L7s Multiple Output example

The Problem (from text Unit 14)

- Problem Statement

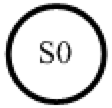
14.5 A sequential circuit has one input (X) and two outputs (Z_1 and Z_2). An output $Z_1 = 1$ occurs every time the input sequence 010 is completed, provided that the sequence 100 has never occurred. An output $Z_2 = 1$ occurs every time the input 100 is completed. Note that once a $Z_2 = 1$ output has occurred, $Z_1 = 1$ can never occur but *not* vice versa. Find a Mealy state graph and state table (minimum number of states is eight).

  - Will do for Mealy and Moore
  - One input X, two outputs Z1 and Z2
  - Z1 = 1 occurs every time 010 is last 3 on input, provided 100 has never occurred
  - Z2 = 1 every time 100 is last 3 on input

Choose a starting state (Mealy)

- This is the state after a reset.
- The slides will show the progression (developed on the board – now slides)

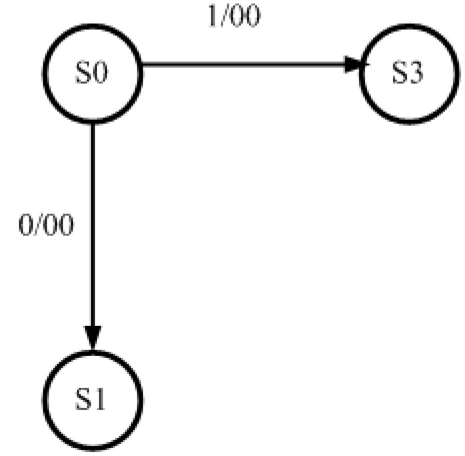
State	Meaning
S0	Starting State



Now add states transition from S0

- When in S0 what happens when a 1 is input or a 0 is input?

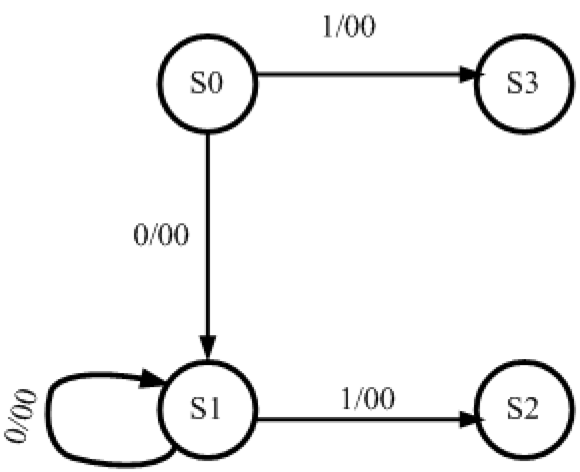
State	Meaning
S0	Starting State
S1	an initial 0 of possibly 010
S3	an initial 1 of possibly 100



In S1

- What happens on input of 0 – stay in S1
- What happens on input of 1 – transition to new state S2.

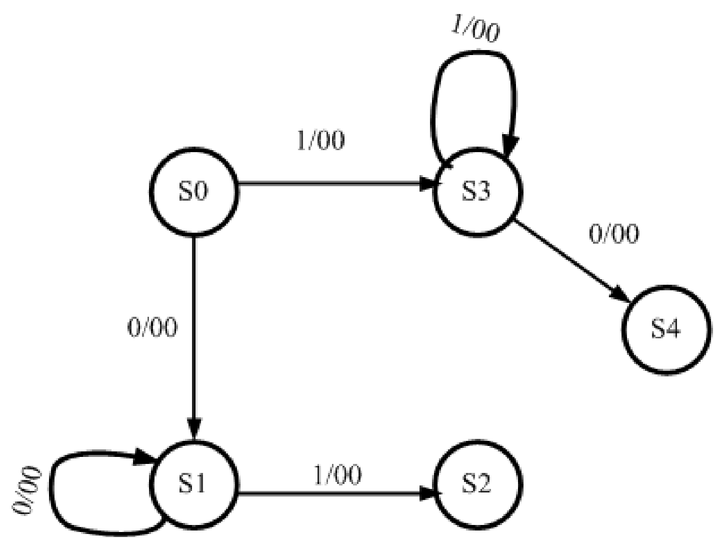
State	Meaning
S0	Starting State
S1	an initial 0 of possibly 010
S2	have 01 as last 2 inputs
S3	an initial 1 of possibly 100



