	0	0	0

$T_A = \Sigma(5, 7, 8, 11, 12, 14)$

$T_B = \Sigma(2, 3, 12, 13)$

$T_A = F_A F_B' xy + F_A x' y' + F_A F_B y' + F_A' F_B y$

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Minterm of T_A:

Minterm	F_A (8)	F_B (4)	X (2)	Y (1)
12	1	1	0	0
8	1	0	0	0
5	0	1	0	1
7	0	1	1	1
11	1	0	1	1
14	1	1	1	0

Minterm of T_B:

Minterm	F_A	F_B	X	Y
12	1	1	0	0
13	1	1	0	1
3	0	0	1	1
2	0	0	1	0

$T_A = f(F_A, F_B, X, Y) = \Sigma(5, 7, 8, 11, 12, 14)$

$T_B = f(F_A, F_B, X, Y) = \Sigma(2, 3, 12, 13)$

F_AF_B \ XY	00	01	11	10
00	0_0	0_1	0_3	0_2
01	0_4	1_5	1_7	0_6
11	1_{12}	0_{13}	0_{15}	1_{14}
10	1_8	0_9	1_{11}	0_{10}

$G_1 = \bar{F_A} F_B \bar{X} Y + \bar{F_A} F_B X Y = \bar{F_A} F_B Y$

$G_2 = F_A F_B \bar{X} \bar{Y} + F_A \bar{F_B} \bar{X} \bar{Y} = F_A \bar{X} \bar{Y}$

$G_3 = F_A F_B \bar{X} \bar{Y} + F_A F_B X \bar{Y} = F_A F_B \bar{Y}$

$G_4 = F_A \bar{F_B} X Y$

$T_A = \bar{F_A} F_B Y + F_A \bar{X} \bar{Y} + F_A F_B \bar{Y}$.

F_AF_B \ XY	00	01	11	10
00	0_0	0_1	1_3	1_2
01	0_4	0_5	0_7	0_6
11	1_{12}	1_{13}	0_{15}	0_{14}
10	0_8	0_9	0_{11}	0_{10}

$G_1 = \bar{F_A} \bar{F_B} X Y + \bar{F_A} \bar{F_B} X \bar{Y} = \bar{F_A} \bar{F_B} X$

$G_2 = F_A F_B \bar{X} \bar{Y} + F_A F_B \bar{X} Y = F_A F_B \bar{X}$

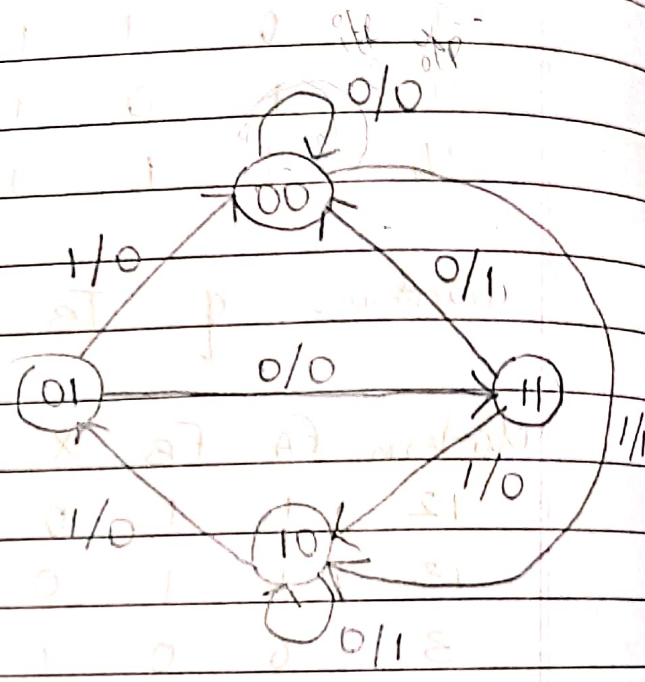
$T_B = \bar{F_A} \bar{F_B} X + F_A F_B \bar{X}$

F_AF_B \ XY	00	01	11	10
00	0_0	0_1	0_3	0_2
01	0_4	0_5	0_7	0_6
11	0_{12}	0_{13}	0_{15}	0_{14}
10	0_8	0_9	$\boxed{1}_{11}$	0_{10}

$Z = F_A \overline{F_B} X Y$

1) (a) D - flipflops

D	Present Q_t	Next Q_{t+1}
0	0	0
1	0	1
0	1	0
1	1	1



Present state		0 0		Z	0 1		Z	1 1		Z	1 0		Z
F_A	F_B	D_A	D_B		D_A	D_B		D_A	D_B		D_A	D_B	
0	0	0	0	0	0	0	0	1	0	0	1	0	0
0	1	1	1	0	1	1	0	0	0	0	0	0	0
1	1	0	0	0	0	0	0	1	0	0	1	0	0
1	0	1	0	0	1	0	0	0	1	0	0	1	0

S R F/F:

NS xy/z

PS		0 0		z	0 1		z	1 1		z	1 0		z
F_A	F_B	S_AR_A	S_BR_B		S_AR_A	S_BR_B		S_AR_A	S_BR_B		S_AR_A	S_BR_B	
0	0	0d	0d	0	0d	0d	0	0d	10	0	0d	10	0
0	1	0d	d0	0	10	d0	0	10	d0	0	0d	d0	0
1	1	01	01	0	d0	01	0	d0	d0	0	01	d0	0
1	0	01	0d	0	d0	0d	0	01	0d	1	d0	0d	0

