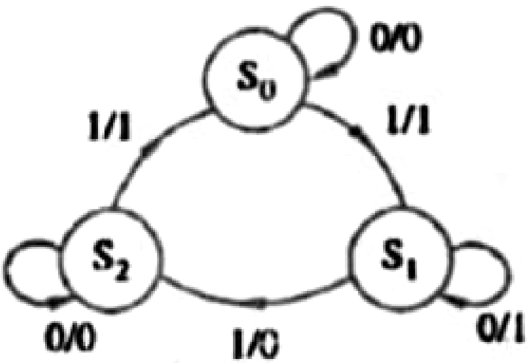
Unit - 5

1. Differentiate between combinational and sequential circuits.
2. Differentiate between Mealy and Moore FSM models.
3. Draw Mealy and Moore FSM models with example state diagram and state table.
4. List out basic design steps of Sequential circuits.
5. Differentiate between synchronous and A synchronous sequential circuits .
6. Implement Sequential circuit using a) D FF b) T FF and C) JK FF

	0	1
A	A/0	B/0
B	A/0	C/1
C	B/0	D/0
D	C/1	D/0

7. Describe Component of ASM and Explain Advantages of ASM
8. Draw ASM chart for the given FSM



Q7 **What are the differences between combinational and sequential circuits?**

Answer :

S.No.	Combinational Logic Circuits	Sequential Logic Circuits
(1)	Output depends only on the present input.	Output depends on the present input and past output also.
(2)	Easier to design.	Comparatively harder to design.
(3)	Speed of operation is high.	Speed of operation is comparatively low.
(4)	Memory unit is not require-ed.	Memory unit is required to store the pa-st outputs.
(5)	**Example :** Parallel adder	**Example :** Serial adder.

and level triggered?

Q1) List the comparison between Moore and Mealy model.

Answer :

S.No.	Moore Model	Mealy Model
(1)	Its output a is function of present state only.	Its output is a function of present state as well as past input.
(2)	Input changes does not affect the output.	Input changes may affect the output of the circuit.
(3)	Moore model requires more number of states for implementing same function.	It requires less number of states for implementing same function.

Q2) Describe about sequence detector.

Answer :

The "sequence detector" is a clocked sequential circuit or machine which is used to detect the des binary sequence. Once we know the sequence which is to be detected, we can draw the state diag for it. From the state diagram, we can design the circuit. Generally it produces an output = 1, when

A) The state diagrams & state tables described earlier are convenient for describing the behaviour

5.2 FINITE STATE MACHINE (FSM) REPRESENTATION USING MOORE AND MEALY STATE MODELS

Q14) Explain in detail about Mealy and Moore state machines.

Answer :

MOORE MACHINE

Definition : When the output of a sequential circuit depends only on the present state of the flip-flop, then it is referred as Moore circuit or Moore machine.

Block Diagram of Moore Machine : As shown in Figure 1 for a Moore circuits, the output changes are synchronized to the clock, since the output Y(t) is a function of the present state only and can therefore change only when the state changes consequently. The output remains stable during any input change as shown in Figure 2. The outputs of Moore model circuit typically exhibit better behaviour than those of Mealy circuits, i.e., input changes do not result in unwanted glitches.

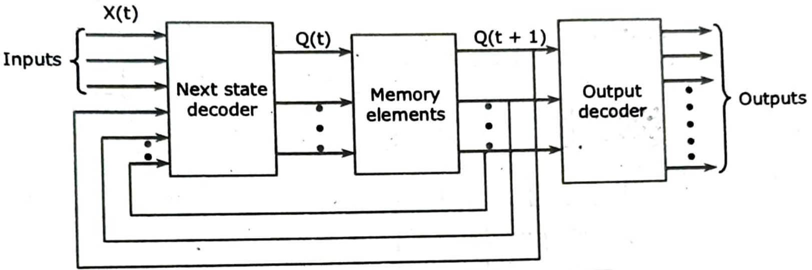


Figure 1 Block Diagram of Moore Machine

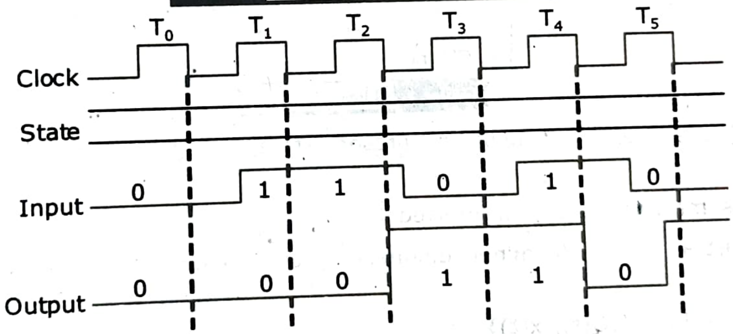


Figure 2 Timing Diagram

Moore machine can be mathematically expressed as,

(1) The next state is determined uniquely by the present state and present inputs. Thus,

$$Q(t + 1) = f\{Q(t), X(t)\}$$

(2) The output function, Y(t) is a function of only the present state and is independent of the external input.

