Analysis of clocked sequential circuits:-

The behavior of sequential circuit is determine from the inputs, the outputs, and the state of its flip-flops. The analysis of a sequential circuit consists of obtaining a table or diagram from the time sequence of inputs, outputs, and internal states. It is also possible to write Boolean expression that describe the behavior of sequential circuit.

State table:- The time sequence of inputs, outputs and flip-flops states may be enumerated in (state table).

State table consist of:-

1- present state:- The states of flip-flops befor the occurence of a clock pulse (P.S)

2- Next state:- The states of flip-flops afthe the application of a clock pulse. (N.S)

3- Output:- The output lists the value of output variables during the present state (P.S)

In general; a sequential circuit with (m) flip-flops and (n) inputs variables will have (2^m) rows, one for each state. The next state and output sections each will have (2^n) columns, one for each input combination.

State diagram:- The information available in a state table may be represented graphically in (state diagram) as shown:-

1- A state is represented by a (circle).

2- Transition between states is indicated by directed lines connecting the circle.

3- Binary number inside each circle identifies the state of each circle

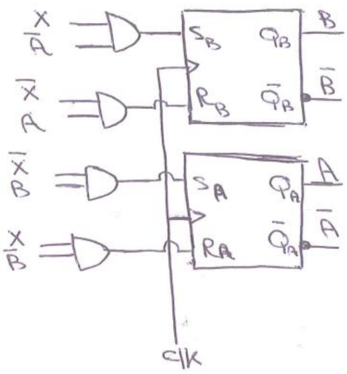
4- Directed lines are labled with two binary numbers seperated by a (/). The input value that causes the state transition is labled first; the number after the symbol (/) gives the value of the output during the present state. [input/output]

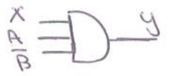
State equations:- It is an algebric expression that specifies the conditions for a flip-flops state table.

Note:- * The characteristic table is useful for analysis and for defining the operation of flip-flop. It is specifies the next state Q_{n+1} when the present states Q_n and inputs are known.

* During the design process, we usually know the transition from present to next state and we wish to find the flip-flop input conditions that cause the required transition. For this reason we will use the excitation table.

Example:- An Example of a clocked sequential circuit is shown below, it has one input variable X, one output variable y, and two RS Flip-Flops Labled A and B.





note:- Analysis the circuit mean find ① state table. ② state equation. ③ state diagram.

Solution:-

present state		Next state X=0		Next state X=1		output X=0	output X=1
A_n	B_n	A_{n+1}	B_{n+1}	A_{n+1}	B_{n+1}	y	y
0	0	0	0	0	1	0	0
0	1	1	1	0	1	0	0
1	0	1	0	0	0	0	1
1	1	1	0	1	1	0	0

- State table -

$y = A_n \bar{B}_n X$ output Equation.