Input		PS	NS
S	R	Q_t	Q_{t+1}
0	d	0	0
1	0	0	1
0	1	1	0
d	0	1	1

PS		I/P		NS		F/F i/p's	
A	B	x	y	A^+	B^+	S_AR_A	S_BR_B
0	0	0	0	0	0	0 d	0 d
0	0	0	1	0	0	0 d	0 d
0	0	1	1	0	1	0 d	1 0
0	0	1	0	0	1	0 d	1 0
0	1	0	0	0	1	0 d	d 0
0	1	0	1	1	1	1 0	d 0
0	1	1	1	1	1	1 0	d 0
0	1	1	0	0	1	0 d	d 0
1	1	0	0	0	0	0 1	0 1
1	1	0	1	1	0	d 0	0 1
1	1	1	1	1	1	d 0	d 0
1	1	1	0	0	1	0 1	d 0
1	0	0	0	0	0	0 1	0 d
1	0	0	1	1	0	d 0	0 d
1	0	1	1	0	0	0 1	0 d
1	0	1	0	1	0	d 0	0 d

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$S_A = f(F_A, F_B, x, y) = \Sigma(5,7) + \Sigma d(9,10,13,15)$

$R_A = f(F_A, F_B, x, y) = \Sigma(8,11,12,14) + \Sigma d(0,1,2,3,4,6)$

$S_B = \Sigma(2,3) + \cancel{\Sigma d(0,1,8,9,10,11)}\ \Sigma d(4,5,6,7,14,15)$

$R_B = \Sigma(12,13) + \Sigma d(0,1,8,9,10,11)$

S_A (F_AF_B \ xy)

F_AF_B \ xy	00	01	11	10
00	0 (0)	0 (1)	0 (3)	0 (2)
01	0 (4)	1 (5)	1 (7)	0 (6)
11	0 (12)	X (13)	X (15)	0 (14)
10	0 (8)	X (9)	0 (11)	X (10)

$G_1 = \bar{F_A}F_B\bar{x}y + \bar{F_A}F_Bxy + F_AF_B\bar{x}y + F_AF_Bxy$

$= \bar{F_A}F_By + F_AF_By$

$S_A = F_By$

R_A

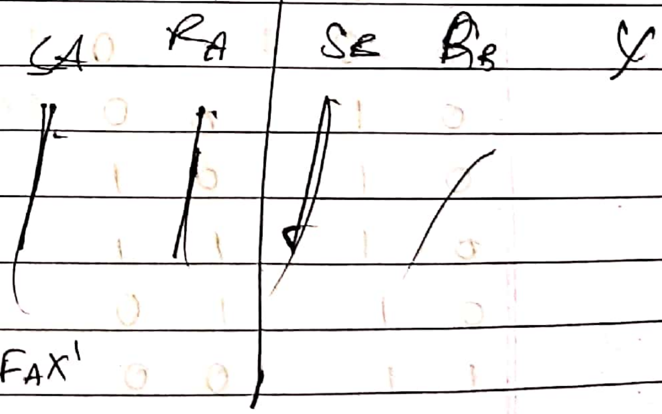
F_AF_B \ xy	00	01	11	10
00	X	X	X	X
01	X	0	0	X
11	1	0	0	1
10	1	0	1	0

$R_A = F_B'xy + x'y' + F_By'$

S_B

F_AF_B \ xy	00	01	11	10
00	0	0	1	1
01	X	X	X	X
11	0	0	X	X
10	0	0	0	0

$S_B = F_A'x$



R_B

F_AF_B \ xy	00	01	11	10
00	X	X	0	0
01	0	0	0	0
11	1	1	0	0
10	X	X	X	X

$R_B = F_Ax'$

$Z = F_A\bar{F_B}xy$

JK F/F:-

4, 12, 13, 12, 13

PS		0 0		Z	0 1		Z	1 1		Z	1 0		Z
F_A	F_B	J_AK_A	J_BK_B		J_AK_A	J_BK_B		J_AK_A	J_BK_B		J_AK_A	J_BK_B	
0	0	0 d	0 d	0	0 d	0 d	0	0 d	1 d	0	0 d	1 d	0
0	1	0 d	d 0	0	1 d	d 0	0	1 d	d 0	0	0 d	d 0	0
1	1	d 1	d 1	0	d 0	d 1	0	d 0	d 0	0	d 1	d 0	0
1	0	d 1	0 d	0	d 0	0 d	0	d 1	0 d	1	d 0	0 d	0

8, 1, 9, 3, 11, 2, 10

i/p			
J	K	Q_t	Q_{t+1}
0	d	0	0
1	d	0	1
d	1	1	0
d	0	1	1

A	B	X	Y	A^+	B^+	J_AK_A	J_BK_B
0	0	0	0	0	0	0 d	0 d
0	0	0	1	0	0	0 d	0 d
0	0	1	1	0	1	0 d	1 d
0	0	1	0	0	1	0 d	1 d
0	1	0	0	0	1	0 d	d 0
0	1	0	1	1	1	1 d	d 0
0	1	1	1	1	1	1 d	d 0
0	1	1	0	0	1	0 d	d 0
1	1	0	0	0	0	d 1	d 1
1	1	0	1	1	0	d 0	d 1
1	1	1	1	1	1	d 0	d 0
1	1	1	0	0	1	d 1	d 0
1	0	0	0	0	0	d 1	0 d
1	0	0	1	1	0	d 0	0 d
1	0	1	1	1	1	d 1	0 d
1	0	1	0	0	1	d 0	0 d

