



江西理工大学
Jiangxi University of Science and Technology
信息工程学院
School of information engineering



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Clip Lecture series

Digital System Design

Spring_2020



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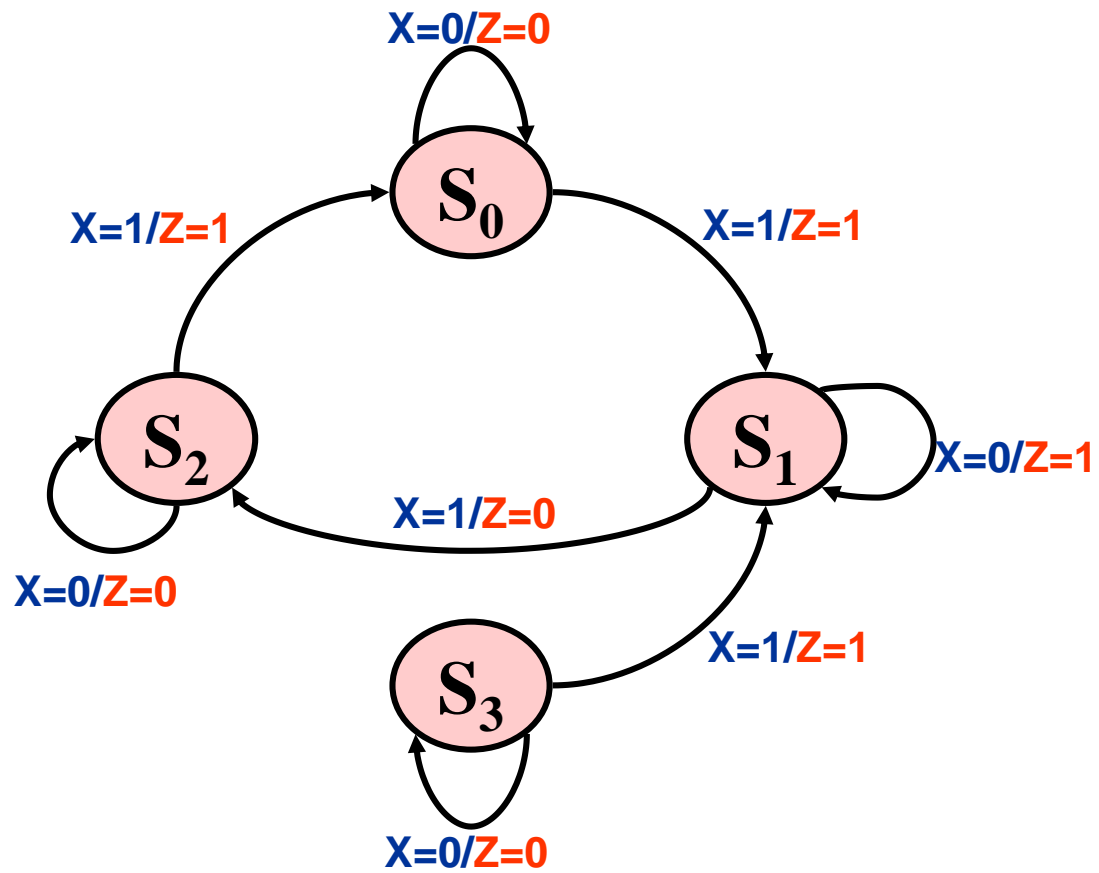
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Sequential circuits