for SR flip-flop the c/cs equation (Q_{n+1}) is:-

$Q_{n+1} = S + \bar{R} Q_n$

$\boxed{S_A = B_n \bar{X} \quad R_A = \bar{B}_n X}$ ← from block diagram

$A_{n+1} = S_A + \bar{R}_A A_n$

$= (B_n \bar{X}) + \overline{(\bar{B}_n X)} \cdot A_n$

$= B_n \bar{X} + (B_n + \bar{X}) \cdot A_n$

$B_{n+1} = S_B + \bar{R}_B B_n$

$\boxed{S_B = \bar{A}_n X \quad R_B = A_n \bar{X}}$ ← from block diagram

$= \bar{A}_n X + \overline{(A_n \bar{X})} B_n$

$= \bar{A}_n X + (\bar{A}_n + X) B_n$

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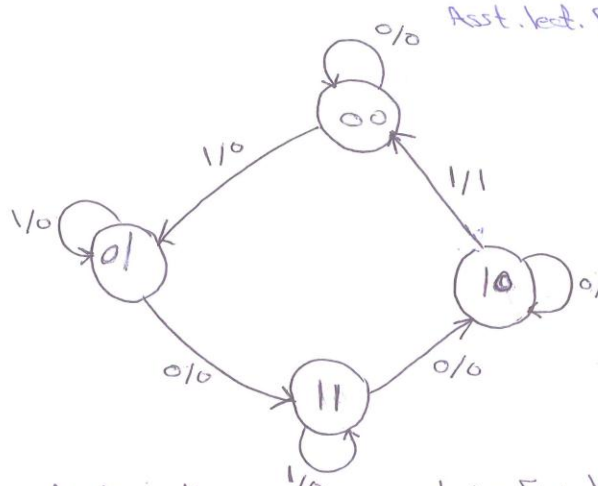
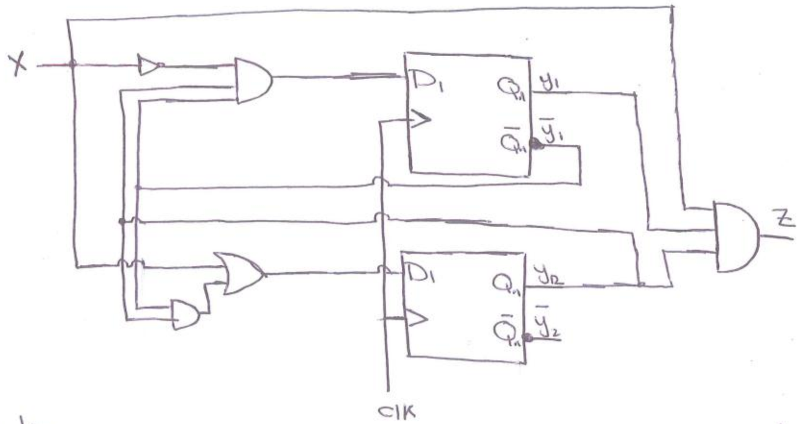


| State diagram |

Example:- Analysis the synch. circuit in Fig. below:-



Solution:-

present state		next state X=0		next state X=1		output X=0	output X=1
y_n1	y_n2	y^1_{n+1}	y^2_{n+1}	y^1_{n+1}	y^2_{n+1}	Z	Z
0	0	0	0	0	1	0	0
0	1	1	1	0	1	0	0
1	0	0	0	0	1	0	0
1	1	0	0	0	1	0	1

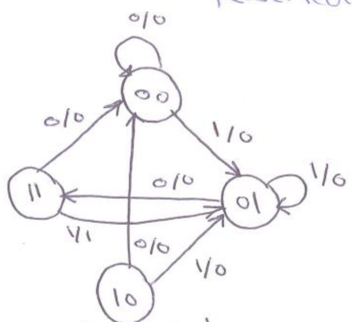
For D flip-flop the c/cs equitison (Q_{n+1}) is:-

$Q_{n+1} = D$ $\quad\quad$ $Z = X y_1 y_2 \leftarrow$ o/p equation

$y_1 n+1 = D_1$ $\quad\quad$ $D_1 = \bar{y}_1 y_2 \bar{X}$

$y_2 n+1 = D_2$ $\quad\quad$ $D_2 = X + \bar{y}_1 y_2$

} from block diagram

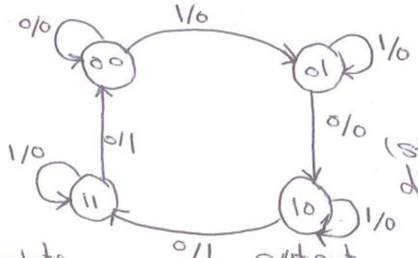


(State diagram)

Example:- A synch. sequential cct. having one external input X with one output Z has the following state diagram. Find:-

1- The state table.

2- The circuit diagram.



(state diagram)

Solution:-

present state		Next state X=0		Next state X=1		output X=0	output X=1
A_n	B_n	A_{n+1}	B_{n+1}	A_{n+1}	B_{n+1}	Z	Z
0	0	0	0	0	1	0	0
0	1	1	0	0	1	0	0
1	0	1	1	1	0	1	0
1	1	0	0	1	1	1	0

(State table)

For SR-flip flop the c/cs equations Q_{n+1} is:-

$$Q_{n+1} = S_n + \overline{R}_n Q_n$$

X \ A_nB_n	$\overline{A}_n\overline{B}_n$	$\overline{A}_nB_n$	A_nB_n	$A_n\overline{B}_n$
$\overline{X}$	0	1	0	1
X	0	0	1	1

Note:-

$A_{n+1} = S_A + \overline{R}_A A_n$

$B_{n+1} = S_B + \overline{R}_B B_n$

$$A_{n+1} = \overline{A}_n B_n \overline{X} + A_n \overline{B}_n + A_n X$$

$$A_{n+1} = \overline{A}_n B_n \overline{X} + (\overline{B}_n + X) A_n$$

$$S_A = \overline{A}_n B_n \overline{X} \;;\; \overline{R}_A = (\overline{B}_n + X) \Rightarrow R_A = \overline{(\overline{B}_n + X)} = B_n \overline{X}$$