$J_A = \Sigma(5, 7) + \Sigma d(8, 9, 10, 11, 12, 13, 14, 15)$

$K_A = \Sigma(8, \overset{13}{11}, 12, 14) + \Sigma d(0, 1, 2, 3, 4, 5, 6, 7)$

$J_B = \Sigma(2, 3) + \Sigma d(4, 5, 6, 7, 12, 13, 14, 15)$

$K_B = \Sigma(12, 13) + \Sigma d(0, 1, 2, 3, 8, 9, 10, 11)$

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J_A

$F_A F_B$ \ XY	00	01	11	10
00	0	0	0	0
01	0	1	1	0
11	X	X	X	X
10	X	X	X	X

$J_A = F_B Y$

K_A

$F_A F_B$ \ XY	00	01	11	10
00	X	X	X	X
01	X	X	X	X
11	1	0	0	1
10	1	0	1	0

$K_A = \bar{X}\bar{Y} + \cancel{\bar{F}_B X \bar{Y} + \bar{F}_A F_B \bar{X}} + F_B \bar{Y} + \bar{F}_B X Y$

J_B

$F_A F_B$ \ XY	00	01	11	10
00	0	0	1	1
01	X	X	X	X
11	X	X	X	X
10	0	0	0	0

$J_B = \bar{F}_A X$

K_B

$F_A F_B$ \ XY	00	01	11	10
00	X	X	X	X
01	0	0	0	0
11	1	1	0	0
10	X	X	X	X

$K_B = F_A \bar{X}$

$Z = F_A F_B X Y$

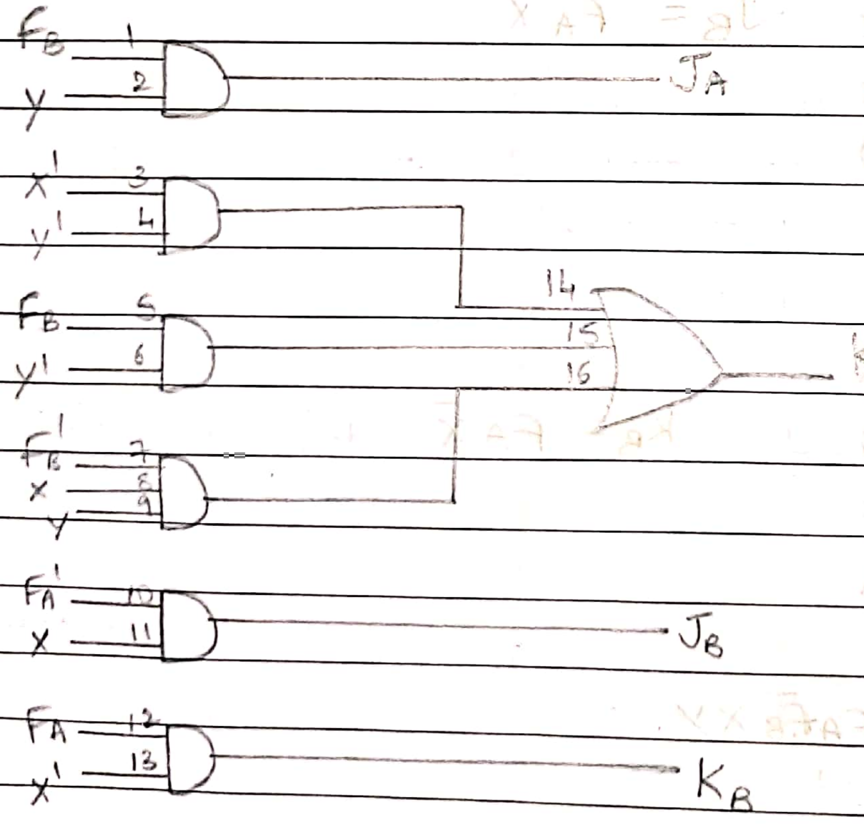
Excitation realization cost:

Comparing the excitation eq^s for all four F/F types gives us some inside into the relative complexity of the logic necessary to implement state machine M1. The actual logic realization wrt JK realization will be simpler.

An SR realization of a state machine is not as ~~samp~~ simple as JK coz of the two missing don't care entrys in the SR excitation table.

Even though the JK uses 2 inputs instead of 1 needed by D & T realization is usually simpler ~~than~~ coz of don't care terms.