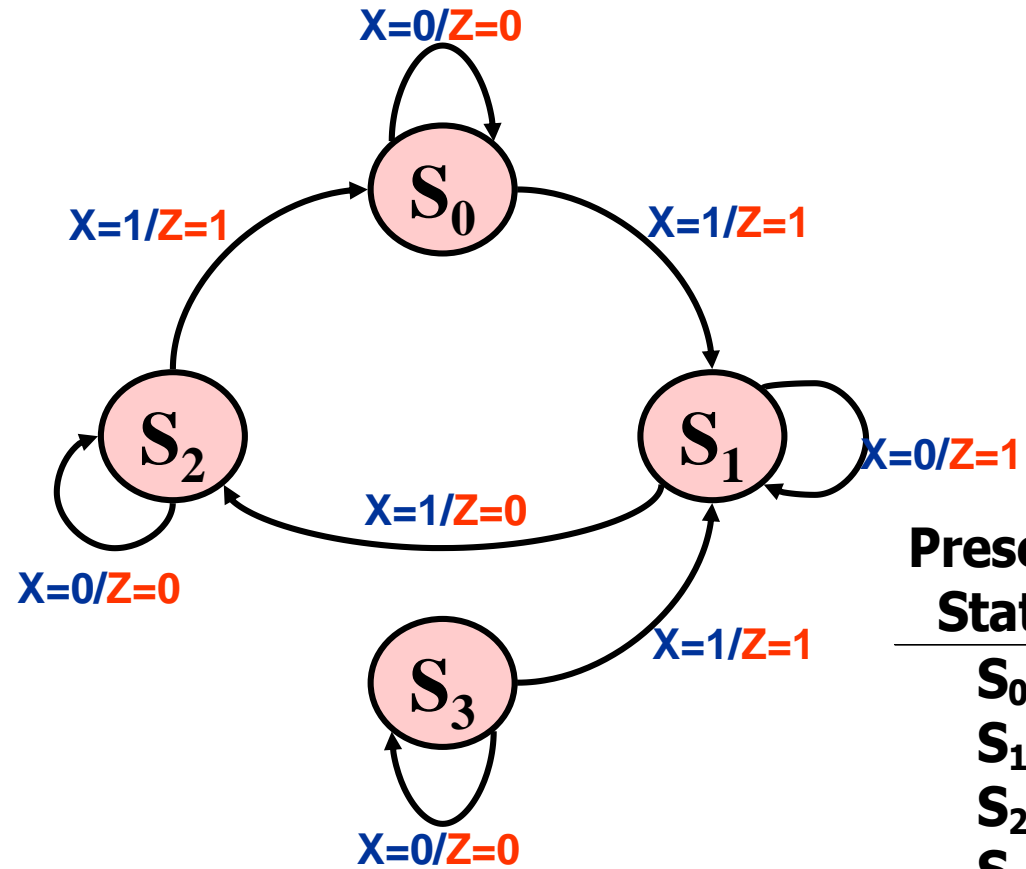
Counters_2



Mealy machine



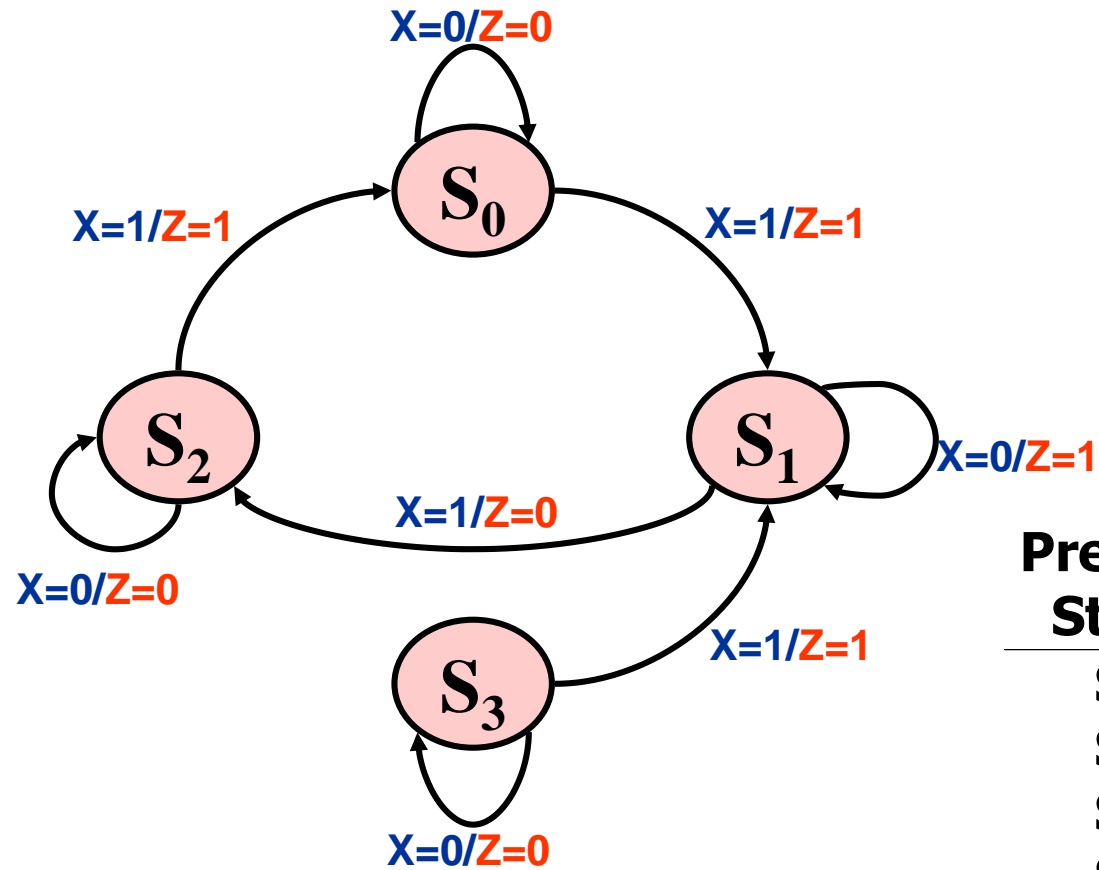
Mealy machine



Present State	Next State		Output	
	X=0	X=1	X=0	X=1
S_0	S_0	S_1	0	1
S_1				
S_2				
S_3				

