

Lecture 14:
Sequential Networks –
Finite State Machines
Moore and Mealy

CSE 140: Components and Design Techniques for
Digital Systems

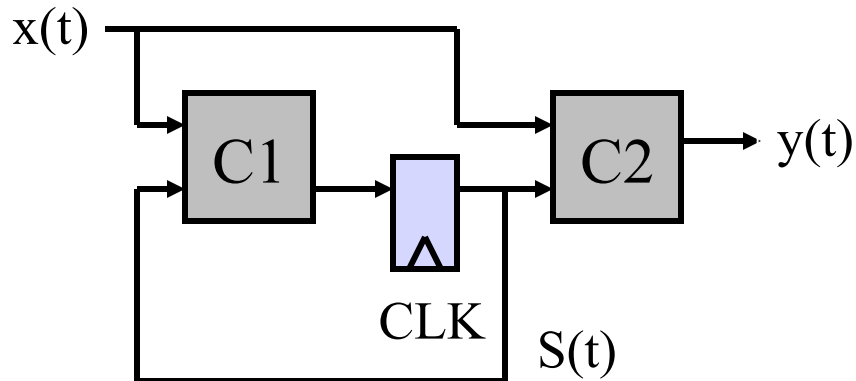
Diba Mirza
Dept. of Computer Science and Engineering
University of California, San Diego

Canonical Form: Mealy and Moore Machines

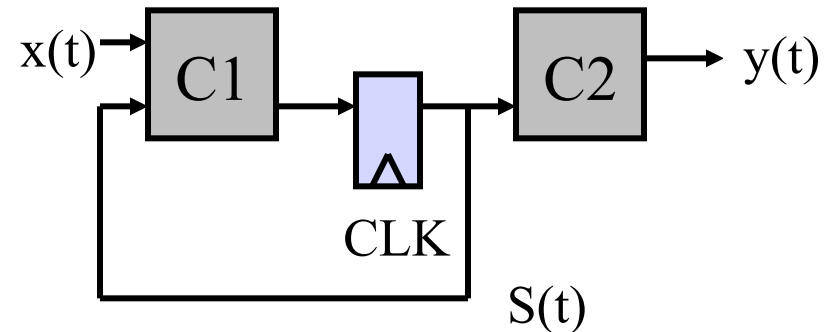
Mealy Machine: $y_i(t) = f_i(X(t), S(t))$

Moore Machine: $y_i(t) = f_i(S(t))$

$$s_i(t+1) = g_i(X(t), S(t))$$

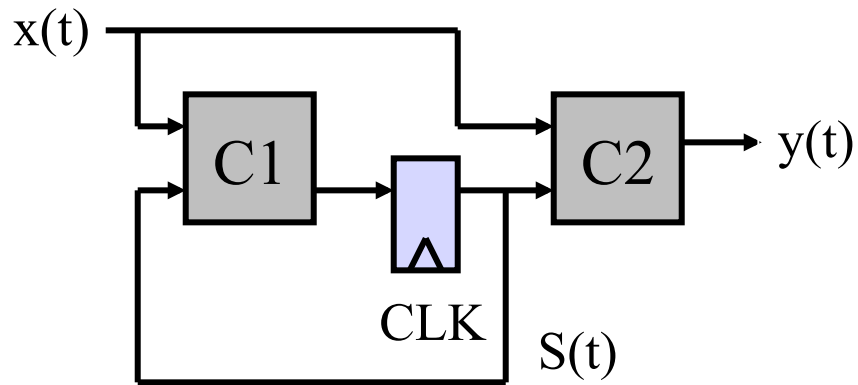


Mealy Machine

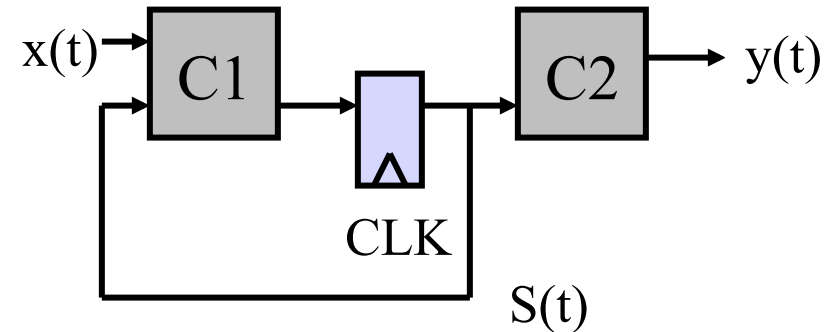


Moore Machine

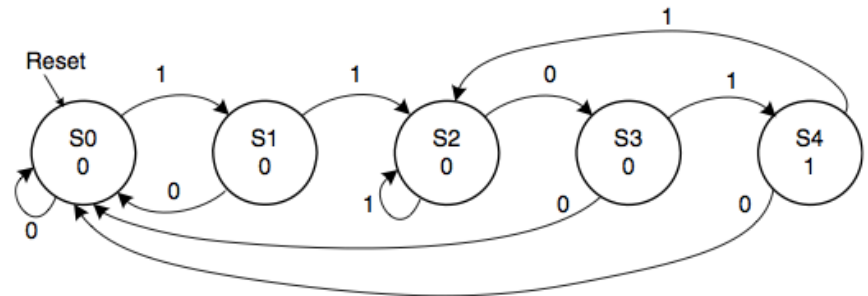
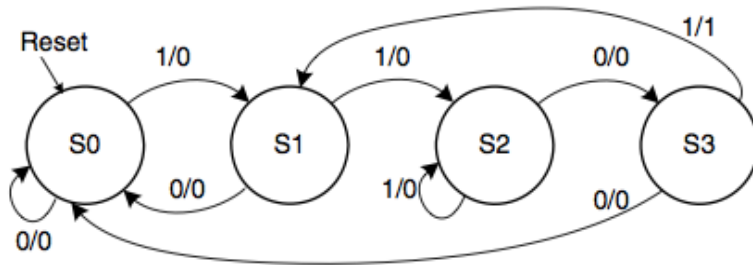
Differences in State Diagram: Mealy vs. Moore Machines