JK F/F:



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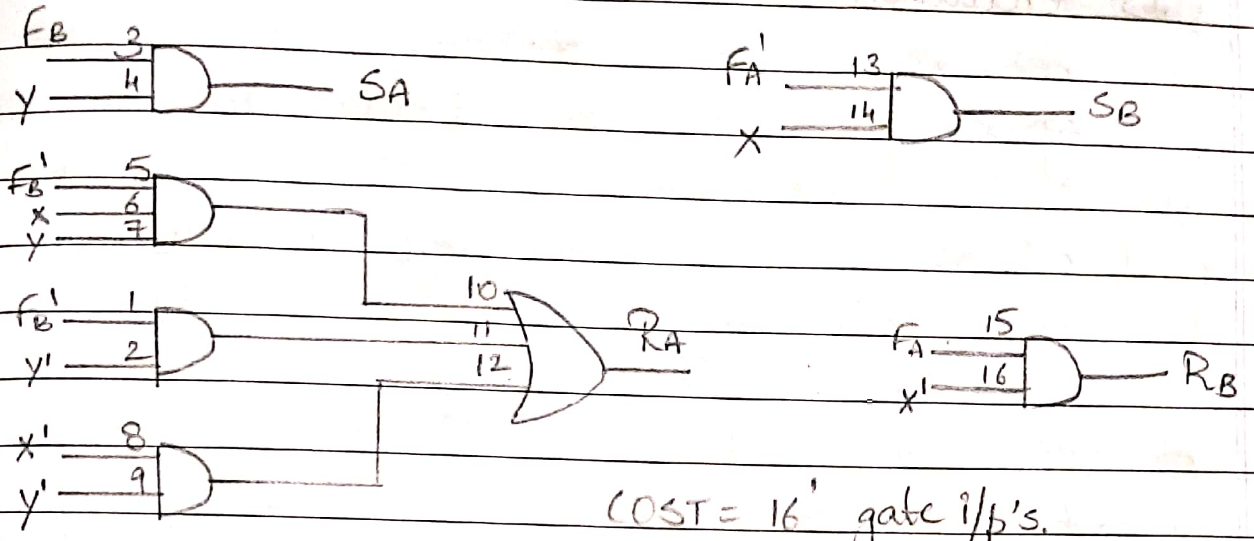
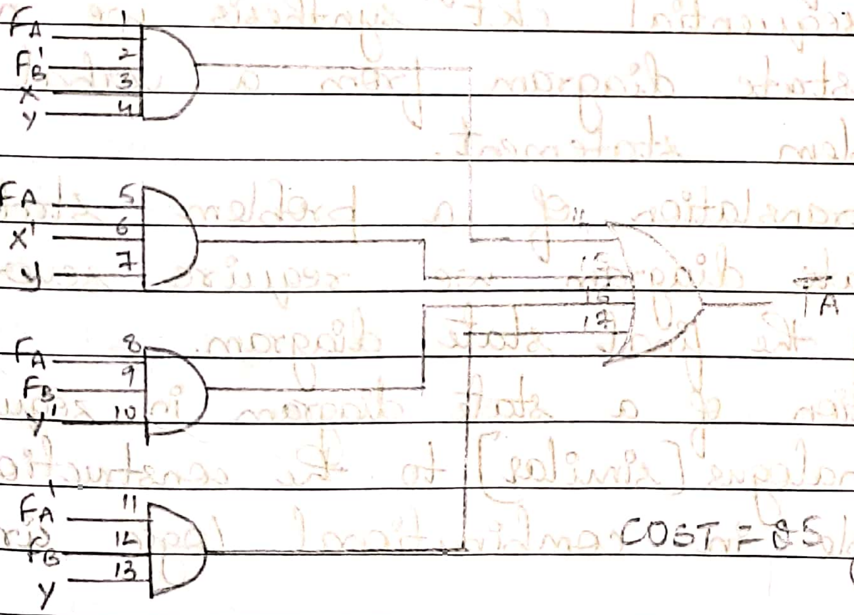
SR F/F:

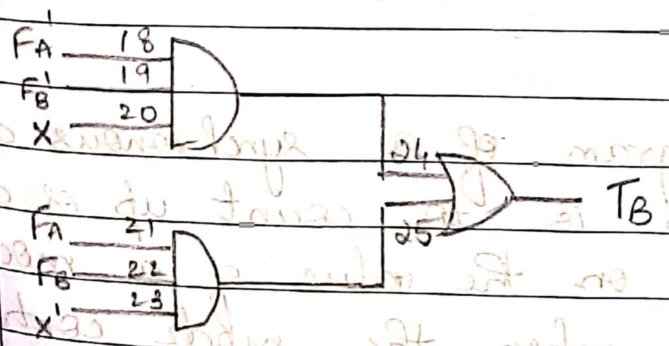


COST = 16 gate i/p's.

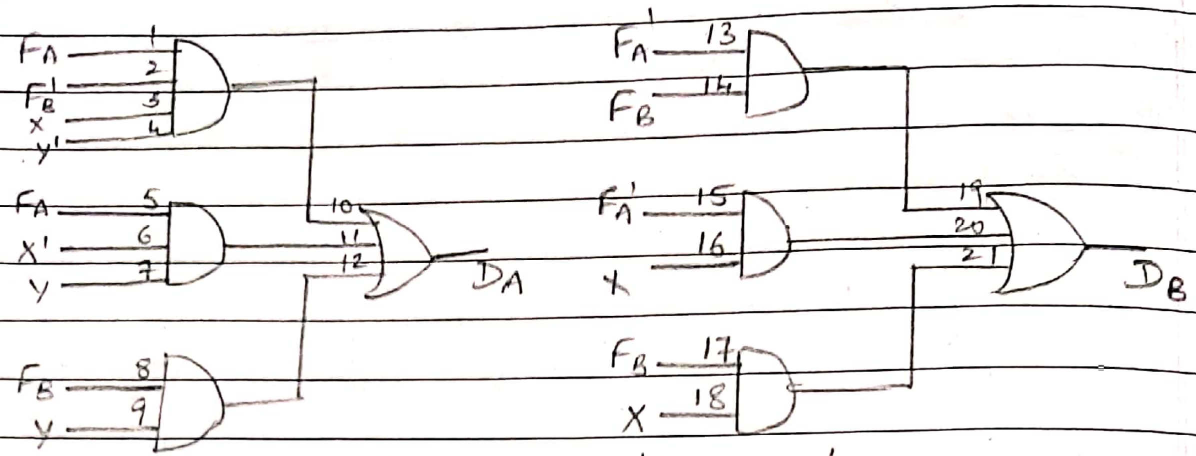
T- excitation (a) for Ta:



COST = 25 gate i/p's.



