SNS COLLEGE OF TECHNOLOGY

Coimbatore -35
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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

19ECB211 – DIGITAL ELECTRONICS

II YEAR / III SEMESTER

UNIT 5 – SEQUENTIAL CIRCUITS

TOPIC 5 – Analysis and design of clocked sequential circuits – Moore/Mealy models example

Analysis Procedure

- Identify type of circuit either Mealy or Moore circuit
- Derive excitation equation (Boolean expression)
- Derive next state and output equations
- Generate state table
- Generate state diagram

Analysis Procedure

DESIGN PROCEDURE FOR CLOCKED SEQUENTIAL CIRCUIT

The following steps are followed to design the clocked sequential logic circuit.

- Obtain the state table from the given circuit information such as a state diagram, a timing diagram or description.
- The number of states may be reduced by state reduction technique.
- Assign binary values to each state in the state table.
- Determine the number of flip flops required and assign a letter symbol to each flip flop.
- Choose the flip flop type to be used according to the application.
- Derive the excitation table from the reduced state table.
- Derive the expression for flip flop inputs and outputs using k-map simplification (The present state and inputs are considered for k-map simplification) and draw logic circuit

Analysis of Sequential Logic

1. **Analysis is the process that starts with an implementation and generates the function or behavior of the sequential** circuit.

   i.e. given a logic schematic, to generate one or more functional descriptions, using state diagrams, state and output tables, and input and output Boolean equations.

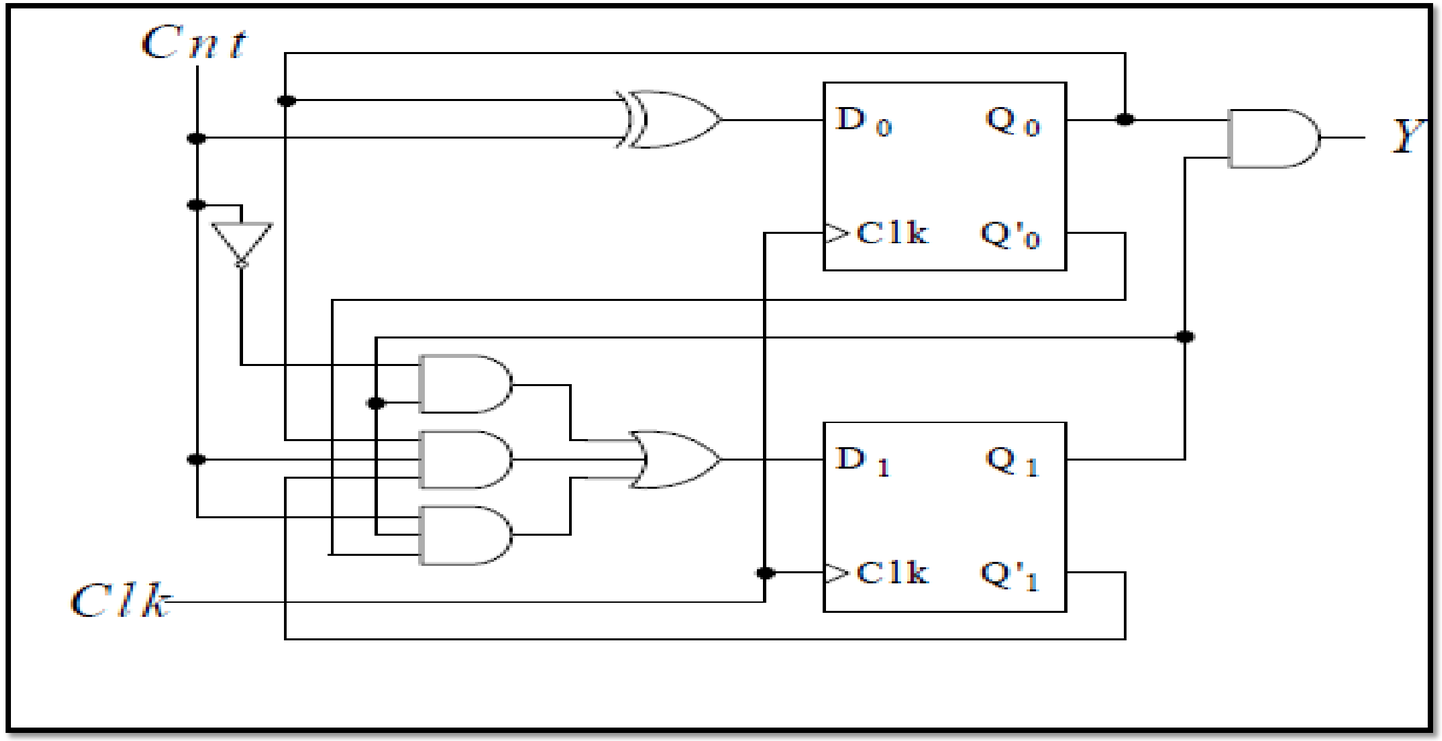
2. **Synthesis, the reverse of analysis, starts with a behavioral description and generates an implementation**

Moore Machine

State-based or Moore-type sequential circuit.