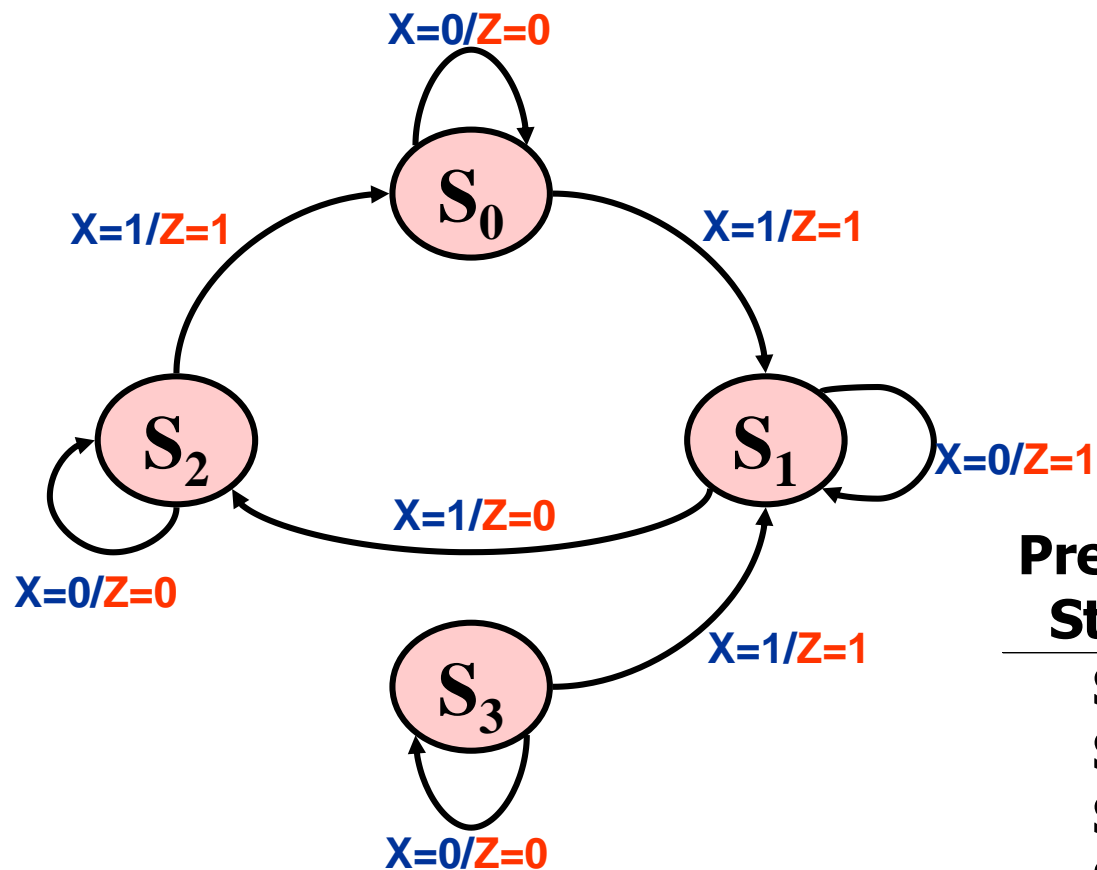


Mealy machine



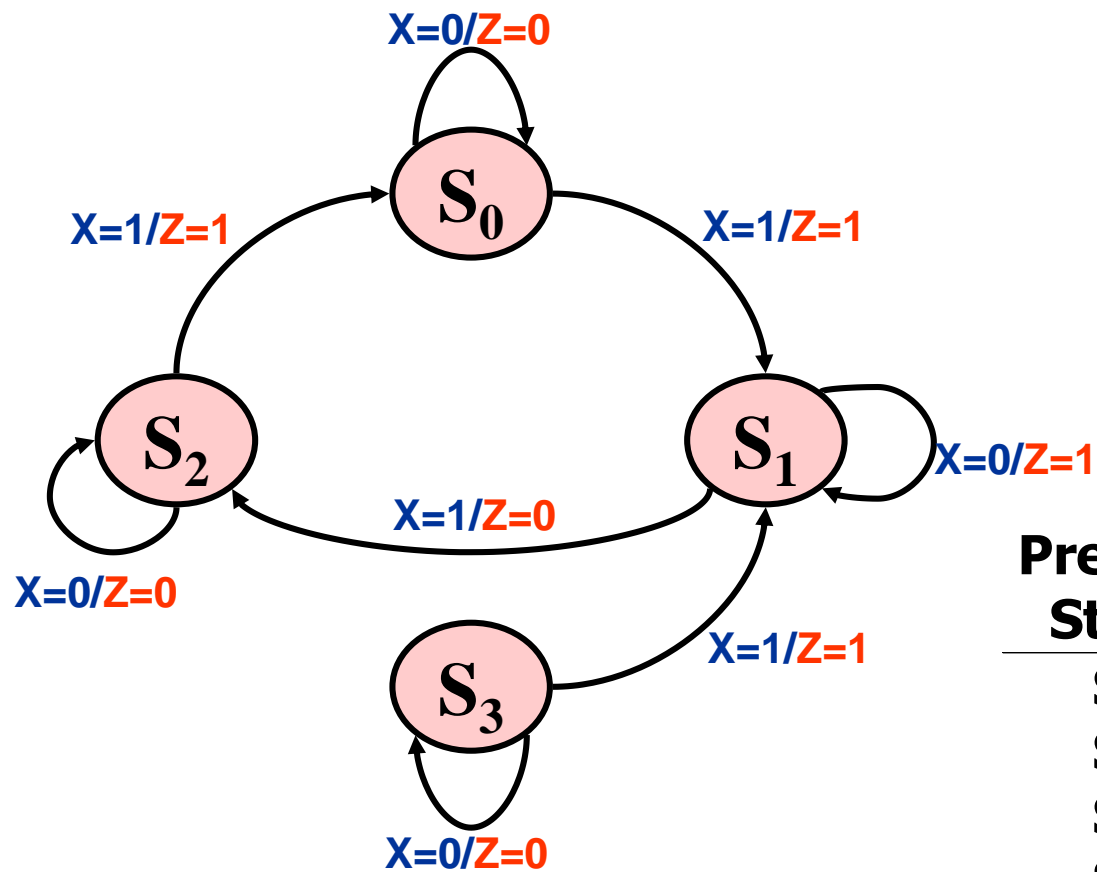
Present State	Next State		Output	
	X=0	X=1	X=0	X=1
S ₀	S ₀	S ₁	0	1
S ₁	S ₁	S ₂	1	1
S ₂				
S ₃				