D- excitation:



cost = 21 gate inputs.

Construction of state diagrams:-

In sequential ckt synthesis we need to develop a state diagram from a verbal or written problem statement.

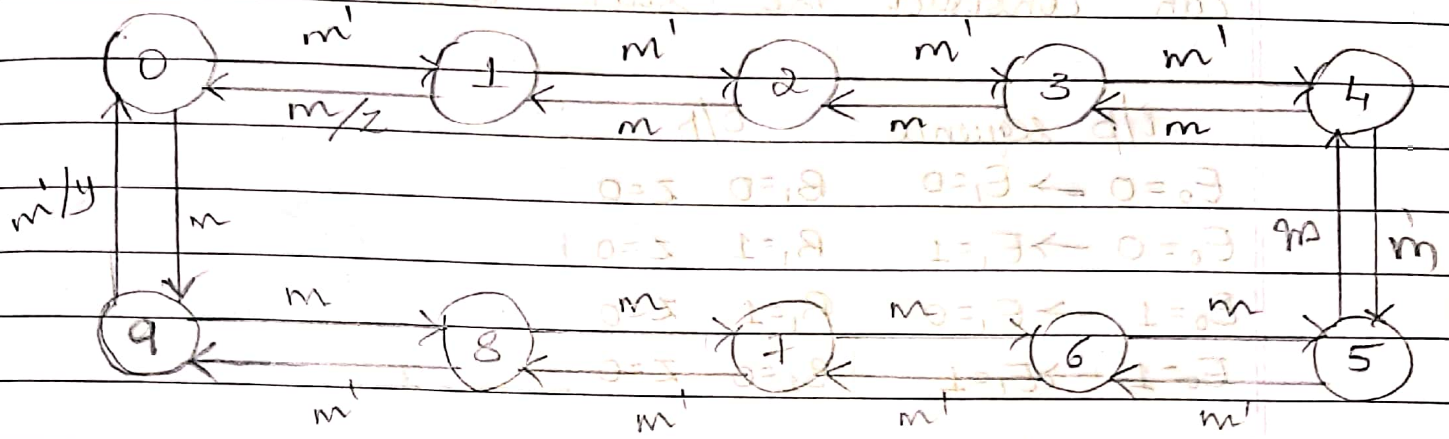
The translation of a problem statement into a state diagram we require several steps before writting the final state diagram.

Construction of a state diagram in sequential design is analogus [similar] to the construction of a truth table in combinational logic circuit.

Problem:-

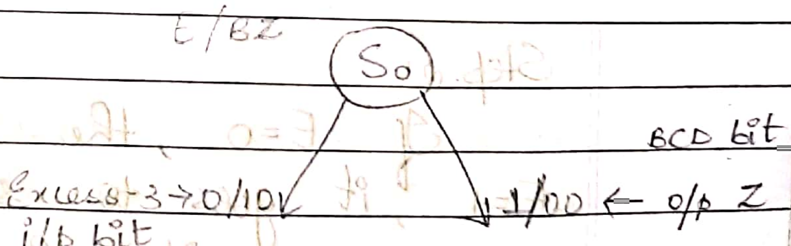
1) Create a state diagram of a synchronous decade counter. The counter is to count up or down in binary depending on the value of a mode control i/p signal, when the mode control i/p M=0, the counter is to count up. When M=1, the counter is to count down. The counter is to repeat a cycle to count from 0 to 9. & then start over if M=0 or count down

from 9 to 0 if M=1. The counter o/p y is to be 1 if counting up & the terminal count is reached, when y goes to ck. Another o/p Z is said to be 1 at the terminal count if counting down.



2) Construct a state diagram for the sequential ckt that will convert a serial excess 3 code into BCD code & it has to ~~written~~ return to the begining after 4 bits. Output Z should be high for any non-excess 3 input code.

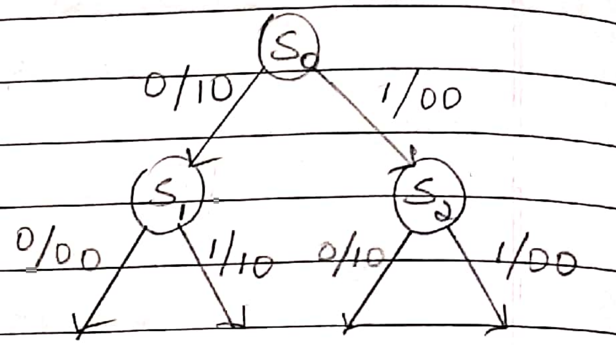
i/p				o/p			
E_3 (8)	E_2 (4)	E_1 (2)	E_0 (1)	B_3	B_2	B_1	B_0
0	0	1	1	0	0	0	0
0	1	0	0	0	0	0	1
0	1	0	1	0	0	1	0
0	1	1	0	0	0	1	1
0	1	1	1	0	1	0	0
1	0	0	0	0	1	0	1
1	0	0	1	0	1	1	0
1	0	1	0	0	1	1	1
1	0	1	1	1	0	0	0
1	1	0	0	1	0	0	1