In S3

- Input of 1 – stay in S3
- Input of 0 – now have 10 of possible 100 seq

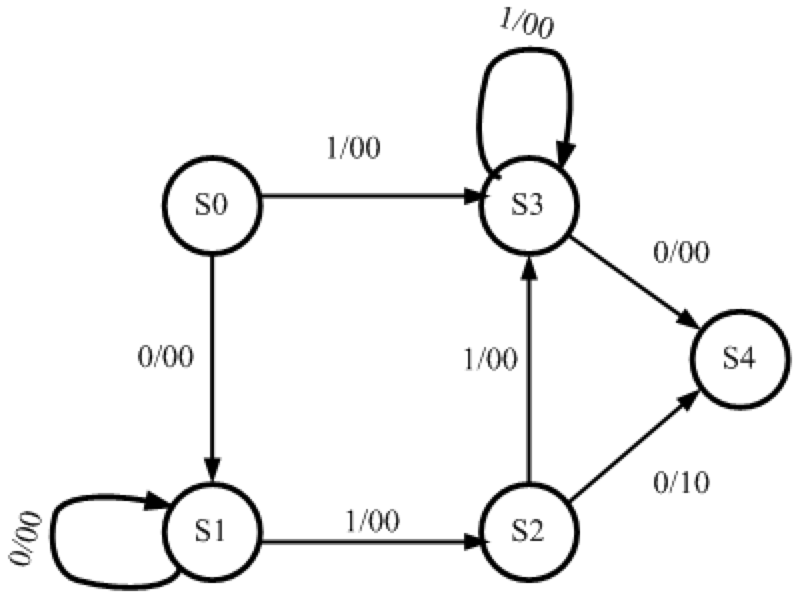
State	Meaning
S0	Starting State
S1	an initial 0 of possibly 010
S2	have 01 as last 2 inputs
S3	an initial 1 of possibly 100
S4	have 10 as last 2 inputs



In S2

- Input 1 – have 11 as last two -1st 1 of 100 – transition to S3
- Input 0 – have completed 010 and have 10 as last two inputs, S4

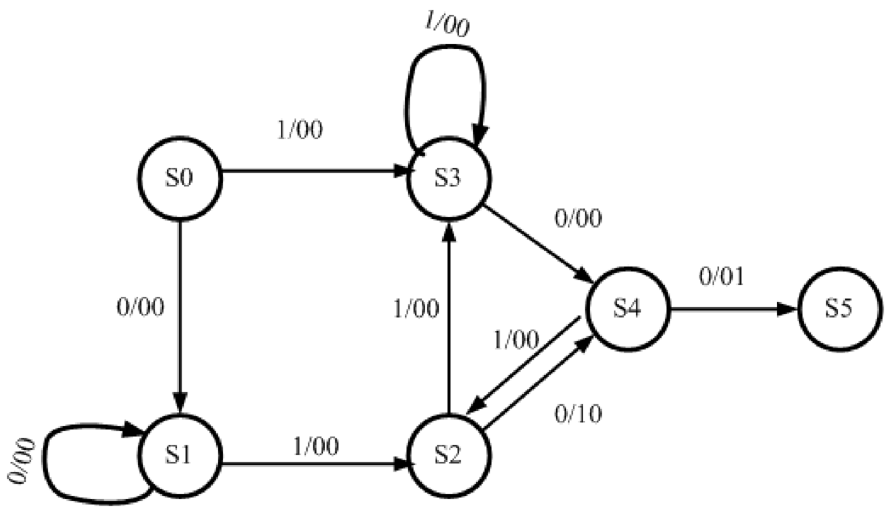
State	Meaning
S0	Starting State
S1	an initial 0 of possibly 010
S2	have 01 as last 2 inputs
S3	an initial 1 of possibly 100
S4	have 10 as last 2 inputs



In S4

- Input 1 – have 01 as last 2 inputs – go to S2
- Input 0 – have 100 as last 3 and sequence 100 – go to new state S5 and sequence 010 can not be recognized again