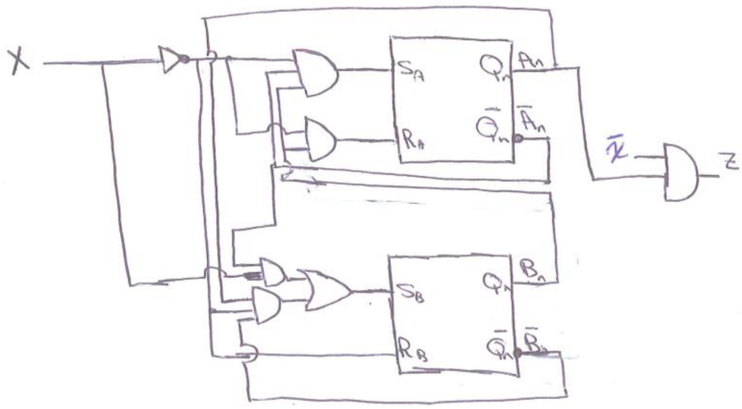
A_nB_n / X	$\bar{A}_n\bar{B}_n$	$\bar{A}_nB_n$	A_nB_n	$A_n\bar{B}_n$
$\bar{X}$	0	0	0	1
X	1	1	1	0

$$B_{n+1} = A_n\bar{B}_n\bar{X} + \bar{A}_nX + B_nX$$

$$S_B = A_n\bar{B}_n\bar{X} + \bar{A}_nX \quad ; \quad \bar{R}_B = X \Rightarrow R_B = \bar{X}$$

A_nB_n / X	$\bar{A}_n\bar{B}_n$	$\bar{A}_nB_n$	A_nB_n	$A_n\bar{B}_n$
$\bar{X}$	0	0	1	1
X	0	0	0	0

$$Z = A_n\bar{X}$$



Block diagram.

Example:-

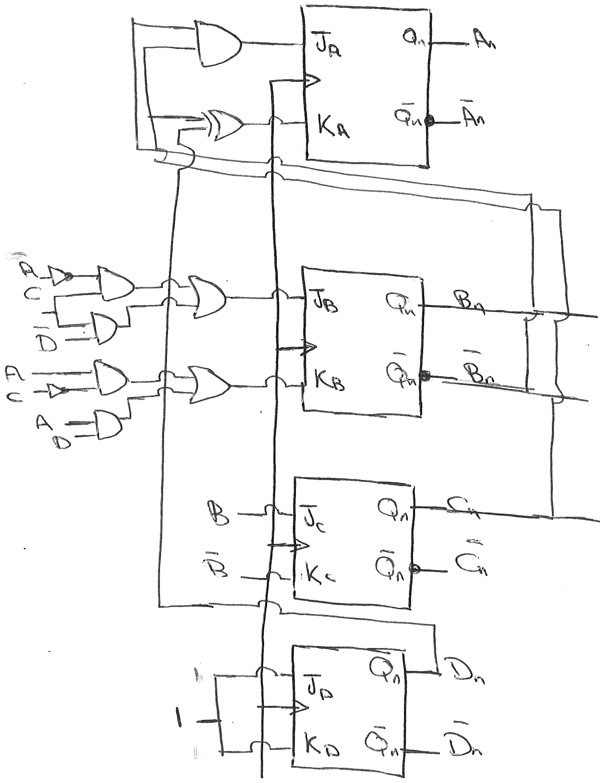
- Design a sequential circuit with J.K Flip-flop to satisfy the following state equations:-

$$A_{n+1} = \bar{A}\bar{B}CD + \bar{A}\bar{B}C + ACD + A\bar{C}\bar{D}$$

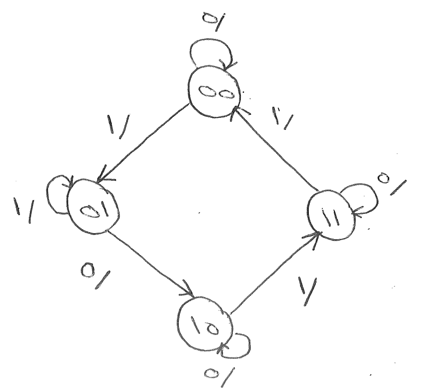
$$B_{n+1} = \bar{A}C + C\bar{D} + \bar{A}B\bar{C}$$

$$C_{n+1} = B$$

$$D_{n+1} = \bar{D}$$



Example:- A sequential circuit has the following state diagram, design the circuit using J-K flip-flop:-



(state diagram)