Mealy Machine

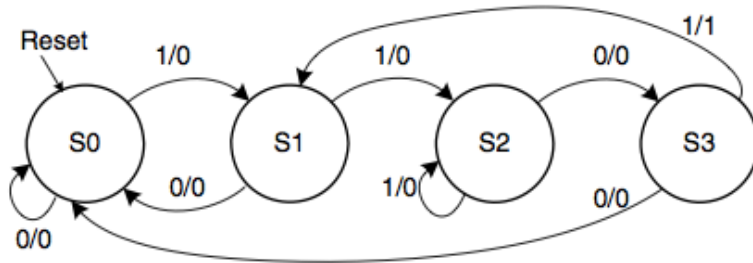


Moore Machine

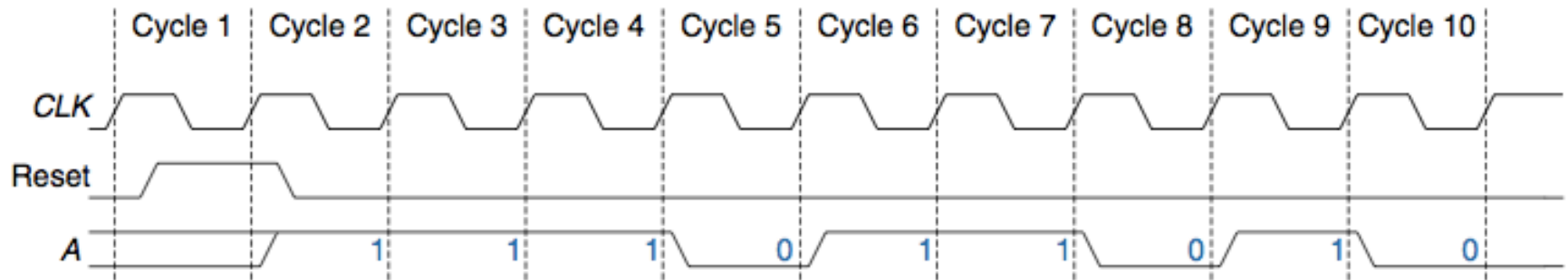
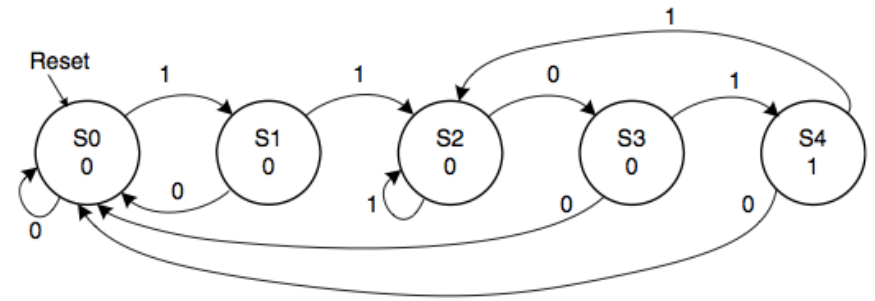


Differences in Timing: Mealy vs. Moore Machines

Mealy Machine



Moore Machine



Free running 2-bit counter was a

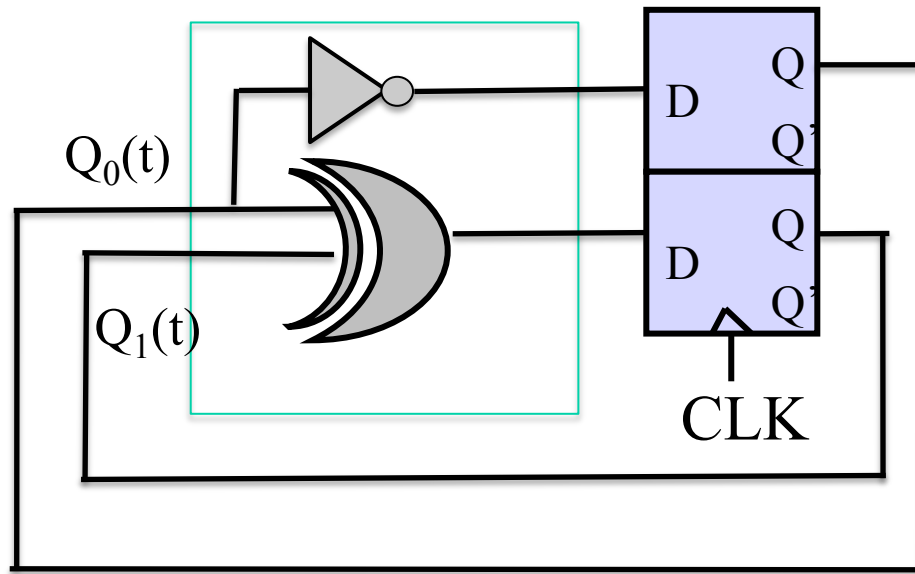
A. Moore machine

B. Mealy Machine

Free running 2-bit counter was a

A. Moore machine

B. Mealy Machine



Implementation of 2-bit counter

Life on Mars?

Pattern Recognizer: A sequential machine has a binary input x (message from a remote robot on Mars). When the sequential machine receives the input sequence $x(t-2, t) = 001$, it means that the robot has detected life on Mars ☺ and the output $y(t) = 1$, otherwise $y(t) = 0$ (no life on Mars ☹).

Draw the Mealy FSM for this problem.