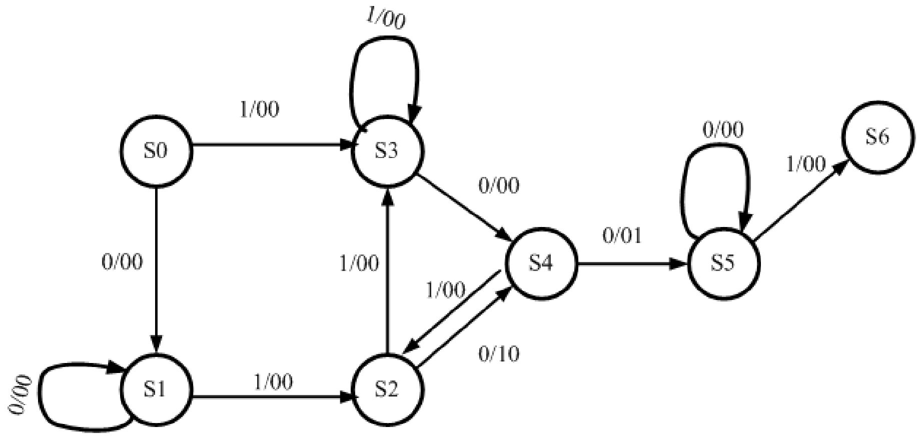
State	Meaning
S0	Starting State
S1	an initial 0 of possibly 010
S2	have 01 as last 2 inputs
S3	an initial 1 of possibly 100
S4	have 10 as last 2 inputs
S5	have seen sequence 100



In S5

- Input 0 – Have 00 as last two – not start of 100
- Input 1 – Have possible start of 100 – transition to S6

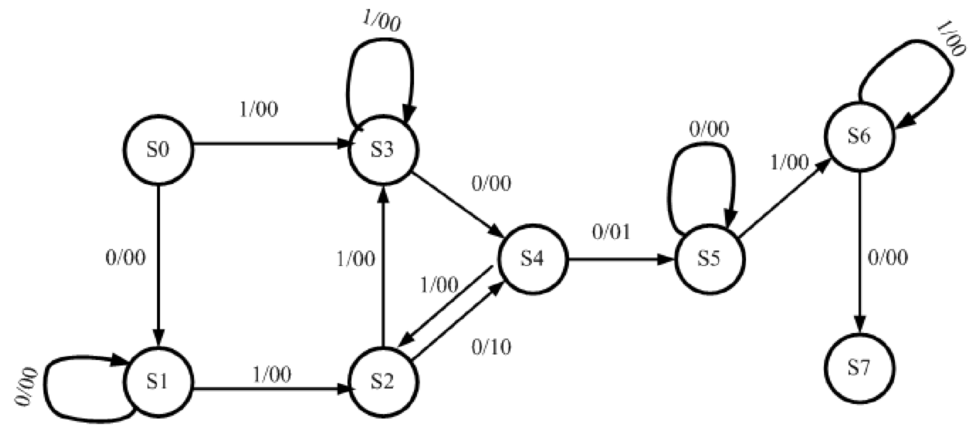
State	Meaning
S0	Starting State
S1	an initial 0 of possibly 010
S2	have 01 as last 2 inputs
S3	an initial 1 of possibly 100
S4	have 10 as last 2 inputs
S5	have seen sequence 100
S6	have a 1 – start of 100