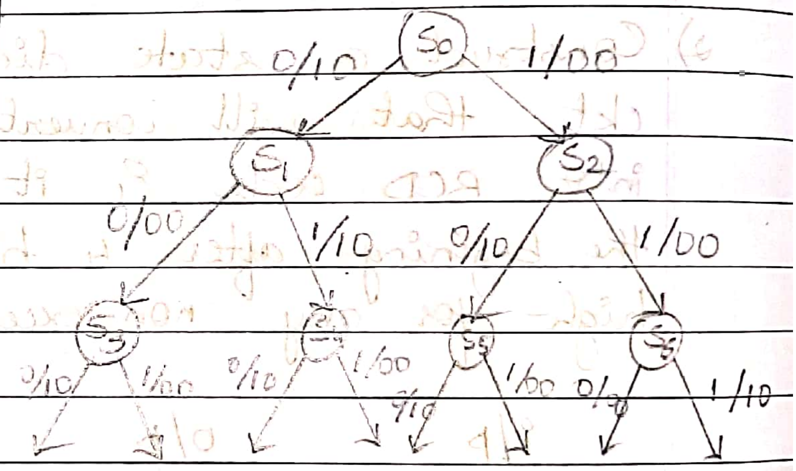
Step 1:

The initial state is S_0. Consider the first excess-3 serial bit. from the table we see that if the LSB of the excess-3 code is 1 then the LSB of the BCD code is 0. So with this we can construct the state table as above.

i/p sequence	o/p	
$E_0 = 0 \rightarrow E_1 = 0$	$B_1 = 0$	$Z = 0$
$E_0 = 0 \rightarrow E_1 = 1$	$B_1 = 1$	$Z = 0$
$E_0 = 1 \rightarrow E_1 = 0$	$B_1 = 1$	$Z = 0$
$E_0 = 1 \rightarrow E_1 = 1$	$B_1 = 0$	$Z = 0$



	i/p	o/p	
$E_0 = 0$	$E_1 = 0 \rightarrow E_2 = 0$	$B_2 = 1$	$Z = 0$
$E_0 = 0$	$E_1 = 0 \rightarrow E_2 = 1$	$B_2 = 0$	$Z = 0$
$E_0 = 0$	$E_1 = \cancel{0}1 \rightarrow E_2 = 0$	$B_2 = 1$	$Z = 0$
$E_0 = 0$	$E_1 = 1 \rightarrow E_2 = 1$	$B_2 = 0$	$Z = 0$
$E_0 = 1$	$E_1 = 0 \rightarrow E_2 = 0$	$B_2 = \cancel{0}1$	$Z = 0$
$E_0 = 1$	$E_1 = 0 \rightarrow E_2 = 1$	$B_2 = 0$	$Z = 0$
$E_0 = 1$	$E_1 = 1 \rightarrow E_2 = 0$	$B_2 = 0$	$Z = 0$
$E_0 = 1$	$E_1 = 1 \rightarrow E_2 = 1$	$B_2 = 1$	$Z = 0$



Step 2:

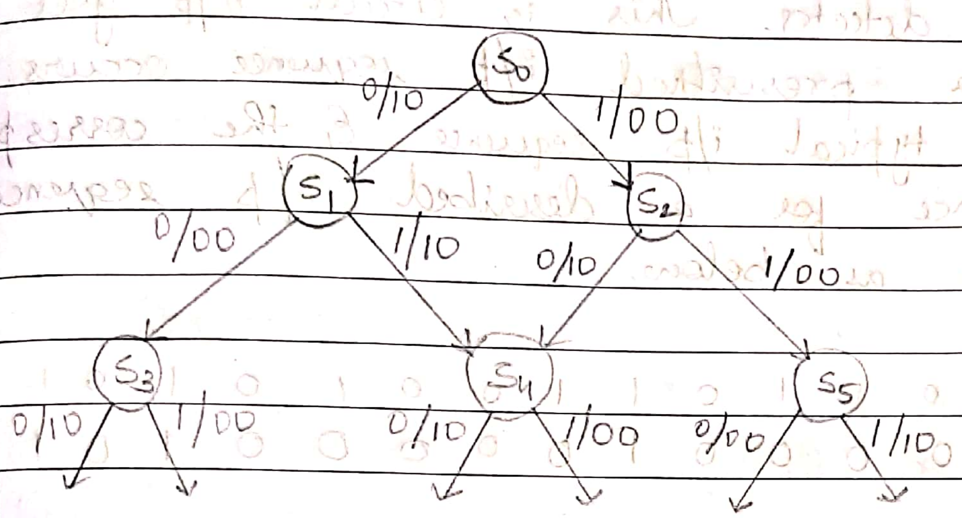
If $E = 0$, the system goes to state S_1, if $E = 1$, it goes to state S_2. Refering the table we can write the state table as above.

Step 3:

A new state is needed for each transition path. The o/p from ~~eq~~ each new state indicate that 3 i/p's are made $[E_0, E_1, E_2]$, E_i refer the state diagram.