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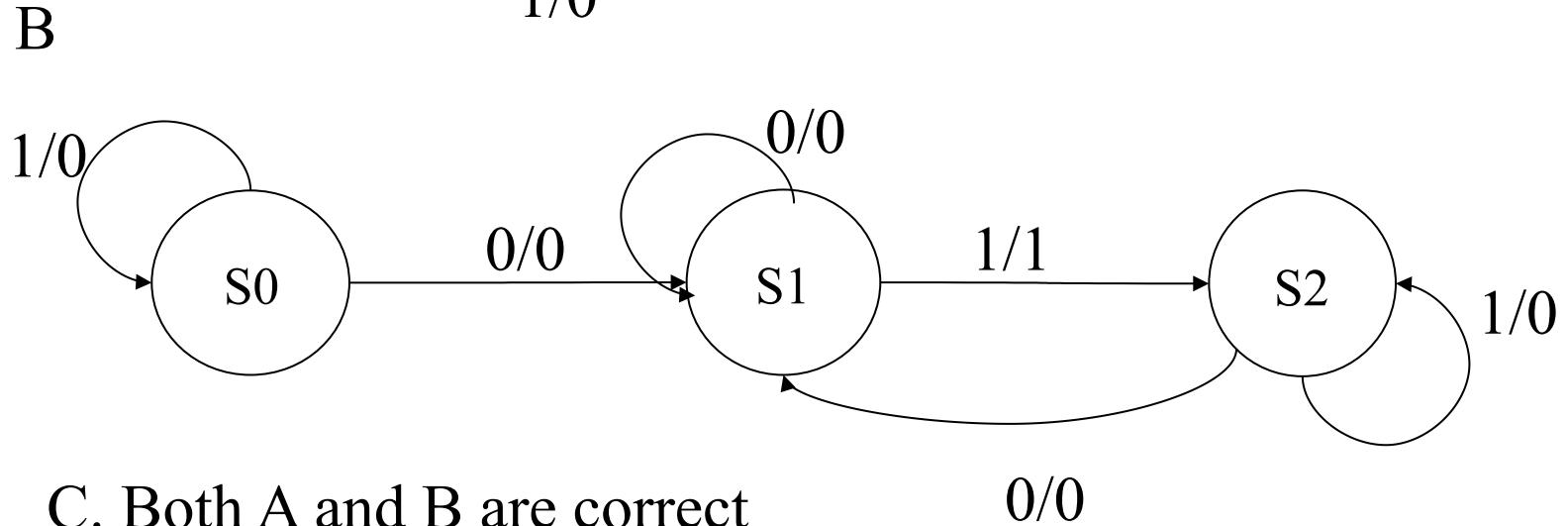
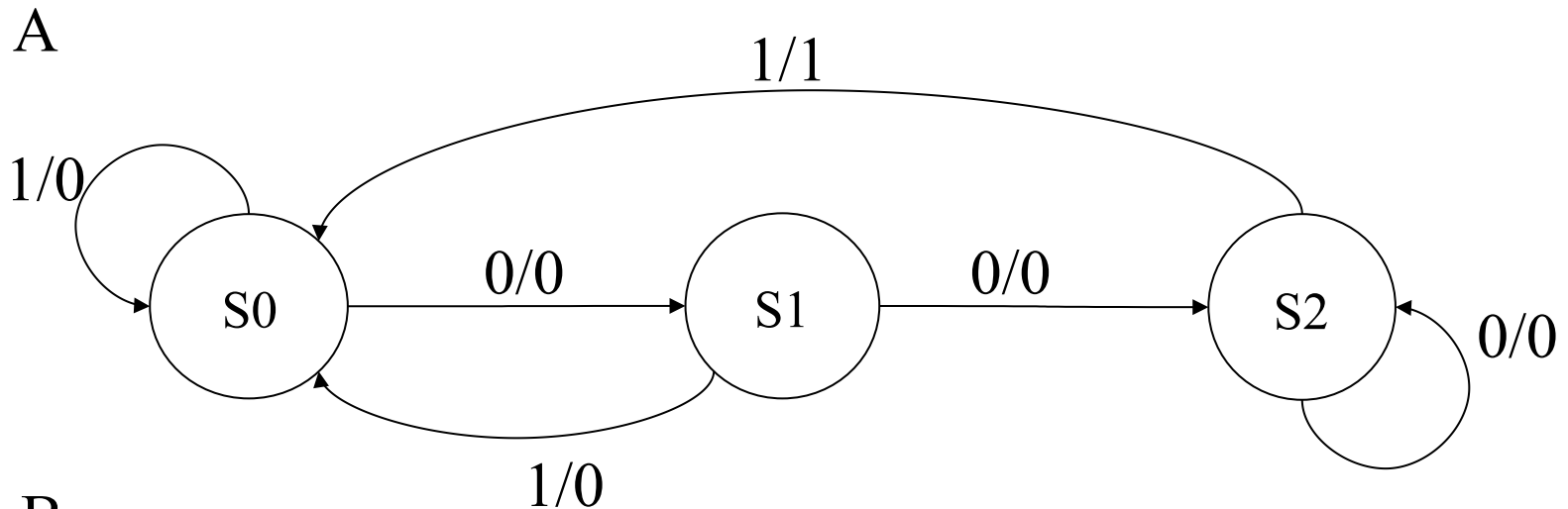
Draw the Mealy FSM for this problem.

- PI Q How many states should the pattern recognizer have
- A. One because it has one output
 - B. One because it has one input
 - C. Two because the input can be one of two states (0 or 1)
 - D. More than two because

PI Q How many states should the pattern recognizer have

- A. One because it has one output
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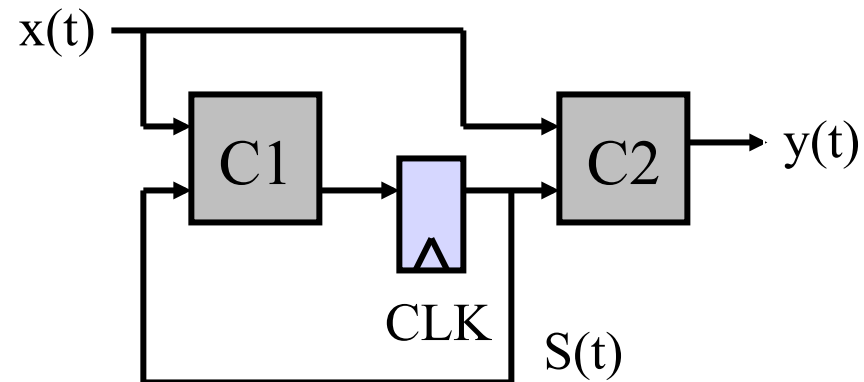
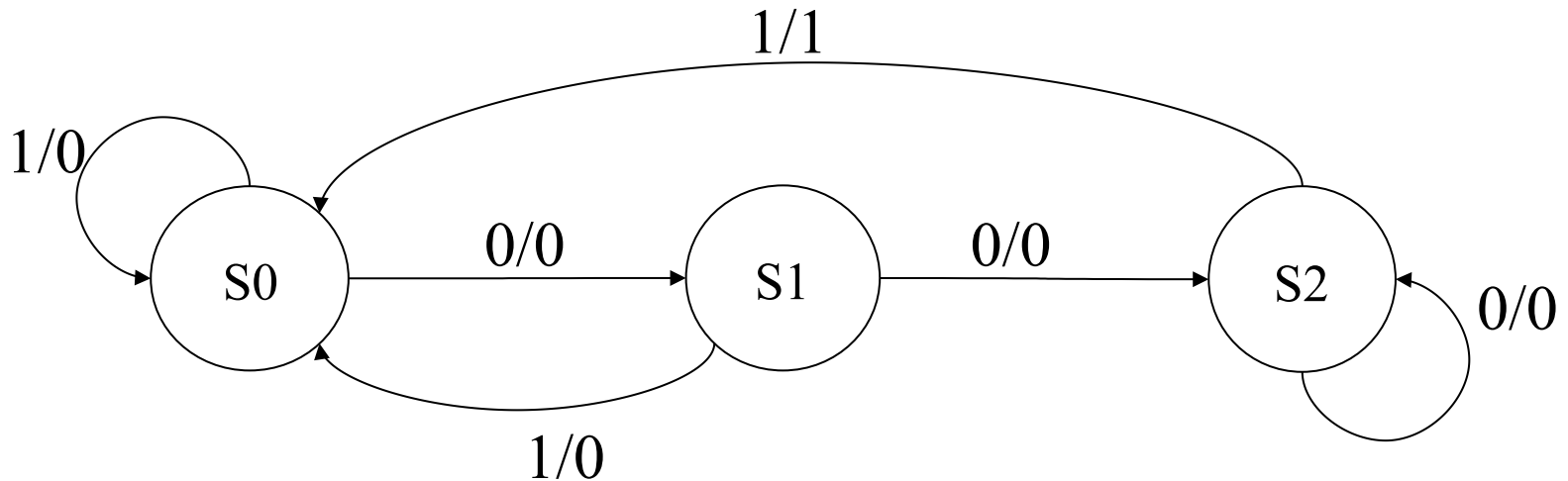
Q: Which of the following diagrams is a correct Mealy solution for the 001 pattern recognizer?