In S6

- Input 0 – have 10 of 100 – go to S7
- Input 1 – Stay in S6

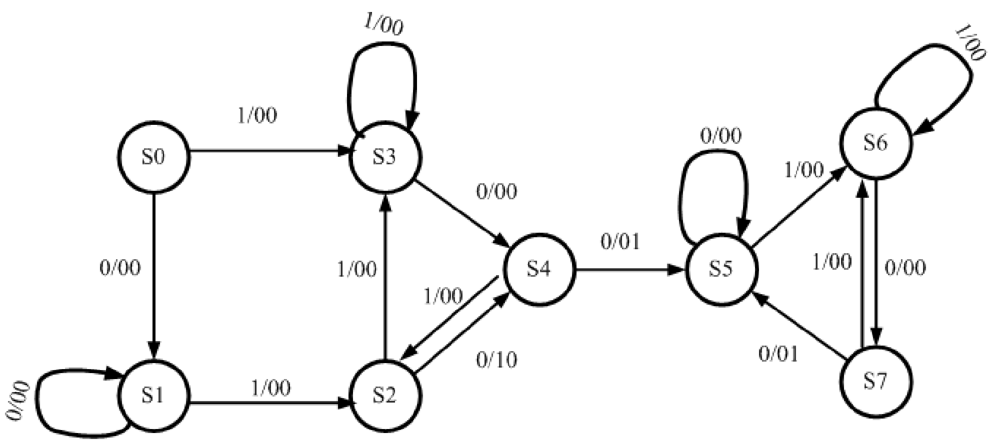
State	Meaning
S0	Starting State
S1	an initial 0 of possibly 010
S2	have 01 as last 2 inputs
S3	an initial 1 of possibly 100
S4	have 10 as last 2 inputs
S5	have seen sequence 100
S6	have a 1 – start of 100
S7	have a 10 of possible 100



In S7

- Input 0 – Now have 100 and output a 1 – go to S5
- Input 1 – Have a 1st 1 and could be start of 100 – go to S6
- Done

State	Meaning
S0	Starting State
S1	an initial 0 of possibly 010
S2	have 01 as last 2 inputs
S3	an initial 1 of possibly 100
S4	have 10 as last 2 inputs
S5	have seen sequence 100
S6	have a 1 – start of 100
S7	have a 10 of possible 100



Moore Machine implementation

- The Moore Machine implementation
- It adds 2 more states and is left to the student to work this through. Remember that the output is associated with the state, not a combination of the state and input as in a Mealy Machine.

State S0

- Have a starting state S0 and its meaning
- Remember – a Moore machine

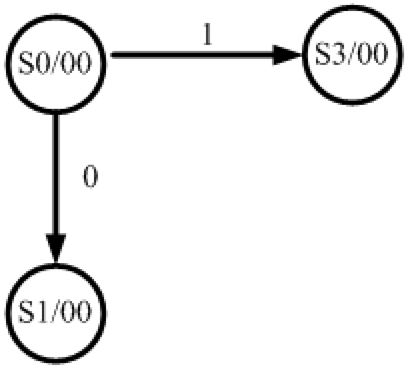
State	Meaning
S0	Starting state

- Note output designation on State symbol

In S0

- 0 input – have the start of 010
- 1 input – have the start of 100

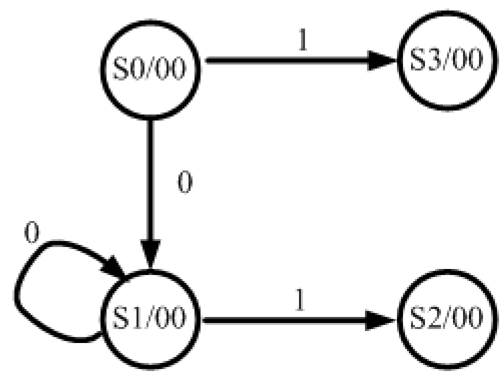
State	Meaning
S0	Starting state
S1	have 1st 0 of start of 010
S3	have 1st 1 of start of 100



In S1

- 0 input – last 2 are 00 – stay in S1
- 1 input – last 2 are 01 – transition to state S2

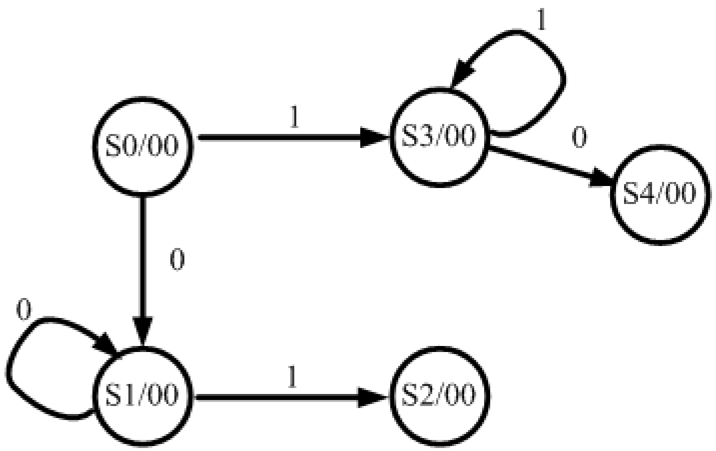
State	Meaning
S0	Starting state
S1	have 1st 0 of start of 010
S2	have 01 as last 2 inputs
S3	have 1st 1 of start of 100
S4	have 10 as last 2 inputs
S5	010 detected – 10 as last two inputs
S6	100 detected – output Z2 = 1
S7	after 100 – a 0 input
S8	after 100 – a 1 input
S9	after 100 – have 10 as last 2