$$Y(t) = g\{Q(t)\}$$

MEALY MACHINE

Definition : When the output of the sequential circuit depends on the present state of the flip-flop and on the inputs then the sequential circuit is referred as a Mealy circuit or Mealy machine.

Block Diagram of Mealy Machine : The Figure 3 shows the simple block diagram of a Mealy machine.

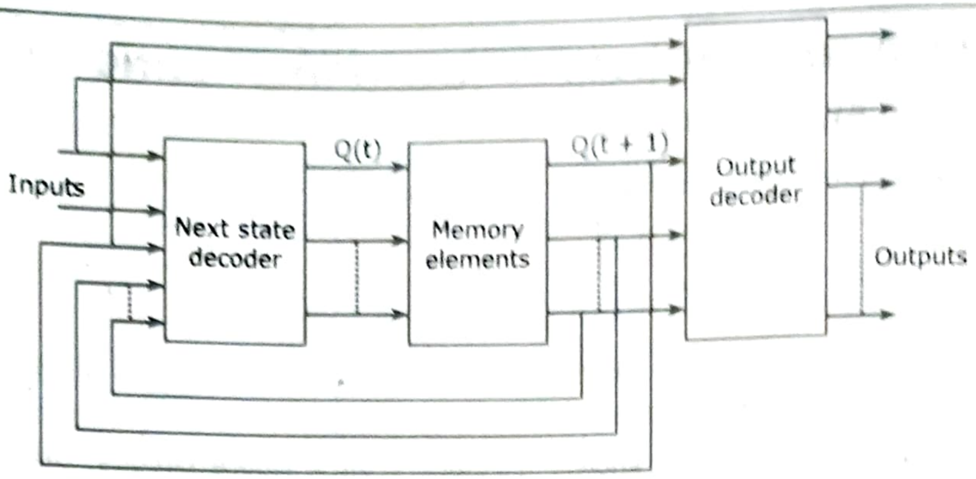


Figure 3 Block Diagram of Mealy Machine

The output Q(t) can change at any time i.e., either the input (or) state changes, since Q(t) is a function of both. This gives rise to Y(t) an unexpected output change at T_0 and T_3 as shown in Figure 4, unwanted glitches result.

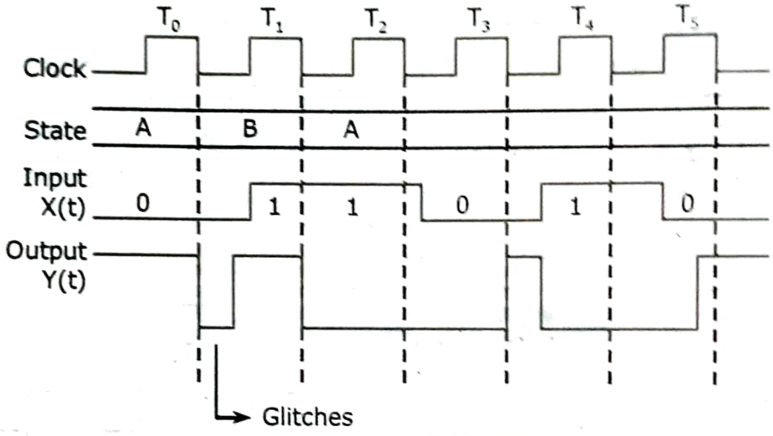


Figure 4 Timing Diagram

Since output Y(t) is a function of input and present state, so Y(t) changes with change in either input (or) present state.

Mealy machine is mathematically expressed as,

(1) The next state Q(t + 1) is determined uniquely by the present state Q(t) and present inputs x(t). Thus,

$$Q(t + 1) = f\{Q(t), x(t)\}$$

Where,

f = State transition function.

(2) The value of output function Y(t) is a function of present state Q(t) and input x(t).

$$\therefore \quad Y(t) = g\{Q(t), x(t)\}$$

Where,

g = Output function.

Q15) With neat sketches explain the representation of FSM using Moore and Mealy state models.