C. Both A and B are correct

D. None of the above

Pattern Recognizer '001'

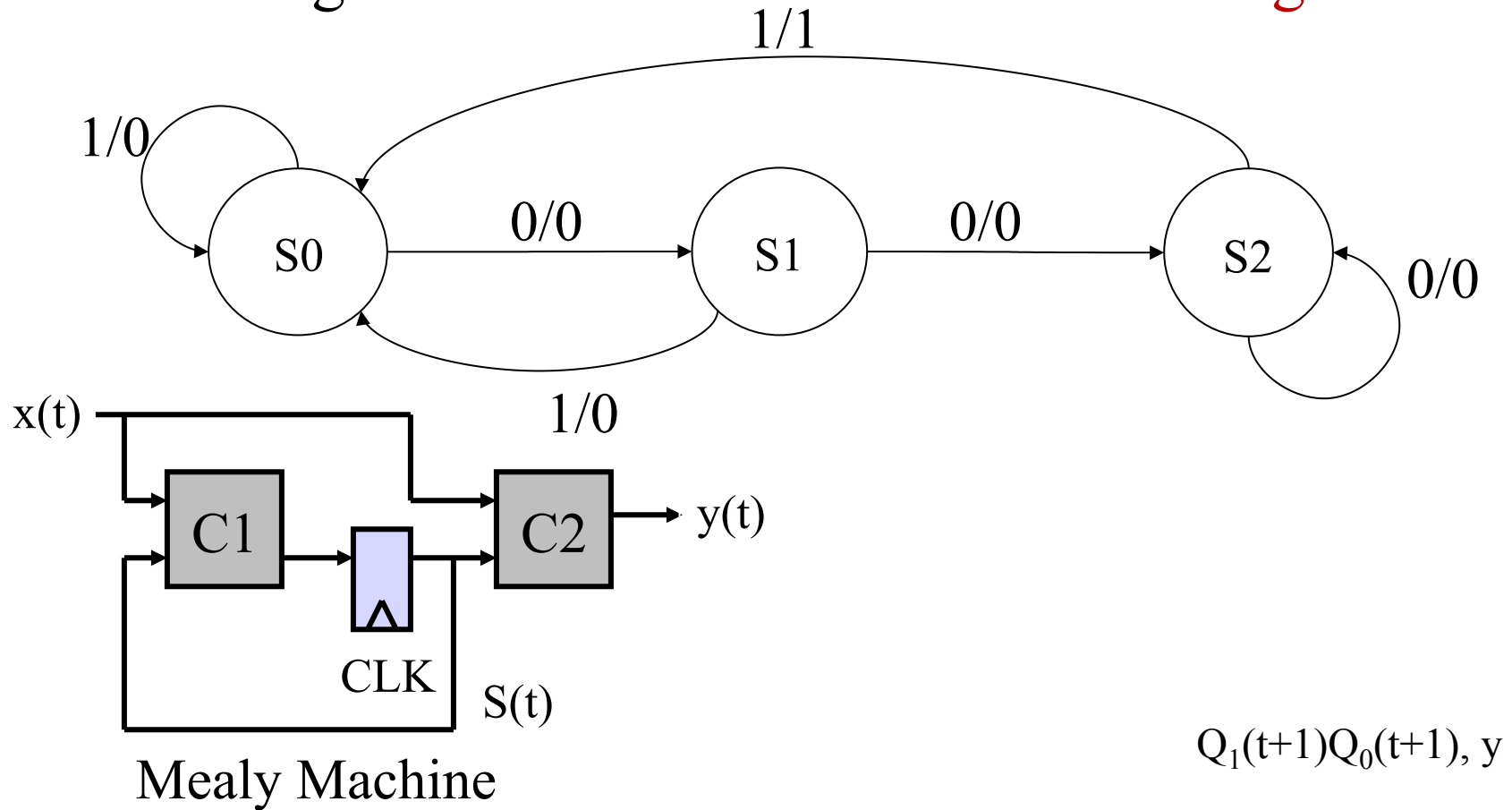


Mealy Machine

Q: What information do we need to design C1?

- A. State table showing (current input $x(t)$, current state $S(t)$ vs. next state, $S(t+1)$)
- B. State table showing (current input, current state vs. current output $y(t)$)
- C. State table showing (current input, current state vs. current output $y(t)$ and next state)
- D. None of the above

State Diagram => State Table with State Assignment



$S(t) \backslash x$	0	1
S0	S1,0	S0,0
S1	S2,0	S0,0
S2	S2,0	S0,1

State Assignment

S0: 00

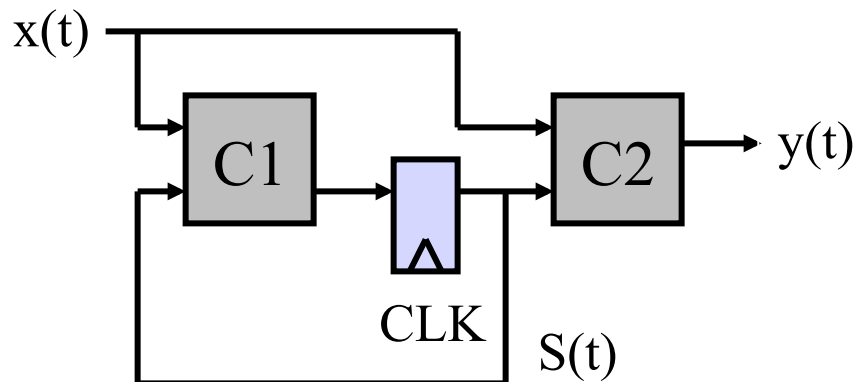
S1: 01

S2: 10

$S(t) \backslash x$	0	1
00	01,0	00,0
01	10,0	00,0
10	10,0	00,1

State Diagram => **State Table** => **Excitation Table** => Circuit

$Q_1(t) Q_0(t) \backslash x$	0	1
00	01,0	00,0
01	10,0	00,0
10	10,0	00,1



Mealy Machine

id	$Q_1 Q_0 x$	D_1	D_0	y
0	000	0	1	0
1	001	0	0	0
2	010	1	0	0
3	011	0	0	0
4	100	1	0	0
5	101	0	0	1
6	110	X	X	X
7	111	X	X	X