In S3

- 0 input – have 10 as last 2 – go to S4
- 1 input – have 11 as last 2 – stay in S3

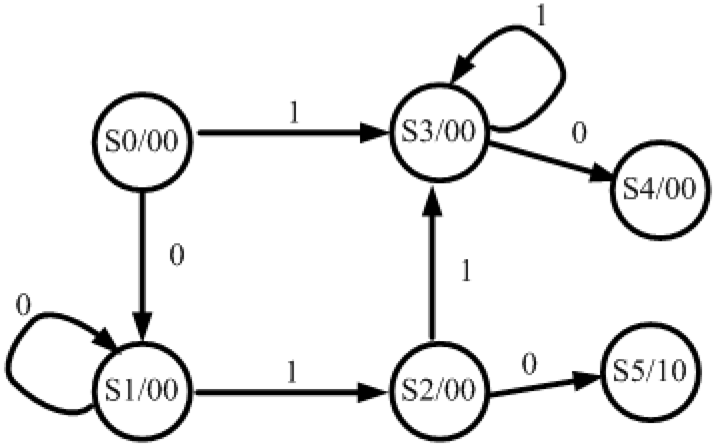
State	Meaning
S0	Starting state
S1	have 1st 0 of start of 010
S2	have 01 as last 2 inputs
S3	have 1st 1 of start of 100
S4	have 10 as last 2 inputs
S5	010 detected – 10 as last two inputs
S6	100 detected – output Z2 = 1
S7	after 100 – a 0 input
S8	after 100 – a 1 input
S9	after 100 – have 10 as last 2



In S2

- 0 input – Have 010 as last 3 – 10 as last 2 – go to state S5 which has Z1=1 as its output
- 1 input – go to S3 as 11 are last 2 inputs

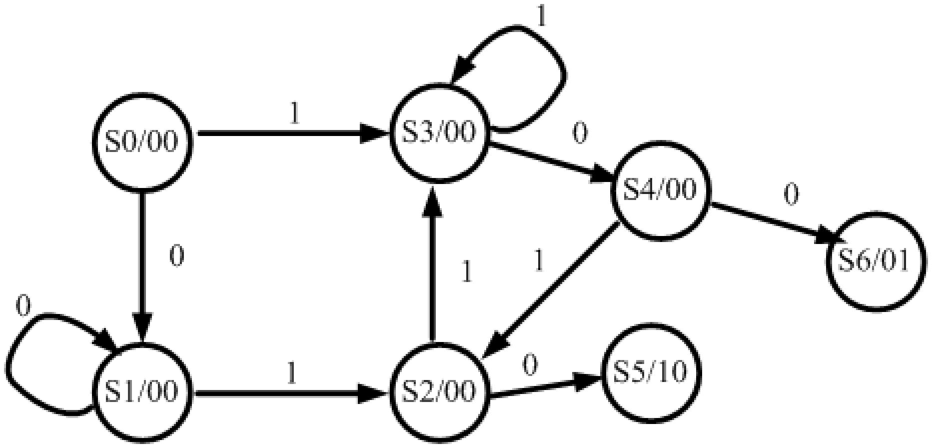
State	Meaning
S0	Starting state
S1	have 1st 0 of start of 010
S2	have 01 as last 2 inputs
S3	have 1st 1 of start of 100
S4	have 10 as last 2 inputs
S5	010 detected – 10 as last two inputs
S6	100 detected – output Z2 = 1
S7	after 100 – a 0 input
S8	after 100 – a 1 input
S9	after 100 – have 10 as last 2



In S4

- 0 input – 100 has been detected – new state S6 where 010 can not be detected output Z2=1
- 1 input – last 3 are 101, i.e., last 2 are 01 – go to S2