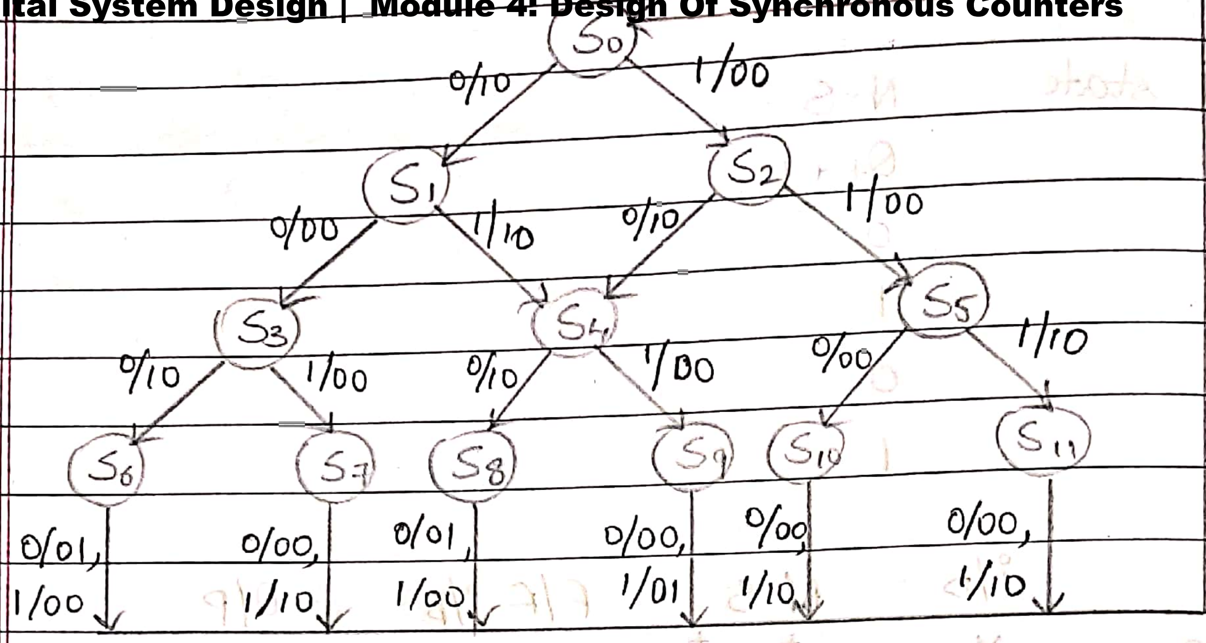
Step 4:

Let us observe that S_4 & S_5, we see that the o/p's for S_4 & S_5 are identical for i/p equal to zero as well as for the i/p equal to 1. This means that the two states S_4 & S_5 are redundant & it can be combined as shown below.

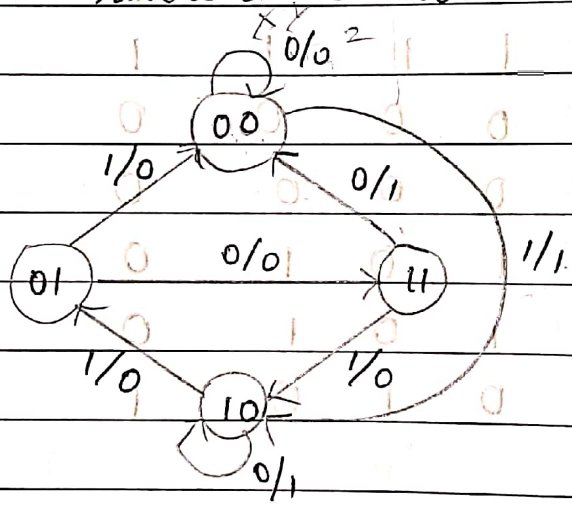


Step 5: States S_3, S_4 & S_5 each have two transition paths

I/P sequence	O/P		
$E_0=0 \to E_1=0 \to E_2=0 \to E_3=0$	$B_3=0$	$Z=1$	
$E_0=0 \to E_1=0 \to E_2=0 \to E_3=1$	$B_3=0$	$Z=0$	
$E_0=0 \to E_1=0 \to E_2=1 \to E_3=0$	$B_3=0$	$Z=0$	
$E_0=0 \to E_1=0 \to E_2=1 \to E_3=1$	$B_3=1$	$Z=0$	
$E_0=0 \to E_1=1 \to E_2=0 \to E_3=0$	$B_3=0$	$Z=1$	
$E_0=0 \to E_1=1 \to E_2=0 \to E_3=1$	$B_3=0$	$Z=0$	
$E_0=0 \to E_1=1 \to E_2=1 \to E_3=0$	$B_3=0$	$Z=0$	
$E_0=0 \to E_1=1 \to E_2=1 \to E_3=1$	$B_3=0$	$Z=1$	
$E_0=1 \to E_1=0 \to E_2=0 \to E_3=0$	$B_3=0$	$Z=1$	
$E_0=1 \to E_1=0 \to E_2=0 \to E_3=1$	$B_3=0$	$Z=0$	
$E_0=1 \to E_1=0 \to E_2=1 \to E_3=0$	$B_3=0$	$Z=0$	
$E_0=1 \to E_1=0 \to E_2=1 \to E_3=1$	$B_3=0$	$Z=1$	
$E_0=1 \to E_1=1 \to E_2=0 \to E_3=0$	$B_3=0$	$Z=0$	
$E_0=1 \to E_1=1 \to E_2=0 \to E_3=1$	$B_3=1$	$Z=0$	Continued in last page.
$E_0=1 \to E_1=1 \to E_2=1 \to E_3 0$	$B_3=0$	$Z=0$	
$E_0=1 \to E_1=1 \to E_2=1 \to E_3 1$	$B_3=0$	$Z=1$	



1) A sequential ckt has 1 i/p & 1 o/p. State diagram is shown below.