State Diagram => State Table => Excitation Table => **Circuit**

id	Q_1Q_0x	D_1	D_0	y
0	000	0	1	0
1	001	0	0	0
2	010	1	0	0
3	011	0	0	0
4	100	1	0	0
5	101	0	0	1
6	110	X	X	X
7	111	X	X	X

$D_1(t)$:

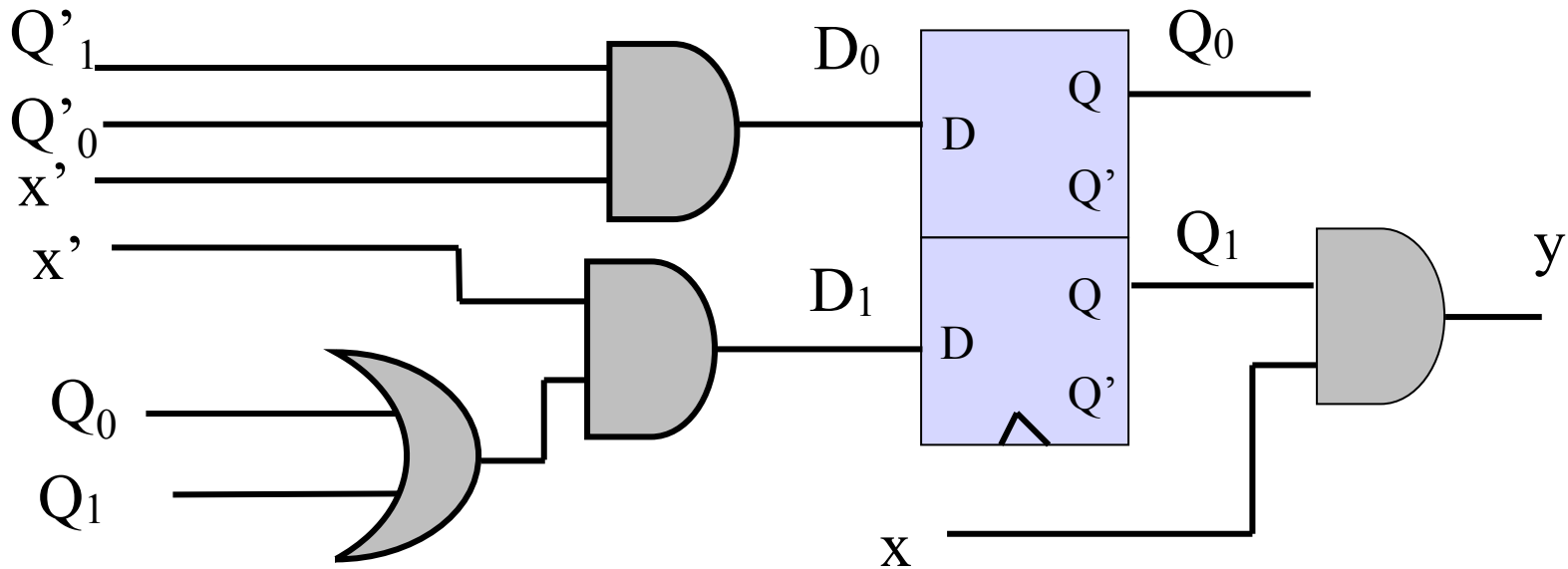
		Q_0	
$x(t)$	⁰ 0	² 1	⁶ X
	¹ 0	³ 0	⁷ X
		Q_1	
		⁴ 1	⁵ 0

$$D_1(t) = x'Q_0 + x'Q_1$$

$$D_0(t) = Q_1'Q_0'x'$$

$$y = Q_1x$$

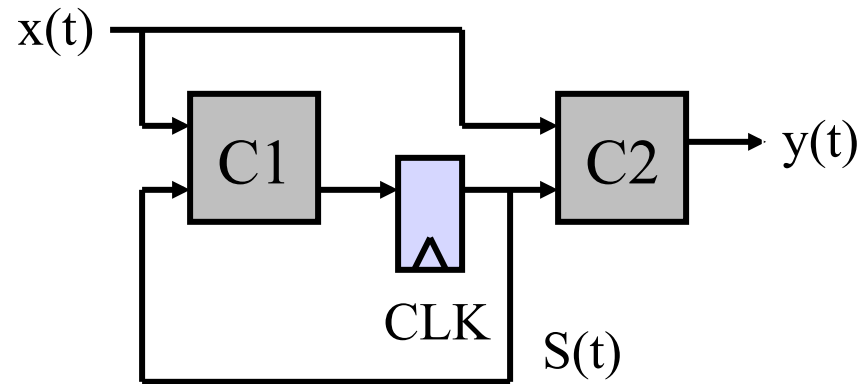
State Diagram => State Table => Excitation Table => **Circuit**