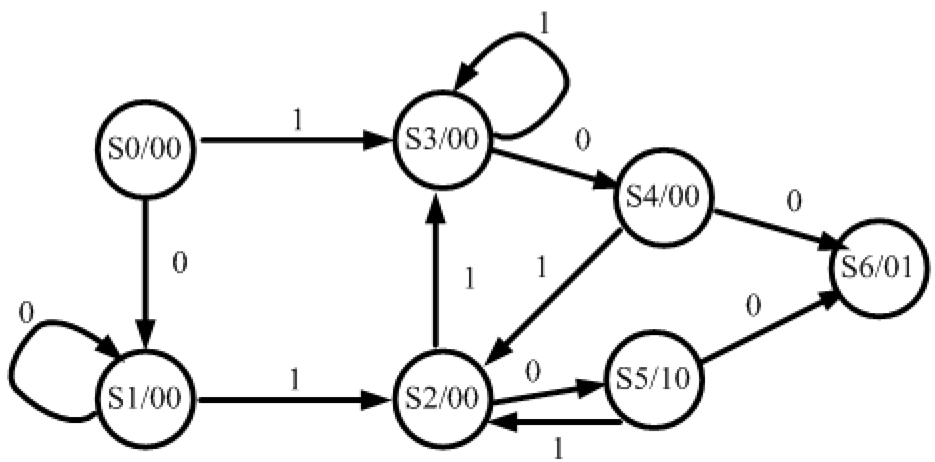
State	Meaning
S0	Starting state
S1	have 1st 0 of start of 010
S2	have 01 as last 2 inputs
S3	have 1st 1 of start of 100
S4	have 10 as last 2 inputs
S5	010 detected – 10 as last two inputs
S6	100 detected – output Z2 = 1
S7	after 100 – a 0 input
S8	after 100 – a 1 input
S9	after 100 – have 10 as last 2



In S5 – 010 detected

- 0 input – 100 are last 3 – go to S6
- 1 input – 101 are last 3, 01 last 2 – go to S2

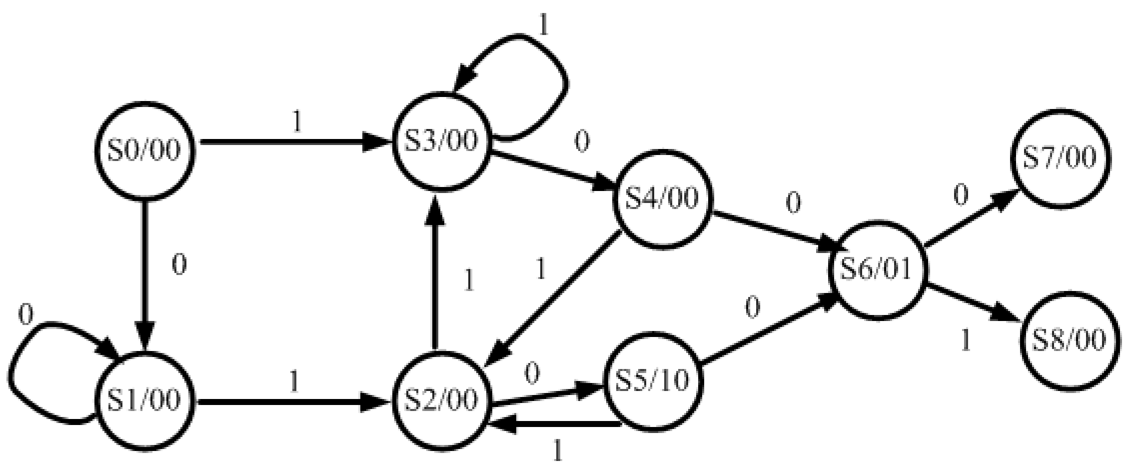
State	Meaning
S0	Starting state
S1	have 1st 0 of start of 010
S2	have 01 as last 2 inputs
S3	have 1st 1 of start of 100
S4	have 10 as last 2 inputs
S5	010 detected – 10 as last two inputs
S6	100 detected – output Z2 = 1
S7	after 100 – a 0 input
S8	after 100 – a 1 input
S9	after 100 – have 10 as last 2



In S6

- S6 have detected 100 and output Z2 = 1
- 0 input – new state S7 – means a 0 input
- 1 input – new state S8 – means a 1 received