Mealy machine



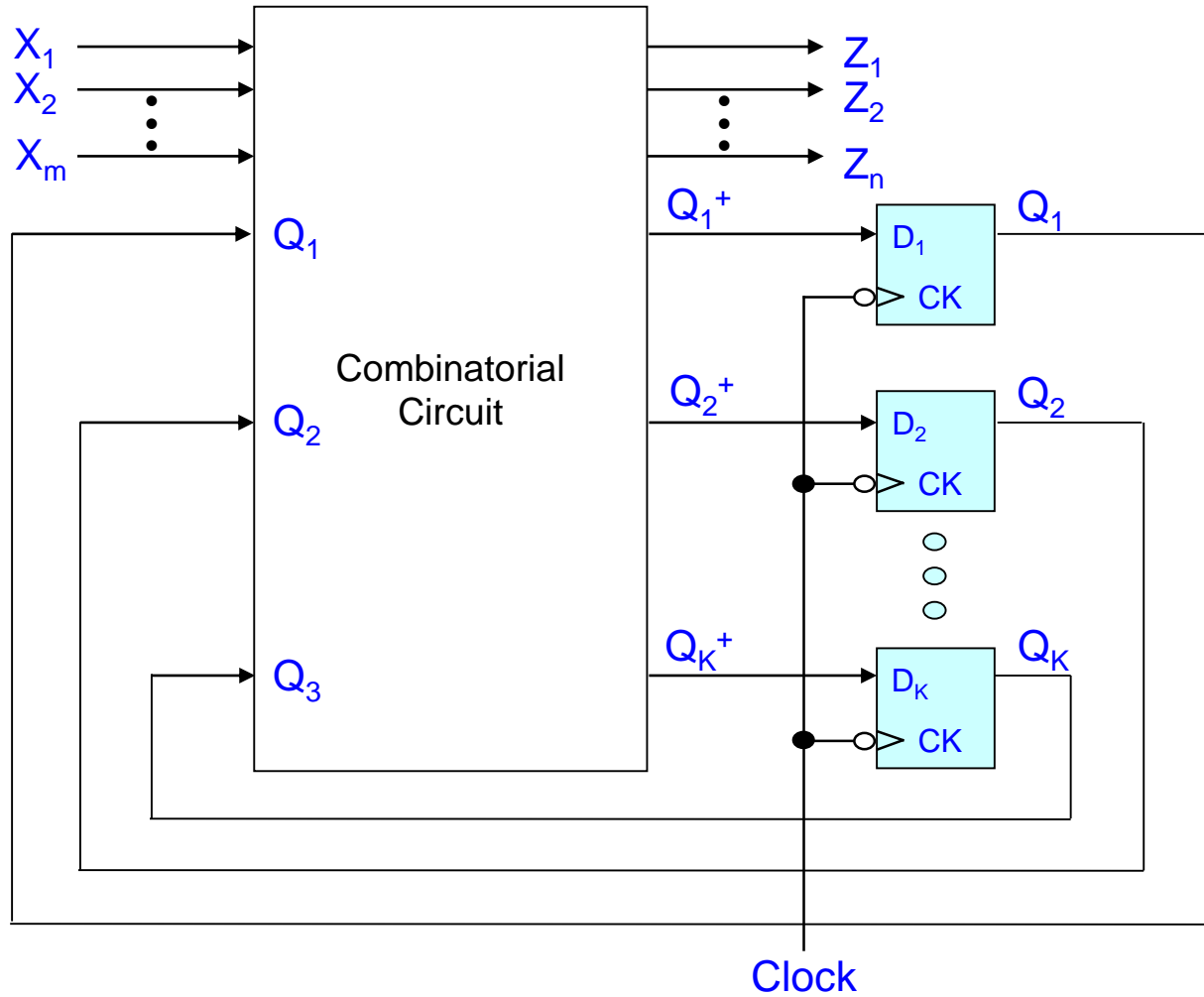
Present State	Next State		Output	
	X=0	X=1	X=0	X=1
S ₀	S ₀	S ₁	0	1
S ₁	S ₁	S ₂	1	1
S ₂	S ₂	S ₀	0	1
S ₃				

Mealy machine



Present State	Next State		Output	
	X=0	X=1	X=0	X=1
S ₀	S ₀	S ₁	0	1
S ₁	S ₁	S ₂	1	1
S ₂	S ₂	S ₀	0	1
S ₃	S ₃	S ₁	0	1

The general form of Mealy machine



A More Complex Sequence Detector



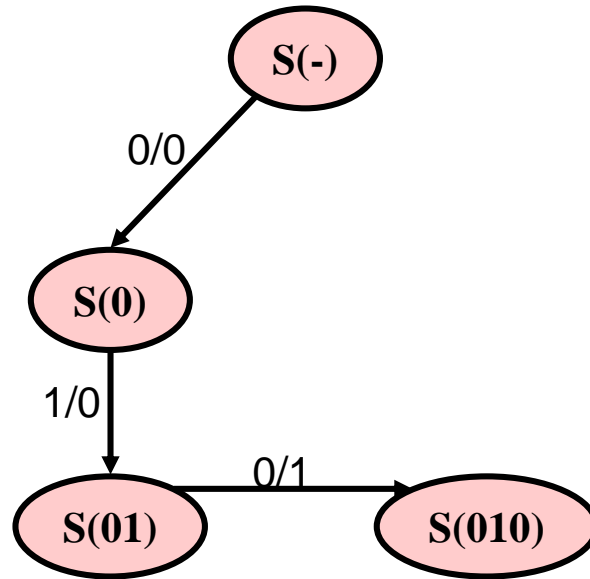
Design a sequence detector whose output Z is one if the input sequence is 010 or 1001