Present state		N.S				O/P	
		x=0		x=1		x=0	x=1
A	B	A^+	B^+	A^+	B^+	y	y
0	0	0	0	1	0	0	1
0	1	1	1	0	0	0	0
1	0	1	0	0	1	1	0
1	1	0	0	1	0	1	0

Now using flip/flops:

D – flip flop:

D	Present state Q_t	N.S Q_{t+1}
0	0	0
1	0	1
0	1	0
1	1	1

P.S A	P.S B	i/p X	N.S A^+	N.S B^+	F/F i/p D_A	F/F i/p D_B	O/P y
0	0	0	0	0	0	0	0
0	0	1	1	0	1	0	1
0	1	0	1	1	1	1	0
0	1	1	0	0	0	0	0
1	1	0	0	0	0	0	1
1	1	1	1	0	1	0	0
1	0	0	1	0	1	0	1
1	0	1	0	1	0	1	0

$D_A =$

X \ AB	00	01	11	10
0	0	1	0	1
1	1	0	1	0

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

$D_B =$

X \ AB	00	01	11	10
0	0	0	0	1
1	0	1	1	0

$\cancel{D_B = A\bar{B}\bar{X}} + (ABX$ $\quad D_B = A\bar{B}\bar{X} + \bar{A}BX$

$y =$

X \ AB	00	01	11	10
0	0	1	0	0
1	1	0	0	1

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

$(0.1s+1)+1(0.1s+1)$

$0.002s^2+0.1s+0.02s+1$ $\qquad$ $0.002s^2+0.02s+0.1s+1$

$0.002s^2+0.12s+1$ $\qquad$ $0.002s^2+0.12s+1$

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T- flipflop

$(0.02s+1)(0.1s+1)+1(0.1s+1)$

$0.002s^2+0.02s+0.1s+1$

$0.002s^2+0.12s+1$

PS $Q(t)$	i/p F/F $T(t)$	N.S $Q(t+1)$
0	0	0
0	1	1
1	0	1
1	1	0

P.S

A	B	0 0 Z T_A T_B i/p	NS A^+	B^+	T_A	T_B	y
0	0	0	0	0	0	0	0
0	0	1	1	0	1	0	1
0	1	0	1	1	1	0	0
0	1	1	0	0	0	1	0
1	0	0	1	0	0	0	1
1	0	1	0	1	1	1	0
1	1	0	0	0	1	1	1
1	1	1	1	0	0	1	0

~~PS i/p NS F/F i/p's o/p~~

~~A B X Y A^+ B^+ T_A T_B Z~~

~~0 0~~

~~0 0~~

T_A

	00	01	11	10
0	0_0	1_1	0_3	1_2
1	0_4	1_5	0_7	1_6

$T_A = \bar{A}B + A\bar{B}$

T_B

X \ AB	00	01	11	10
0	0_0	0_1	1_3	0_2
1	0_4	1_5	1_7	1_6

$T_B = \cancel{\bar{A}B} + XB + XA + AB$

SR F/F:-

i/p S	R	Q_t	Q_{t+1}
0	d	0	0
1	0	0	1
0	1	1	0
d	0	1	1

A	B	i/p X	N-S A^+	B^+	S_A	R_A	S_B	R_B	y
0	0	0	0	0	0	d	0	d	0
0	0	1	1	0	1	0	0	d	1
0	1	0	1	1	1	0	d	0	0
0	1	1	0	0	0	d	0	1	0
1	0	0	1	0	d	0	0	d	1
1	0	1	0	1	0	1	1	0	0
1	1	0	0	0	0	1	0	1	1
1	1	1	1	0	d	0	0	1	0

S_A =

X \ AB	00	01	11	10
0	0	1	0	1
1	X	0	X	0

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

R_A

X \ AB	00	01	11	10
0	X	0	X	0
1	0	1	0	1

$R_A = \bar{A}BX + A\bar{B}X$

S_B

X \ AB	00	01	11	10
0	0	0	0	X
1	0	1	0	0

$S_B = \bar{A}BX$

R_B

X \ AB	00	01	11	10
0	X	X	1	0
1	X	0	1	1

y

X \ AB	00	01	11	10
0	0	1	0	0
1	1	0	0	1

JK F/F:-

J	K	Q_t	Q_{t+1}
0	d	0	0
1	d	0	1
d	1	1	0
d	0	1	1

A	B	X (i/p)	A^+	B^+	J_A	K_A	J_B	K_B	y
0	0	0	0	0	0	d	0	d	0
0	0	1	1	0	1	d	0	d	1
0	1	0	1	1	1	d	d	0	0
0	1	1	0	0	0	d	d	1	0
1	0	0	1	0	d	0	0	d	1
1	0	1	0	1	d	1	1	d	0
1	1	0	0	0	d	1	d	1	1
1	1	1	1	0	d	0	d	1	0