***Answer* :**

MEALY STATE OF FSM

When the outputs depend on the current inputs as well as states, then the FSM can be named to

PART - B

ESSAY QUESTIONS WITH ANSWERS

5.1 BASIC DESIGN STEPS

Q12) Explain the basic design steps for the analysis of synchronous sequantial circuit with an example.

Answer :

The analysis of sequential circuits is used to determine the next state and output functions so that the behaviour of the circuit can be predicted. Analysis provides tabular descriptions of sequential circuits. These are particularly useful when sequential circuits are to be designed.

The suggested analysis procedure of a sequential circuit is given below,

STEP I : Draw the given logic schematic diagram.

STEP II : Determine the excitation equations for the flip-flop control inputs, from the logic diagram.

STEP III : Substitute the excitation equations into flip-flop characteristics equations to get transition equations.

STEP IV : Use the transition equations to construct a transition table.

STEP V : Determine the output equations.

STEP VI : Add the output values to the transition table for each state (Moore model) or state/input combination (Mealy model) to create a transition/output table.

STEP VII : Name the states and substitute state names for state variable combinations in the transition/output table to get state/output table.

STEP VIII : Draw a state diagram corresponding to the state/output table.

Example : The analysis of the sequential circuits and the steps involved in it are explained through the following sequential circuit shown in Figure 1.

STEP I (Excitation and Output Expression) : As in case of combinational circuits, algebraic expressions can be used to express sequential circuits. In Figure 1, there are two D flip-flops and signals on their output has been named as Q_1 and Q_2. These two outputs are the state variables, their value is the current state of the circuit. The signals corresponding to D input have been named as D_1 and D_2. These signals provide the excitation for the D flip-flops on occurrence of the clock. Logic equations that express the excitation signals as functions of current state and input are called excitation equations and can be derived for the circuit corresponding in Figure 1 as,

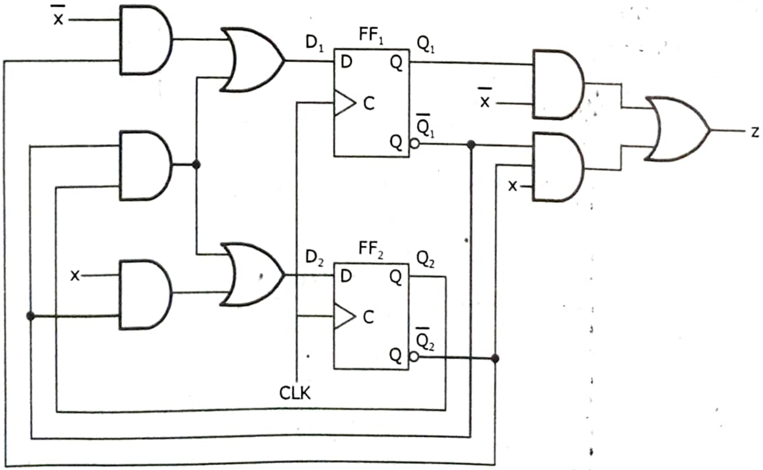


Figure 1 Example of a Mealy Model of Clocked Synchronous Sequential Circuit

$$D_1 = \bar{x}\bar{Q}_2 + \bar{Q}_1Q_2 \quad \ldots (1)$$

$$D_2 = x\bar{Q}_1 + \bar{Q}_1Q_2 \quad \ldots (2)$$

and the output expression is

$$z = \bar{x}Q_1 + x\bar{Q}_1\bar{Q}_2 \quad \ldots (3)$$

Step II (Transition Equations) : These are the equations which express the next value of the state variables as a function of current state and input. These are obtained by substituting the excitation expressions of a flip-flop into its characteristic equation. For example in Figure 1, the flip-flops used are D type. The characteristic equations are,

$$Q_1^+ = D_1$$

$$Q_2^+ = D_2$$

Substituting the excitation equations of D_1 and D_2 given by Eqs. (1) and (2), we get,

$$Q_2^+ = \bar{x}\bar{Q}_2 + \bar{Q}_1Q_2$$

$$Q_2^+ = \bar{x}\bar{Q}_1 + \bar{Q}_1Q_2$$

Step III (Transition Tables) : Transition table is the tabular representation of the transition and output equations. This table has three columns one each for present state variable, the next state variables and the output variables.

The present state section contains all the possible combinations of values for the state variables. Thus if there are p state variables, then this section contains 2^p rows. The next state section has one column for each combination of values of the external input variables. Hence if there are n external input variables, then this section consists of 2^n columns. The structure of third section of transition table depends upon whether the circuit is Mealy or Moore type. As the outputs for Mealy circuit are functions of both the present state and external inputs, output state section thus contains one column for each combination of values of input/present variables.