The output values depend solely on its present state.

Derive the next-state, the output tables, and the state diagram for the (modulo-4 counter) sequential circuit represented by the following schematic.



Moore Machine

Solution:

Step 1 (Moore): Derive **excitation equations.**

i.e., boolean expressions for the inputs of each flip-flop in the schematic, in terms of the external input Cnt and the ff outputs Q1 and Q0.

Since there are two ffs in our example, we derive two expressions for D1 and D0:

$$D_0 = Cnt \oplus Q_0 = Cnt'Q_0 + CntQ_0'$$
$$D_1 = Cnt'Q_1 + CntQ_1'Q_0 + CntQ_1Q_0'$$

Moore Machine

Solution:

Step 2:

Derive the **next-state equations by substituting the excitation equations into the flip-flop characteristic** equations.

The **characteristic equations formally describe the functional behavior of a latch or flip-flop.**

They specify the flip-flop's next state as a function of its current state and inputs.

For the D flip-flop, the characteristic equation is

$$Qnext = D$$

Thus, the next-state equations are:

$$Q_{0next} = D_0 = Cnt \oplus Q_0 = Cnt'Q_0 + CntQ_0'$$

$$Q_{1next} = D_1 = Cnt'Q_1 + CntQ_1'Q_0 + CntQ_1Q_0'$$

Step 2b (Moore):

Derive the **output equation**.

$$Y = Q_1Q_0$$

Moore Machine

Solution:

Step 3a:

Derive the next-state table from the next-state equations.

Each row corresponds to a state of the sequential circuit which is defined by the binary values stored in its ffs.

Each column represents one set of input values.

Each entry defines the value of the sequential circuit in the next clock cycle after the rising edge of the Clk.

Present State	Next State		Outputs
Q_1Q_0	$Q_{1\,next}\,Q_{0\,next}$		Y
	$Cnt = 0$	$Cnt = 1$	
00	00	01	0
01	01	10	0
10	10	11	0
11	11	00	1

Moore Machine

Solution:

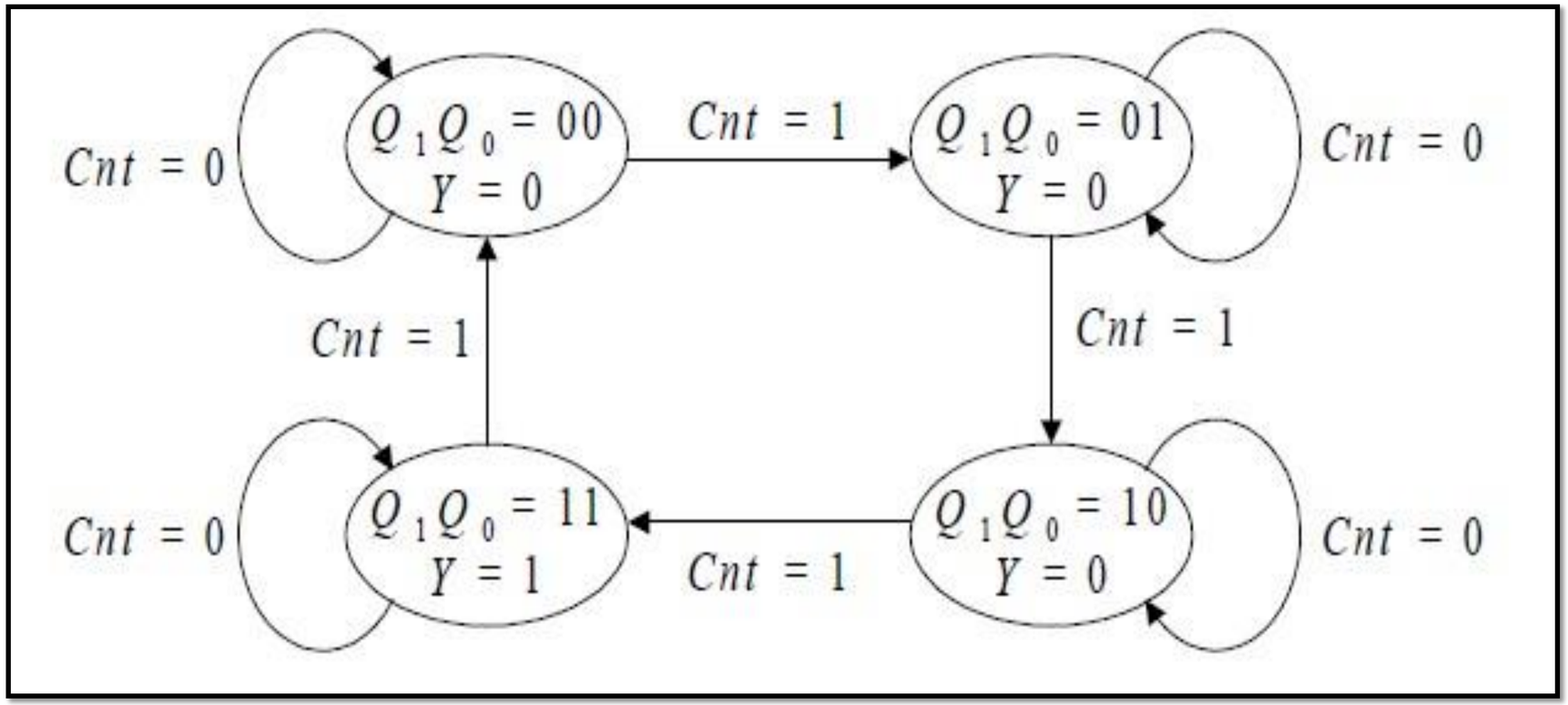
Step3b:

- Instead of a next-state table, we could use a state diagram to represent the behavior of the sequential circuit.
- A state diagram is basically a pictorial representation of the next-state table. It has exactly one node for each present state in the next-state table.
- As long as Cnt=1, the sequential circuit visits the states in the sequence 0,1,2,3,0,1,2,….
- When Cnt=0, the circuit stays in its present state until Cnt changes to 1, at which point the counting continues.
- We conclude that the circuit is a modulo-4 counter with one control signal, Cnt.

Moore Machine

Step3b:

- Statediagram

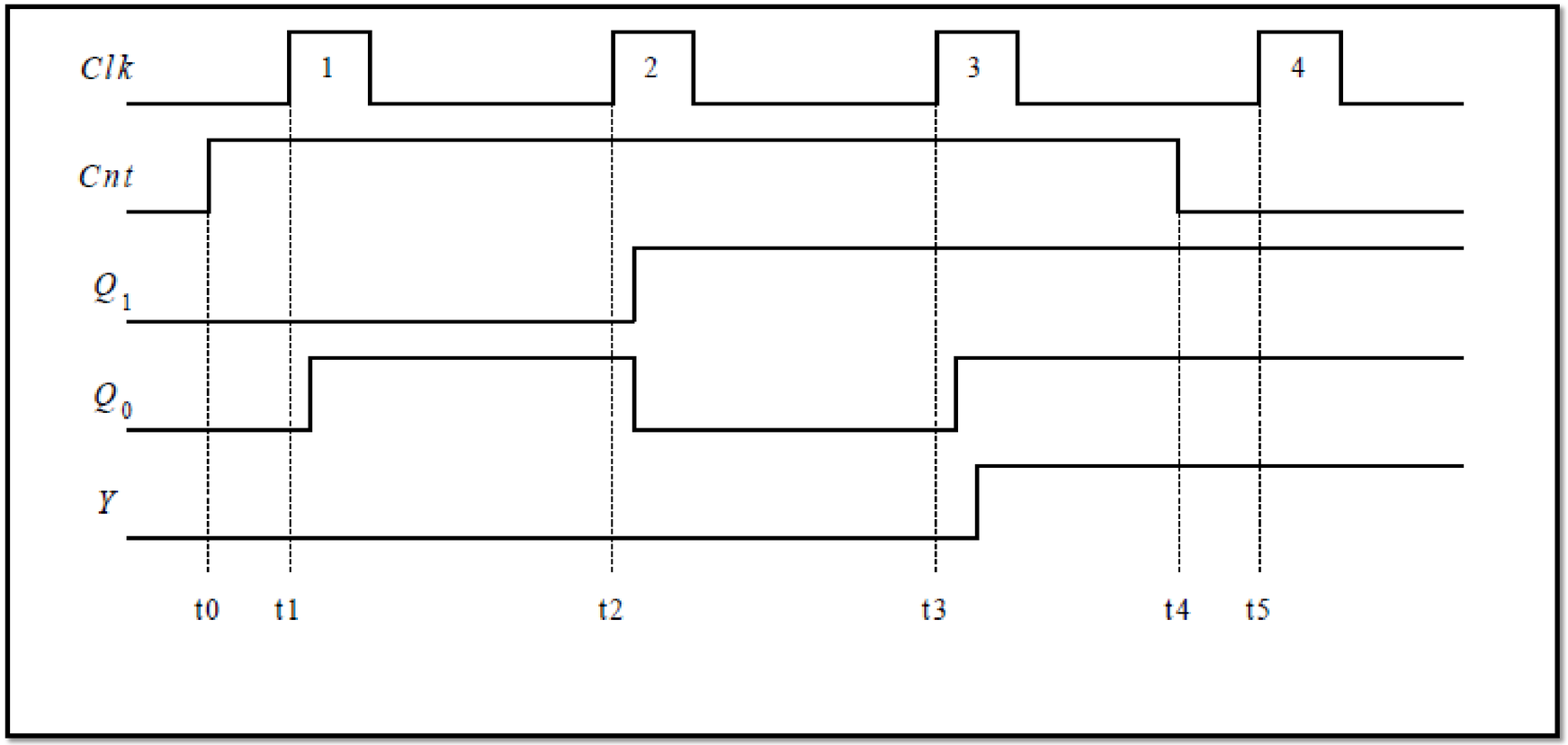


Moore Machine

Solution:

Step 4:

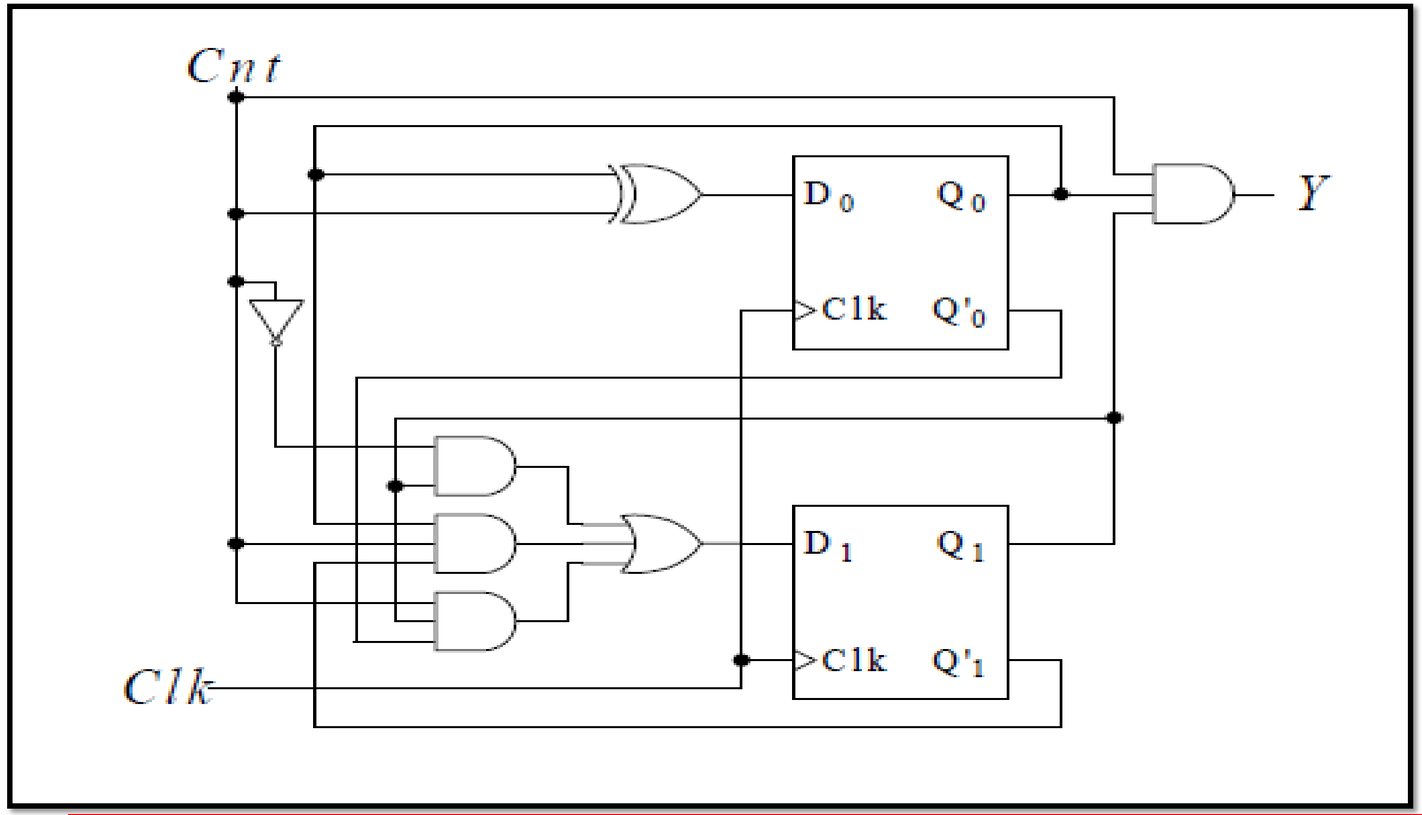
The timingdiagramis shown below:



Mealy Model

Input-based or Mealy-type sequential circuit. The output values are dependent on the input values as well as its present state.

Derive the next state, the output tables, and the state diagram for the (modulo-4 counter) sequential circuit represented by the following schematic.



Mealy Model

Solution:

Step1 (Mealy): Derive excitation equations.

$$D_0 = Cnt \oplus Q_0 = Cnt'Q_0 + CntQ_0'$$
$$D_1 = Cnt'Q_1 + CntQ_1'Q_0 + CntQ_1Q_0'$$

Step2a (Mealy): Derive the next-state equations.

$$Q_{0next} = D_0 = Cnt \oplus Q_0 = Cnt'Q_0 + CntQ_0'$$
$$Q_{1next} = D_1 = Cnt'Q_1 + CntQ_1'Q_0 + CntQ_1Q_0'$$

Step2b (Mealy): Derive the output equation.

$$Y = CntQ_1Q_0$$

Mealy Model

Solution:

Step3a(Mealy):

Derive the next-state/output table. Every entry in the next-state table will represent the next-state and the output value, separated by a slash (/).

Present State	Next State / Outputs	
Q_1Q_0	$Q_{1\,next}Q_{0\,next}$ / Y	
	$Cnt = 0$	$Cnt = 1$
00	00 / 0	01 / 0
01	01 / 0	10 / 0
10	10 / 0	11 / 0
11	11 / 0	00 / 1