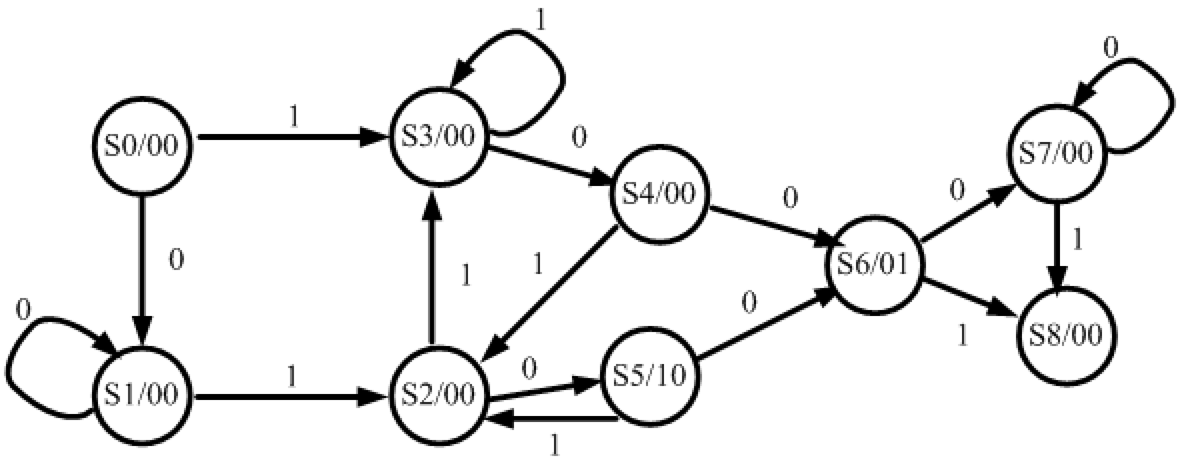
State	Meaning
S0	Starting state
S1	have 1st 0 of start of 010
S2	have 01 as last 2 inputs
S3	have 1st 1 of start of 100
S4	have 10 as last 2 inputs
S5	010 detected – 10 as last two inputs
S6	100 detected – output Z2 = 1
S7	after 100 – a 0 input
S8	after 100 – a 1 input
S9	after 100 – have 10 as last 2



In S7 – have a 0

- 0 input – Stay in S7
- 1 input – transition to S8

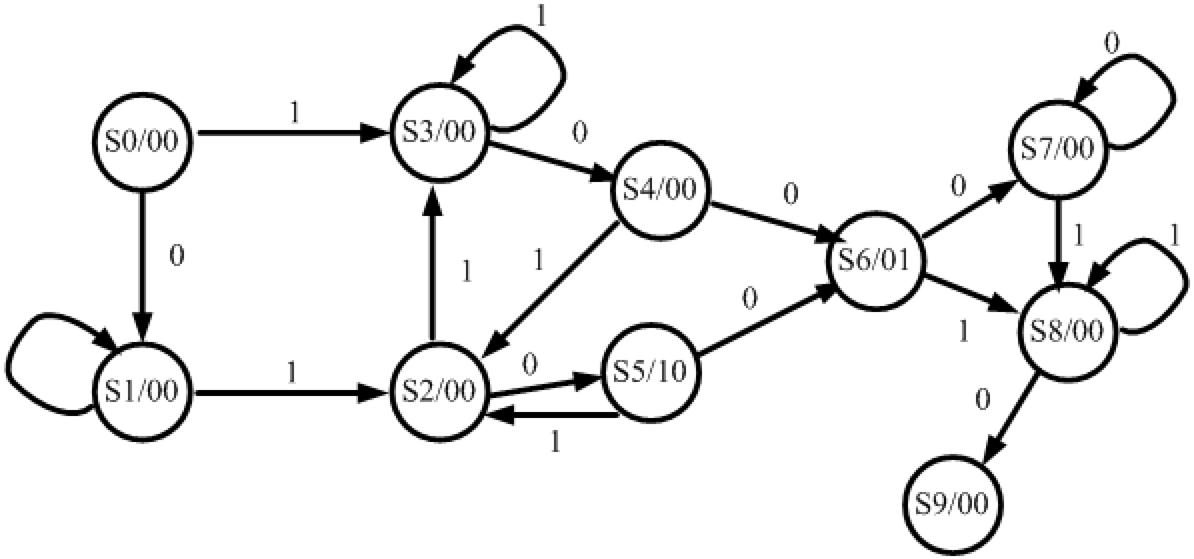
State	Meaning
S0	Starting state
S1	have 1st 0 of start of 010
S2	have 01 as last 2 inputs
S3	have 1st 1 of start of 100
S4	have 10 as last 2 inputs
S5	010 detected – 10 as last two inputs
S6	100 detected – output Z2 = 1
S7	after 100 – a 0 input
S8	after 100 – a 1 input
S9	after 100 – have 10 as last 2