$$D_1(t) = x'Q_0 + x'Q_1$$

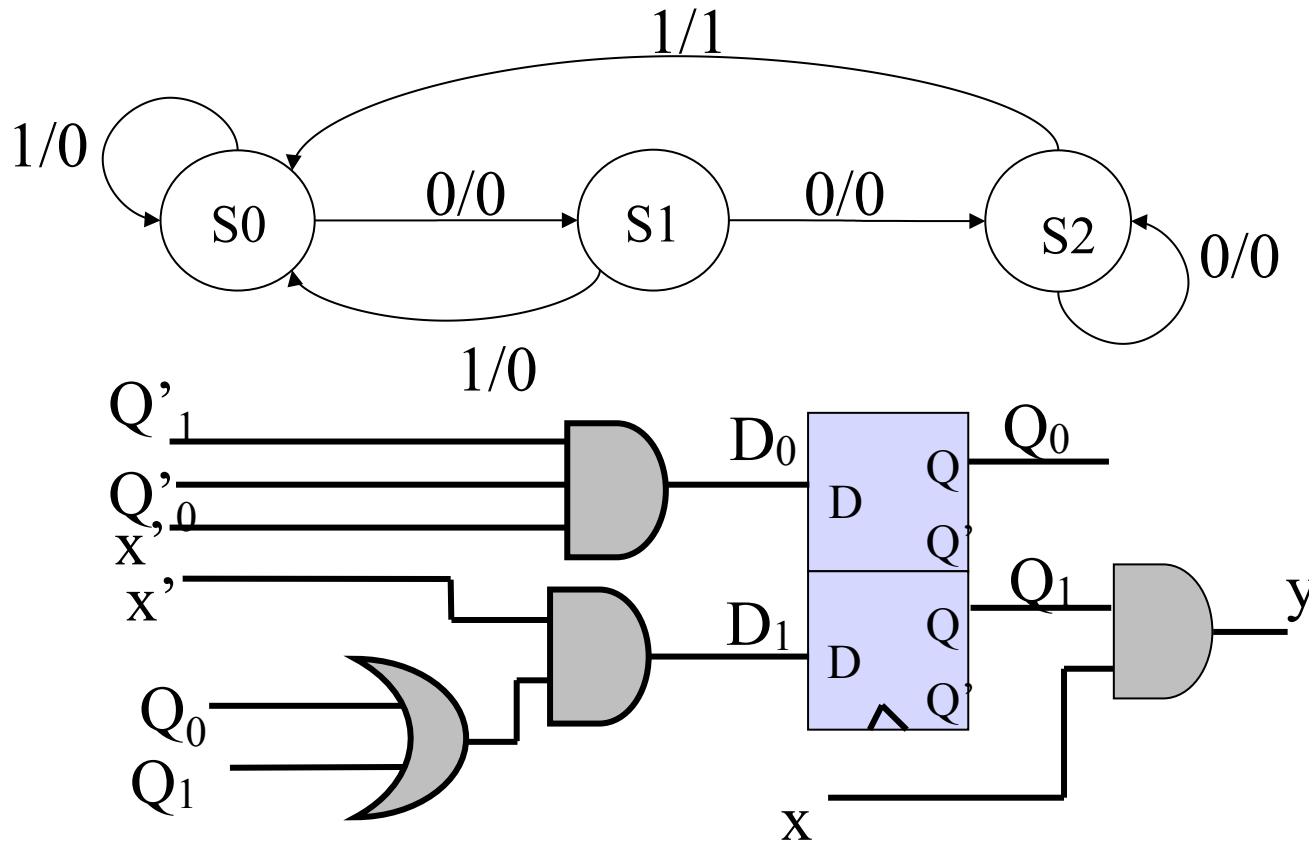
$$D_0(t) = Q'_1Q'_0x'$$

$$y = Q_1x$$



Mealy Machine

State Diagram => State Table => Excitation Table => **Netlist**



iClicker: The relation between the above state diagram and sequential circuit.

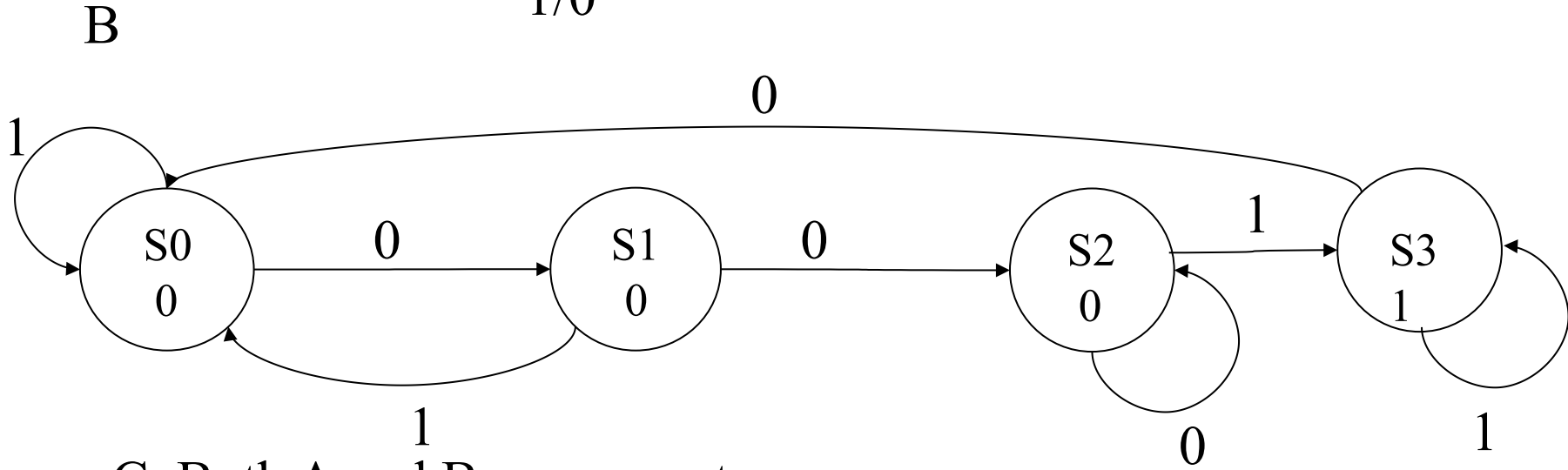
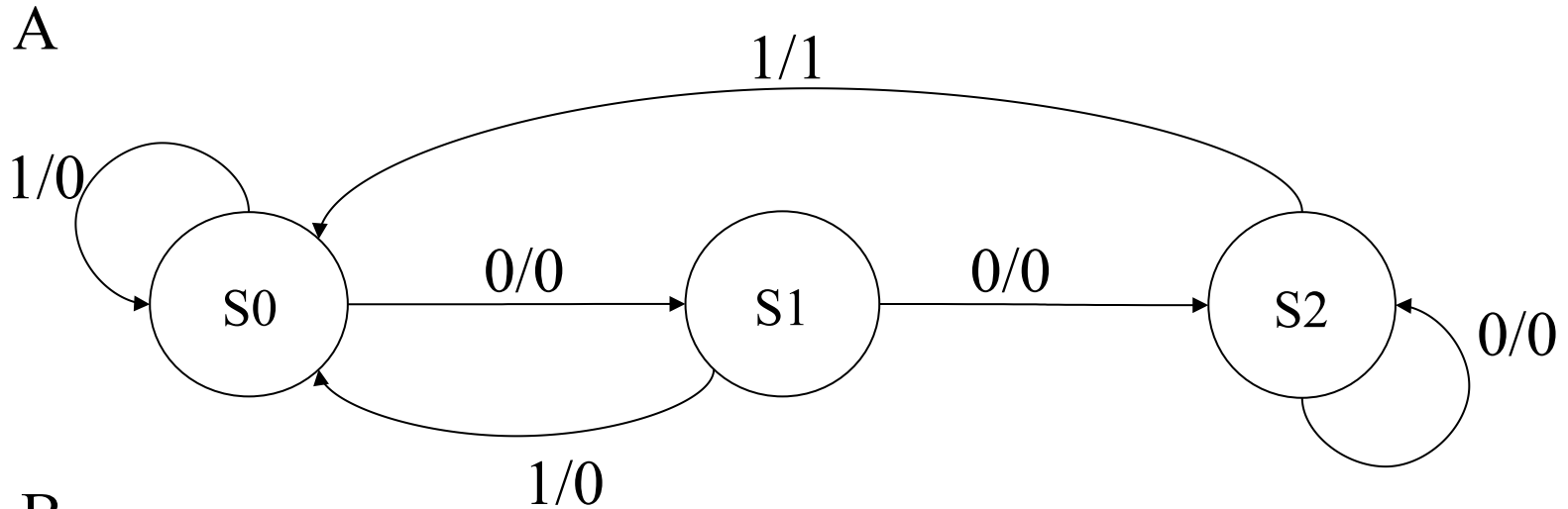
- A. One to one.
- B. One to many
- C. None of the above

Life on Mars?