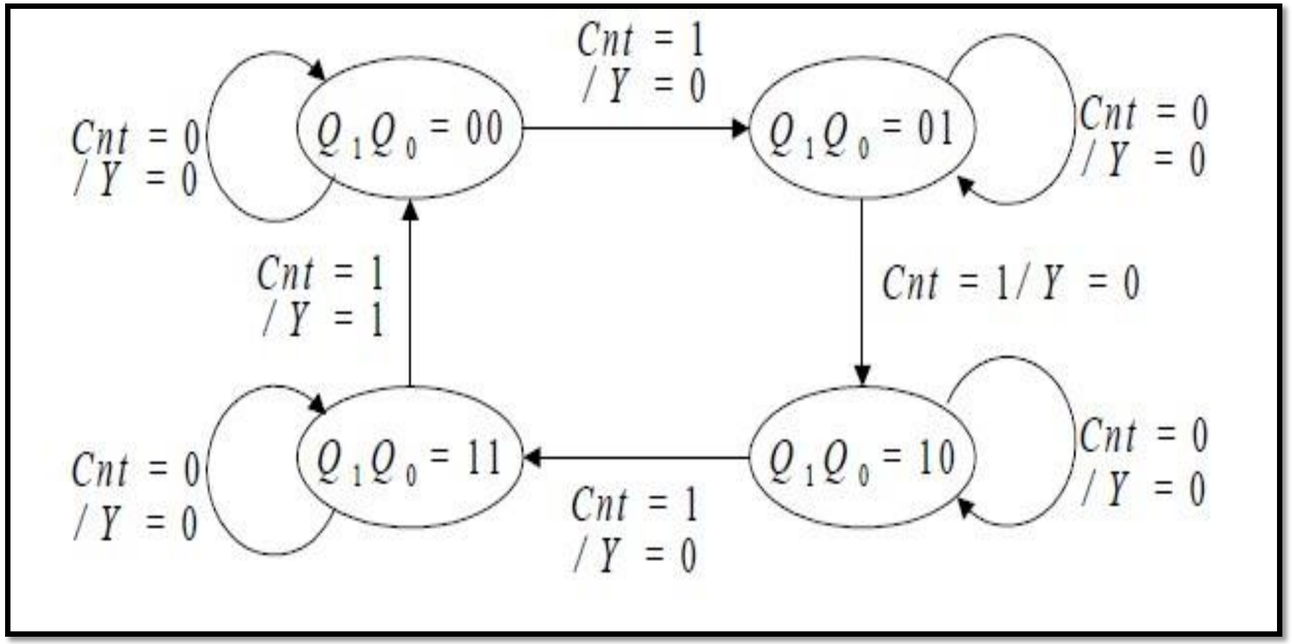
Mealy Model

Solution:

Step3b (Mealy):Derive the State diagram.

The output is not associated with the state but with the transition arc.

Each arc is labeled with both the input values that move the circuits from the present state to the next state, and the output values, which correspond to the input values in the present state.

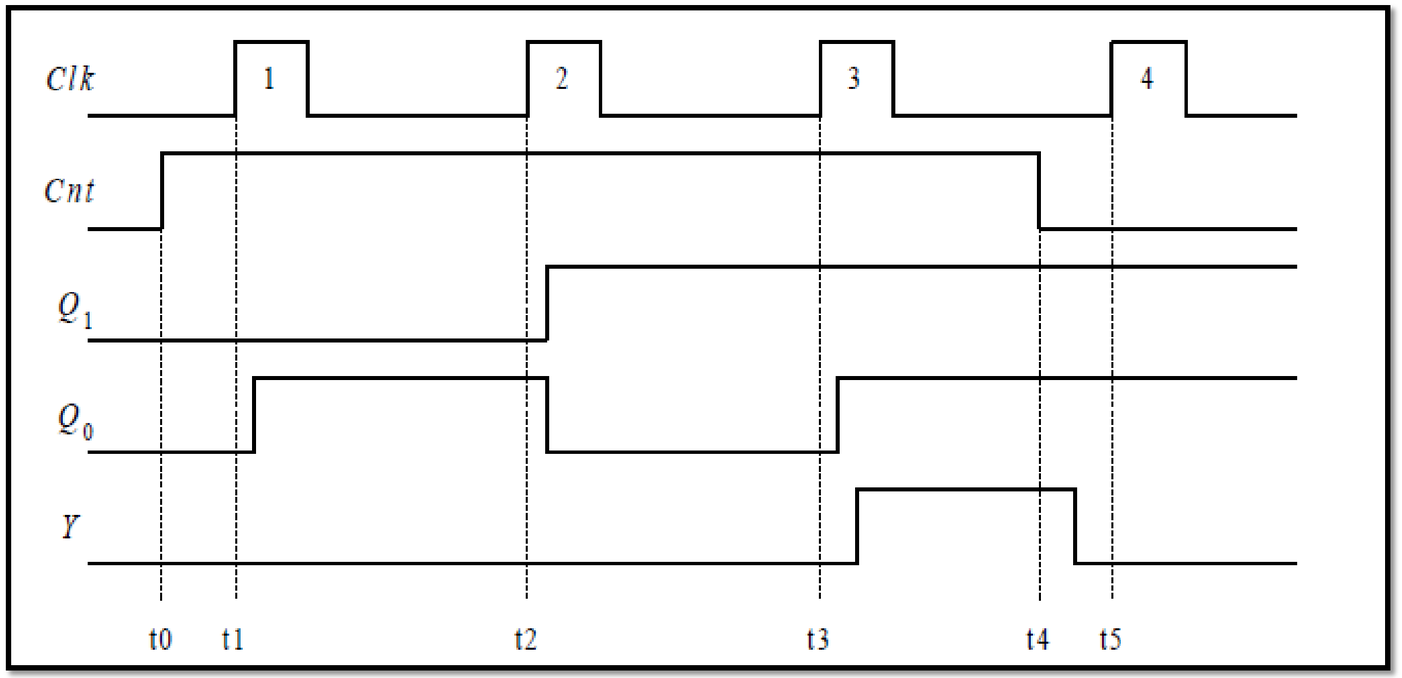


Mealy Model

Solution:

Step4 (Mealy):Thetiming diagramis shown below:

In clockcycle3, thecounterwill beinstateQ1Q0= 11 andtheoutputsignalY = 1.
At t4, Y = 0 becausethe inputsignalCnt =0 eventhoughthe counteris still in stateQ1Q0= 11.



THANK YOU