In S8 – have xx01

- 0 input – now have 10 – go to new state S9
- 1 input – stay in S8

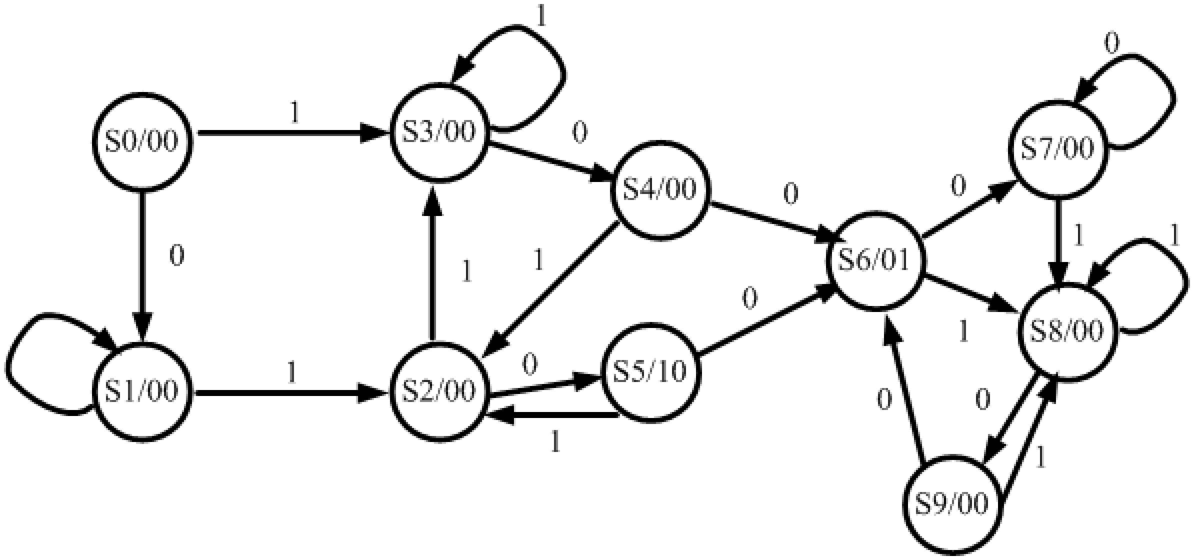
State	Meaning
S0	Starting state
S1	have 1st 0 of start of 010
S2	have 01 as last 2 inputs
S3	have 1st 1 of start of 100
S4	have 10 as last 2 inputs
S5	010 detected – 10 as last two inputs
S6	100 detected – output Z2 = 1
S7	after 100 – a 0 input
S8	after 100 – a 1 input
S9	after 100 – have 10 as last 2



In state S9

- 0 input – have seen 100 as last 3 – back to S6
- 1 input – have 1st 1 of 100 – back to S8

State	Meaning
S0	Starting state
S1	have 1st 0 of start of 010
S2	have 01 as last 2 inputs
S3	have 1st 1 of start of 100
S4	have 10 as last 2 inputs
S5	010 detected – 10 as last two inputs
S6	100 detected – output Z2 = 1
S7	after 100 – a 0 input
S8	after 100 – a 1 input
S9	after 100 – have 10 as last 2



Have seen contrast of Mealy/Moore

- Worked the development of a Mealy and Moore machine for the same specification
  - Mealy – 8 states
  - Moore – 10 states
- Machine has property that once certain conditions are met – a group of states can never be reached again. This type of machine is hard to test given the property of observeablilty.