Pattern Recognizer: A sequential machine has a binary input x (message from a remote robot on Mars). When the sequential machine receives the input sequence $x(t-2, t) = 001$, it means that the robot has detected life on Mars ☺ and the output $y(t) = 1$, otherwise $y(t) = 0$ (no life on Mars ☹).

Draw the Moore FSM for this problem.

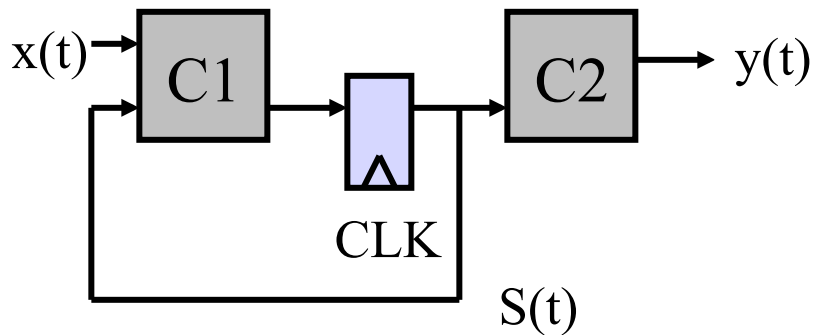
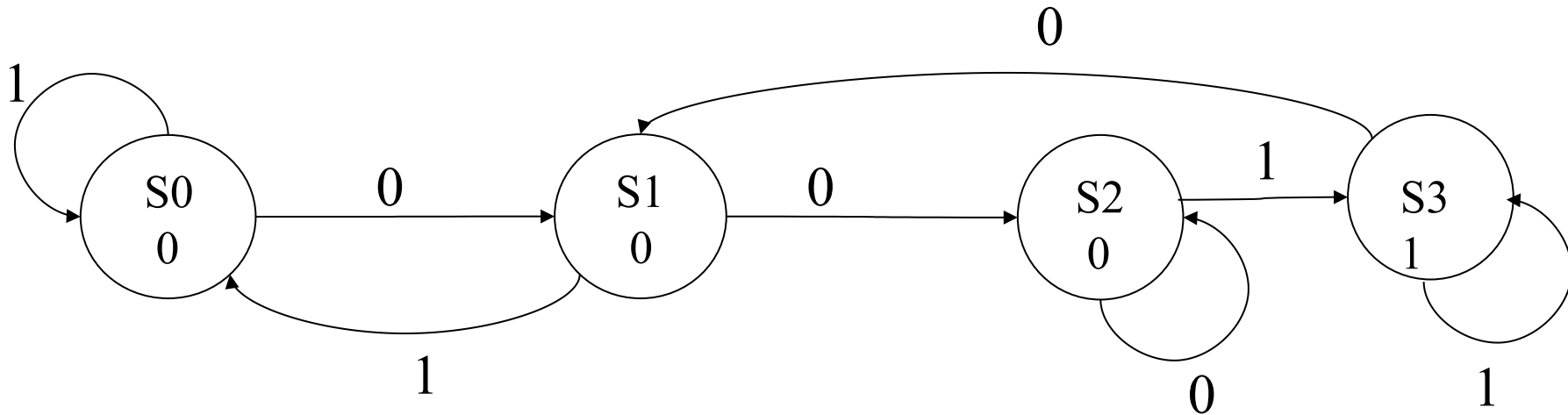
Q: Which of the following diagrams is a correct Moore solution to the '001' pattern recognizer?



C. Both A and B are correct

D. None of the above

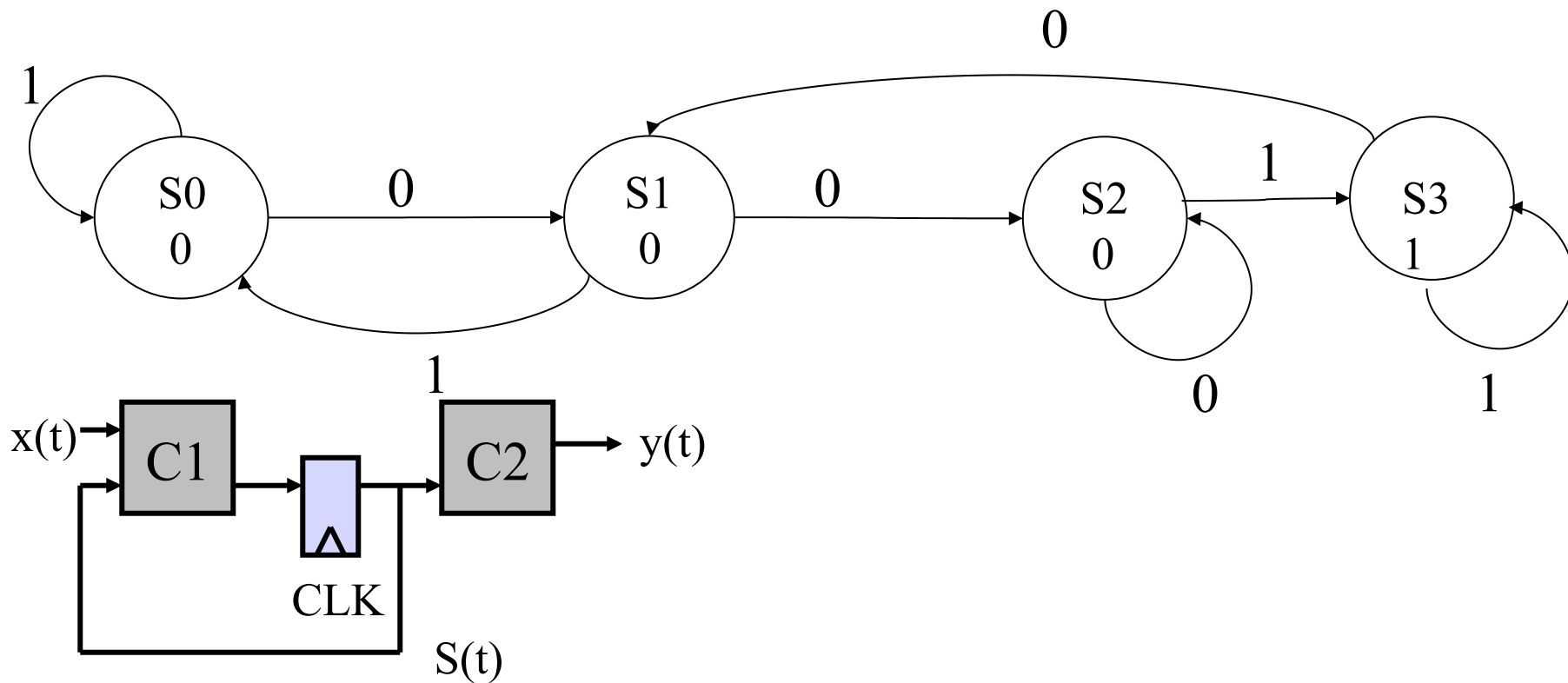
Pattern Recognizer '001'



Moore Machine

Q: What information do we need to design C2?