The transition tables for example in Figure 1 is shown in Table 1. In present state section, the four combinations of Q_1 and Q_2 are listed. As there is only one external input variable, there are two columns in next state section one for x = 0 and other for x = 1.

The entries within next state section correspond to Q_1^+ and Q_2^+ values for the various values of x_1, Q_1 and Q_2. These values are obtained by evaluating the Eqs. (1) and (2). The output section also has two columns to correspond to the two possible values of the input variable x. The entries for this section of table are obtained by evaluating Eq. (3), for all combinations of values of x, Q_1 and Q_2.

Table 1 Transition Table for Example in Figure 1

Present State (Q_1Q_2)	Next State $Q_1^+Q_2^+$		Output Z	
	Input (x)		Input (x)	
	0	1	0	1
00	10	01	0	1
01	11	11	0	0
10	10	00	1	0
11	00	00	1	0

Step IV (Excitation Table) : The excitation table shows the flip-flop excitation input values required to make the machine go to next state, for each combination of coded state and input.

This structure and content of this table depends on the type of flip-flops used. The excitation table consists of three sections, the present state, excitation and output sections. The present state and output section are obtained as discussed for transition table. However the excitation section is obtained by evaluating excitation expression.

The excitation table for example in Figure 1 is shown in Table 2 and is obtained by evaluation of excitation equations for D_1 and D_2 given by Eqs. (1) and (2).

Table 2 Excitation Table for Example in figure

Present State (Q_1Q_2)	Excitation (D_1D_2)		Output (z)	
	Input (x)		Input (x)	
	0	1	0	1
00	10	01	0	1
01	11	11	0	0
10	10	00	1	0
11	00	00	1	0

Step V (State Table) : The state table indicates all transitions from each present state to the next state for different values of input signal. The state table has three sections, the present state, next state and output section. Each combination of values of the state variables is assigned a unique alphanumeric symbol. Then the present and next state sections of state table are obtained by simply replacing the binary code for each code in the transition table by the new symbol.

The output section is identical with that of transition table. The state table for circuit in example in Figure 1 is shown in Table 3.

Table 3 State Table for Example in Figure 1

Present State	Next State (D_1D_2)		Output (z)	
	Input (x)		Input (x)	
	0	1	0	1
00 → A	C	B	0	1
01 → B	D	D	0	0
10 → C	C	A	1	0
11 → D	A	A	1	0

Step VI (State Diagram (or) State Transition Diagrams) : This is graphical representation of state table. Each state is represented by a labelled node. Directed branches connect the nodes to show transitions between states. The directed branches are labelled according to the values of the external input variables permit the transition to exist. The outputs of the sequential circuit are also indicated on the state diagram. For Mealy sequential circuits, the outputs appear on the directed branches along with external inputs. Whereas in case of Moore type of circuits, the outputs are included within the nodes along with their associated states. The state diagram for the circuit in Figure 1 is shown in Figure 2.

	the data when the	Flip-flop are used
(4)	It is based on the enable function input.	It works on the basis of clock pulses.
(5)	It is a level triggered, it means that the output of the present state and input of the next state depends on the level that is binary input 1 or 0.	It is an edge triggered, it means that the output and the next state input changes when there is a change in clock pulse whether it may a positive or negative clock pulse.

Q3) Distinguish between synchronous and asynchronous sequential circuit. [July

Answer :

S.No.	Synchronous Sequential Circuits	Asynchronous Sequential Circuits
(1)	In synchronous circuits, memory elements are clocked flip-flops.	In asynchronous circuits, memory elements are either unclocked flip-flops or time delay elements.
(2)	In synchronous circuits, the change in input signals can affect memory element upon activation of clock signal.	In asynchronous circuits change in input signals can affect memory element at any instant of time.
(3)	The maximum operating speed of clock depends on time delays involved.	Because of absence of clock, asynchronous circuits can operate faster than synchronous circuits.
(4)	Easier to design.	More difficult to design.

Q4) Define the terms characteristic equation, characteristic table and excitation table. [June/July

Answer :

Q9) What are the basic components of ASM?

Answer :

Following are the three basic components of ASM charts,

(1) State box.

(2) Decision box.

(3) Conditional output box.

Q10) What the advantages of ASM chart?

Answer :

The advantages of ASM chart include the following,

(1) Easy to understand.

(2) May have one or more equivalent forms.

(3) Can describe both combinational and sequential circuits.

(4) Have structured approach to visualize a sequential problem.