- A. State table showing (current input $x(t)$, current state $S(t)$ vs. next state, $S(t+1)$)
- B. State table showing (current input, current state vs. current output $y(t)$)
- C. State table showing (current state vs. current output $y(t)$ and next state)
- D. State table showing (current state vs. current output $y(t)$)
- E. None of the above



Moore Machine

$S(t) \backslash x$	0	1
S0	S1,0	S0,0
S1	S2,0	S0,0
S2	S2,0	S3,0
S3	S1,1	S3,1

State Assignment

S0: 00

S1: 01

S2: 10

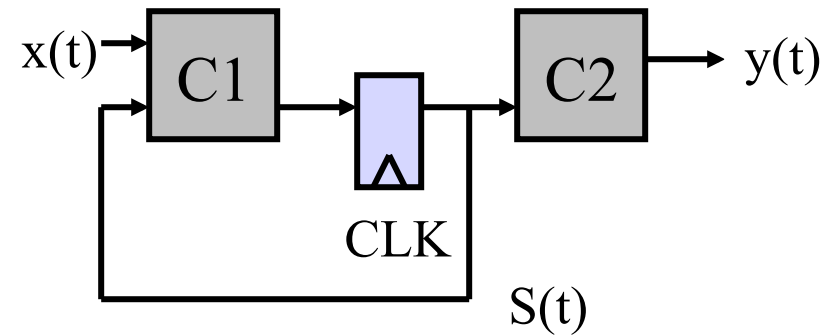
S3: 11

$Q_1(t+1)Q_0(t+1), y$

$S(t) \backslash x$	0	1
00		
01		
10		
11		

$Q_1(t+1)Q_0(t+1), y$

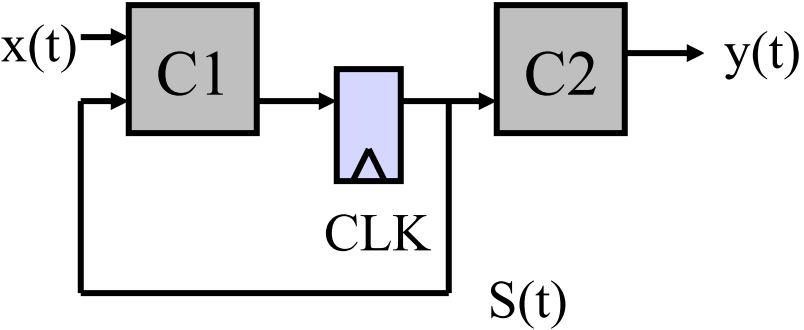
$Q_1Q_0 \backslash x$	0	1
00	01,0	00,0
01	10,0	00,0
10	10,0	11,0
11	01,1	11,1



Moore Machine

id	Q_1Q_0x	D_1	D_0	y
0	000	0	1	0
1	001	0	0	0
2	010	1	0	0
3	011	0	0	0
4	100	1	0	0
5	101	1	1	0
6	110	0	1	1
7	111	1	1	1

id	Q_1Q_0x	D_1	D_0	y
0	000	0	1	0
1	001	0	0	0
2	010	1	0	0
3	011	0	0	0
4	100	1	0	0
5	101	1	1	0
6	110	0	1	1
7	111	1	1	1



Moore Machine

$D_1(t):$

	Q_0			
	0	1	0	1
$x(t)$	0	0	1	1
	Q_1			

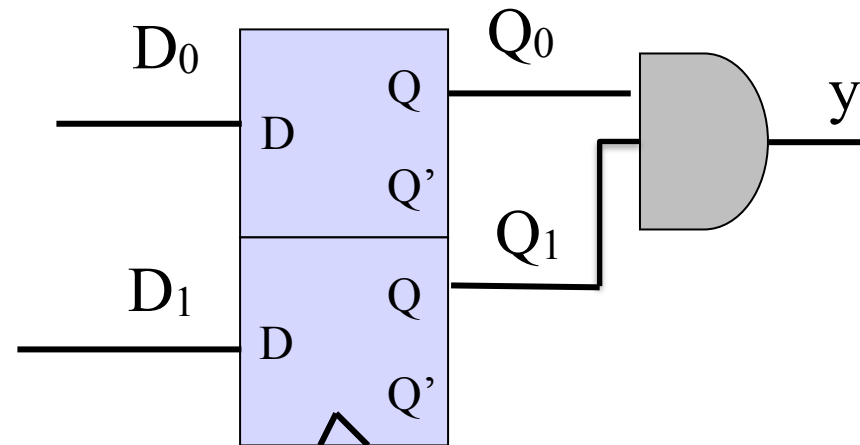
$D_0(t):$

	Q_0			
	1	0	1	0
$x(t)$	0	0	1	1
	Q_1			

$y(t):$

	Q_0			
	0	0	1	0
$x(t)$	0	0	1	0
	Q_1			

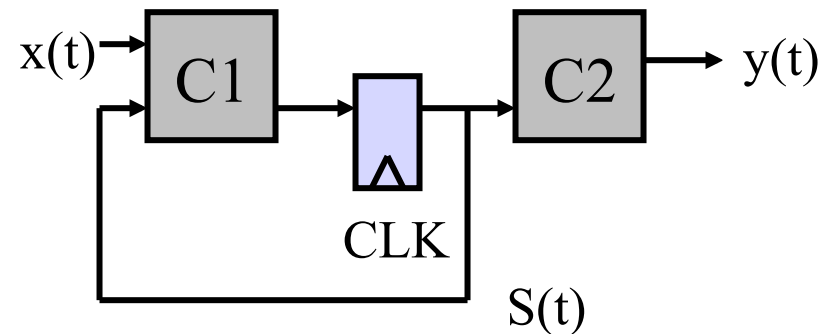
State Diagram => State Table => Excitation Table => **Circuit**



$$D_1(t) = Q_1' Q_0 x' + Q_1 Q_0' + Q_1 x$$

$$D_0(t) = Q_1' Q_0' x' + Q_1 Q_0 + Q_1 x$$

$$y = Q_1 Q_0$$



Moore Machine