X =	0	0	1	0	1	0	0	1	0	0	0	1	0	0	1	1	0
Z =	0	0	0	1	0	1	0	1	1	0	0	0	1	0	1	0	0

Mealy Sequence Detector



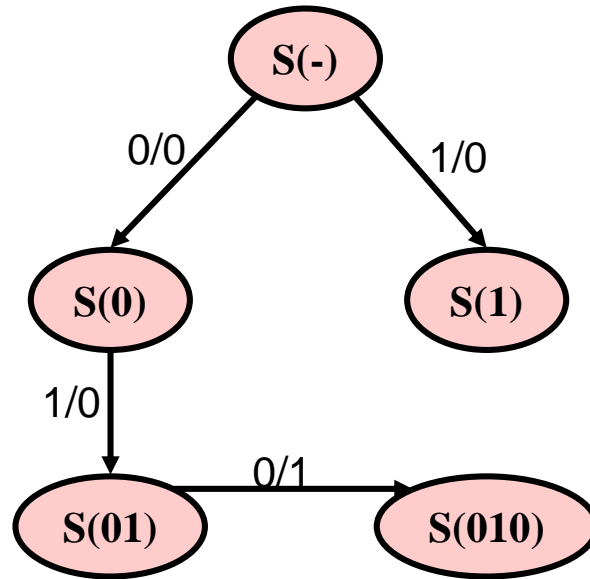
Target Sequences:
010
1001



Mealy Sequence Detector



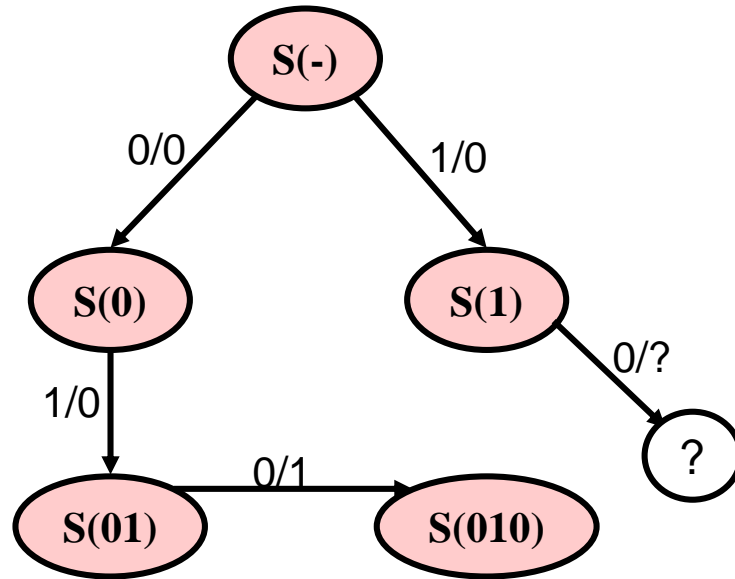
Target Sequences:
010
1001



Mealy Sequence Detector



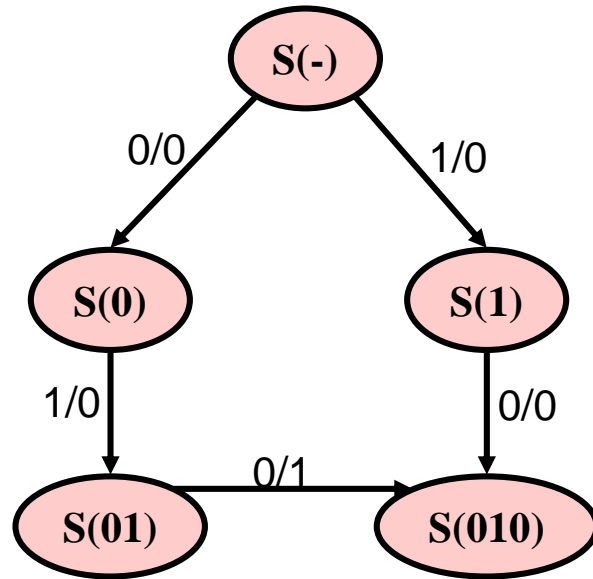
Target Sequences:
010
1001



Mealy Sequence Detector



Target Sequences:
010
1001



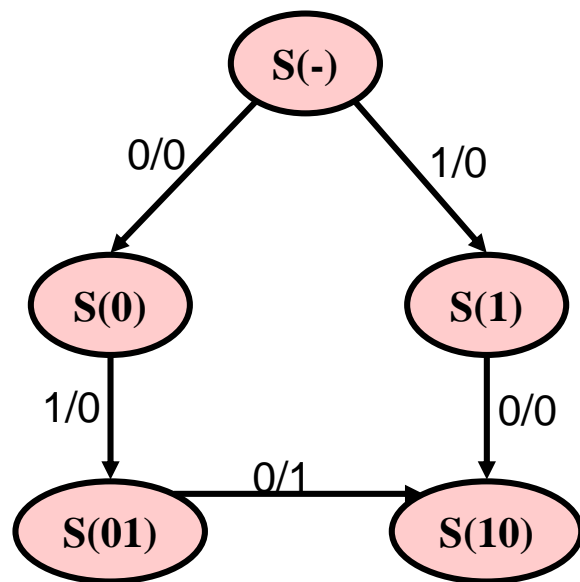
Mealy Sequence Detector



Target Sequences:

010

1001



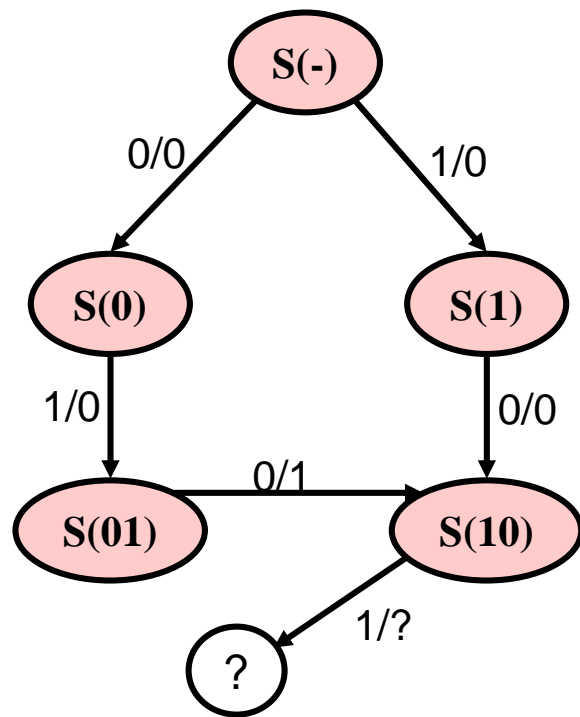
Mealy Sequence Detector



Target Sequences:

010

1001

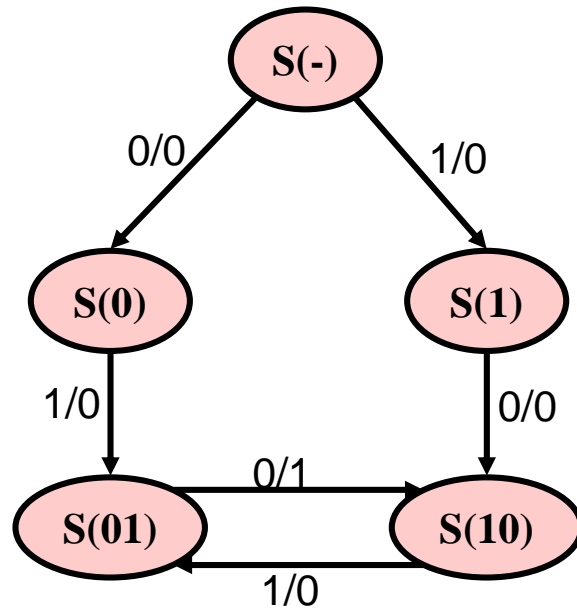


Mealy Sequence Detector

Target Sequences:

010

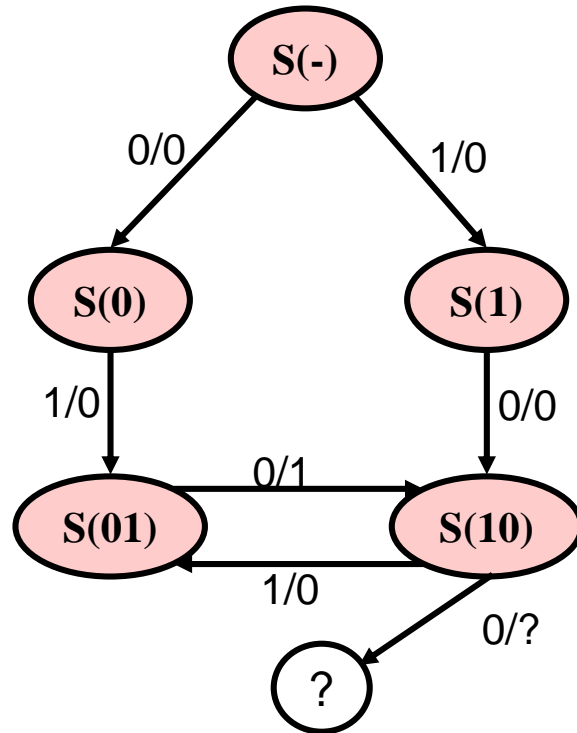
1001



Mealy Sequence Detector



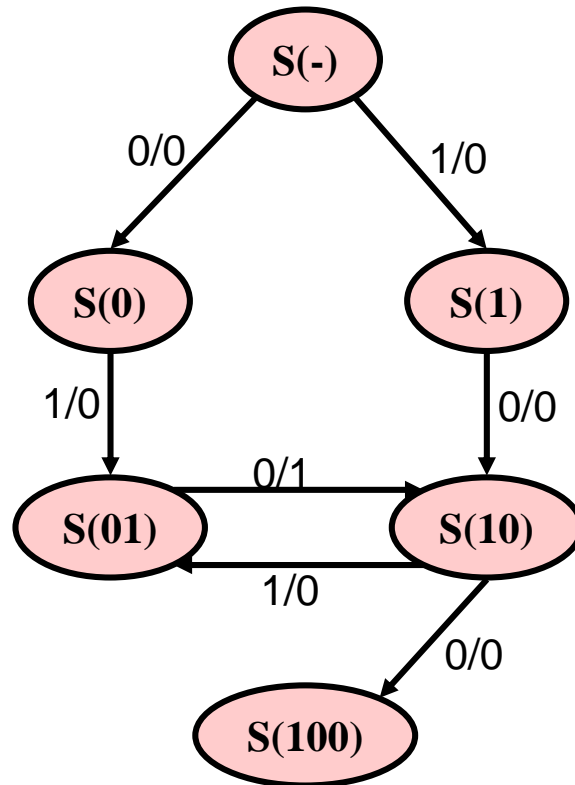
Target Sequences:
010
1001



Mealy Sequence Detector



Target Sequences:
010
1001



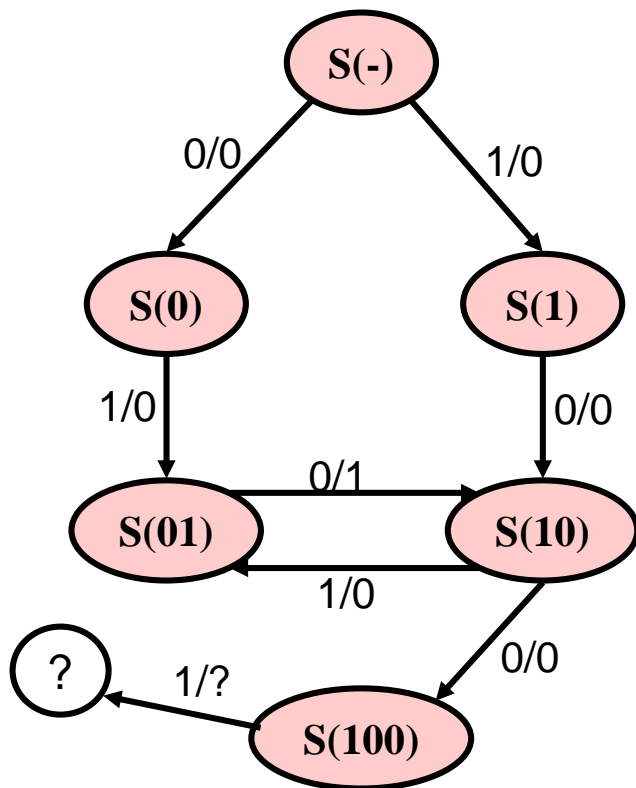
Mealy Sequence Detector



Target Sequences:

010

1001



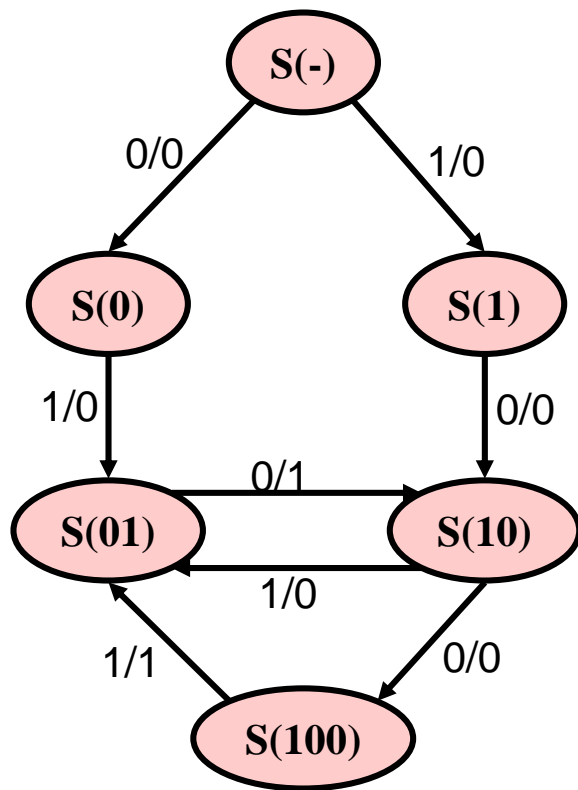
Mealy Sequence Detector



Target Sequences:

010

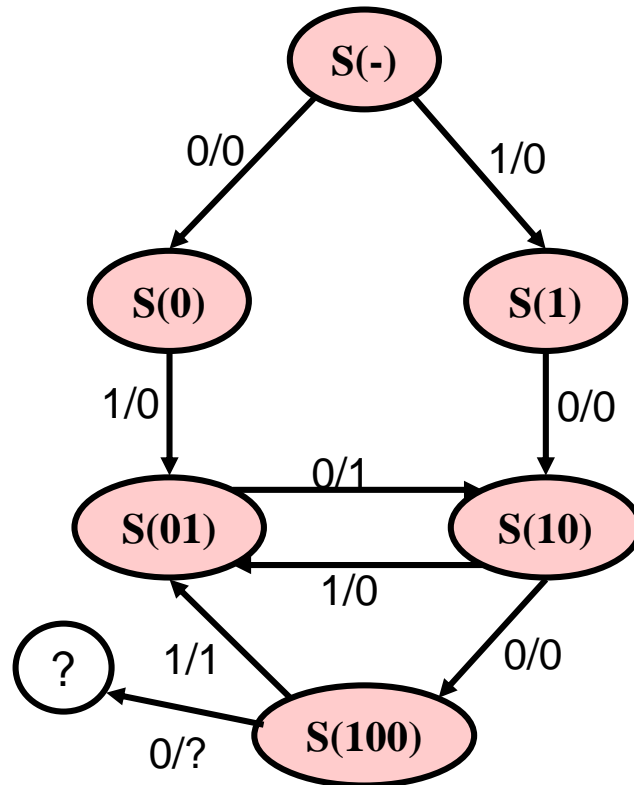
1001



Mealy Sequence Detector



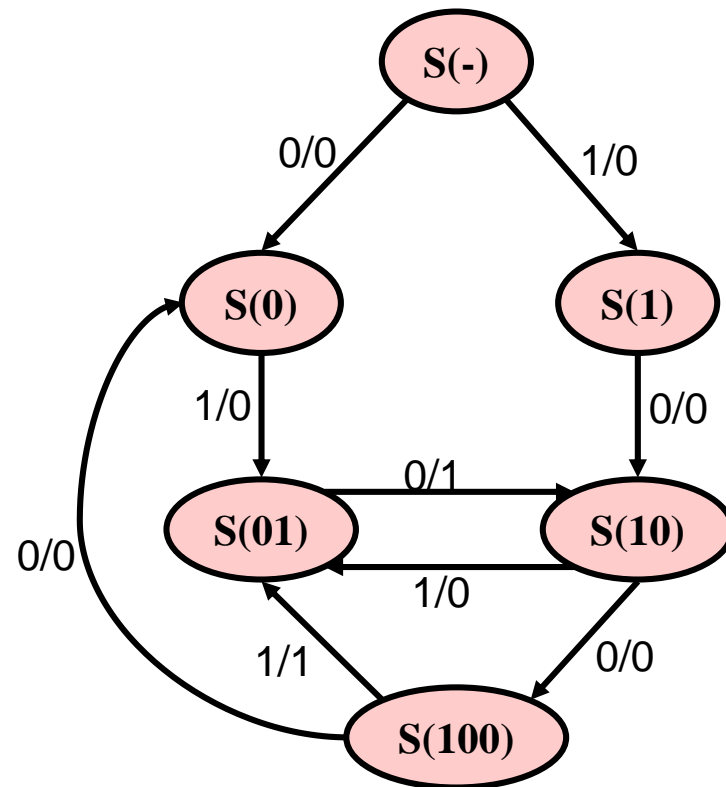
Target Sequences:
010
1001



Mealy Sequence Detector

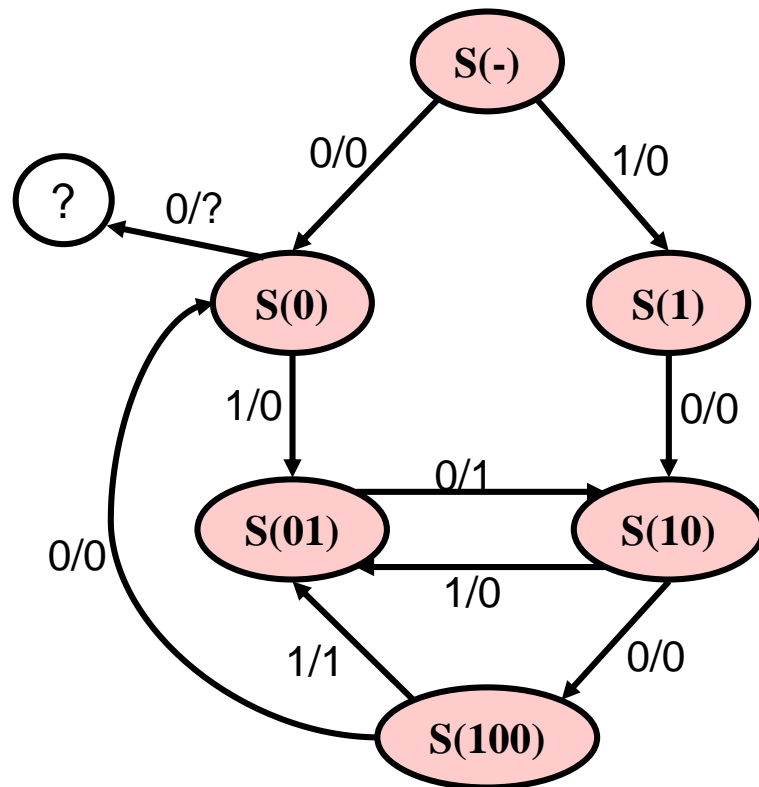


Target Sequences:
010
1001



Mealy Sequence Detector

Target Sequences:
010
1001

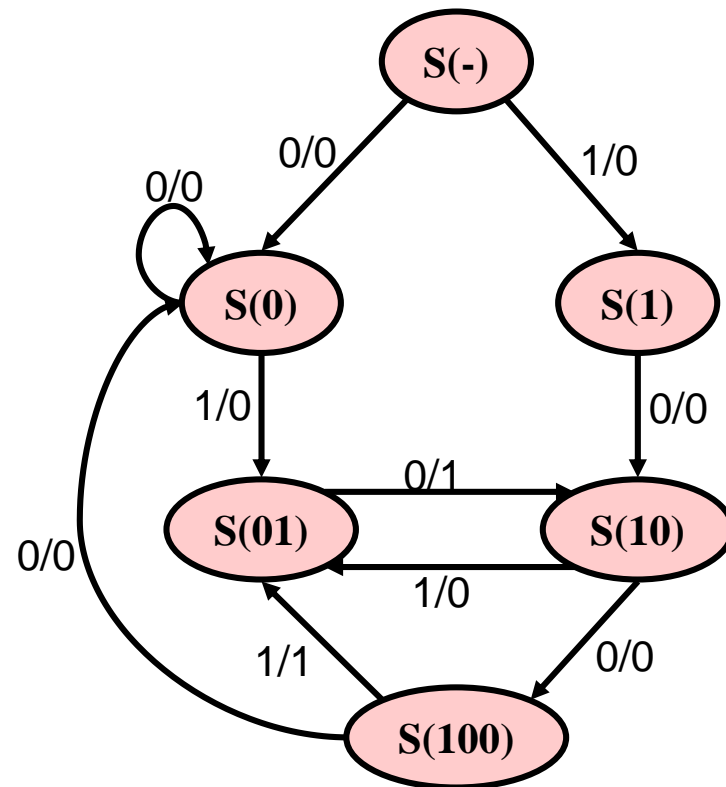


Mealy Sequence Detector

Target Sequences:

010

1001



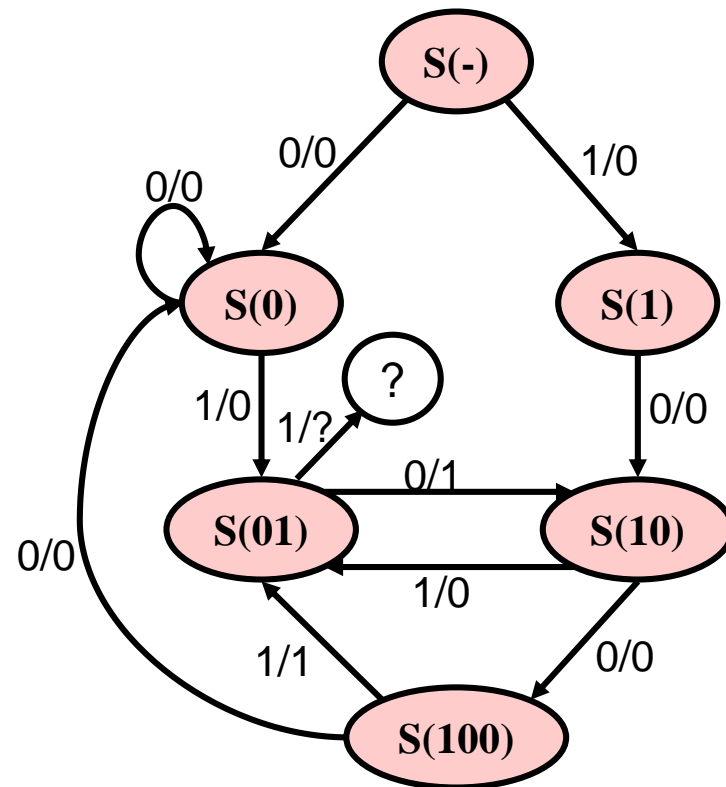
Mealy Sequence Detector



Target Sequences:

010

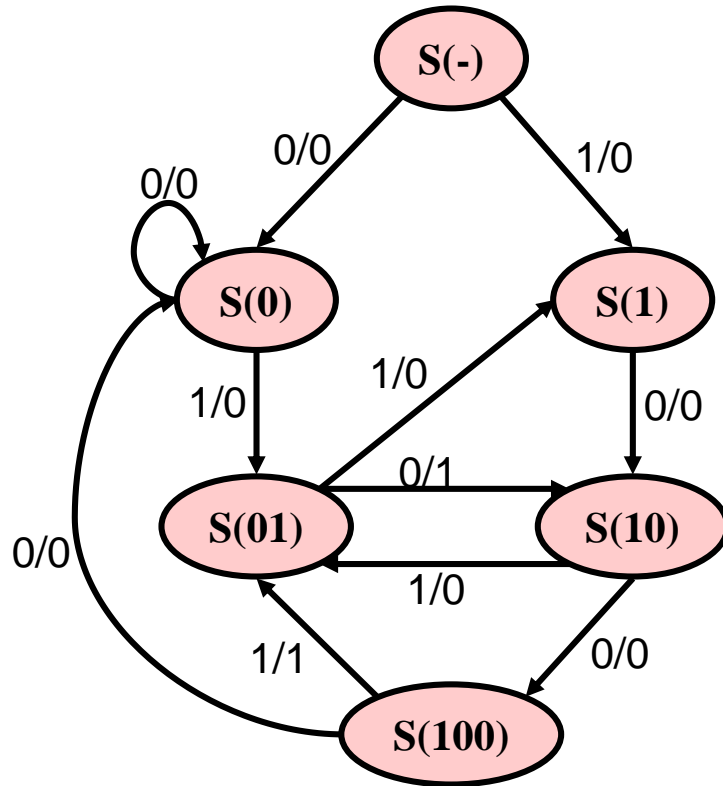
1001



Mealy Sequence Detector



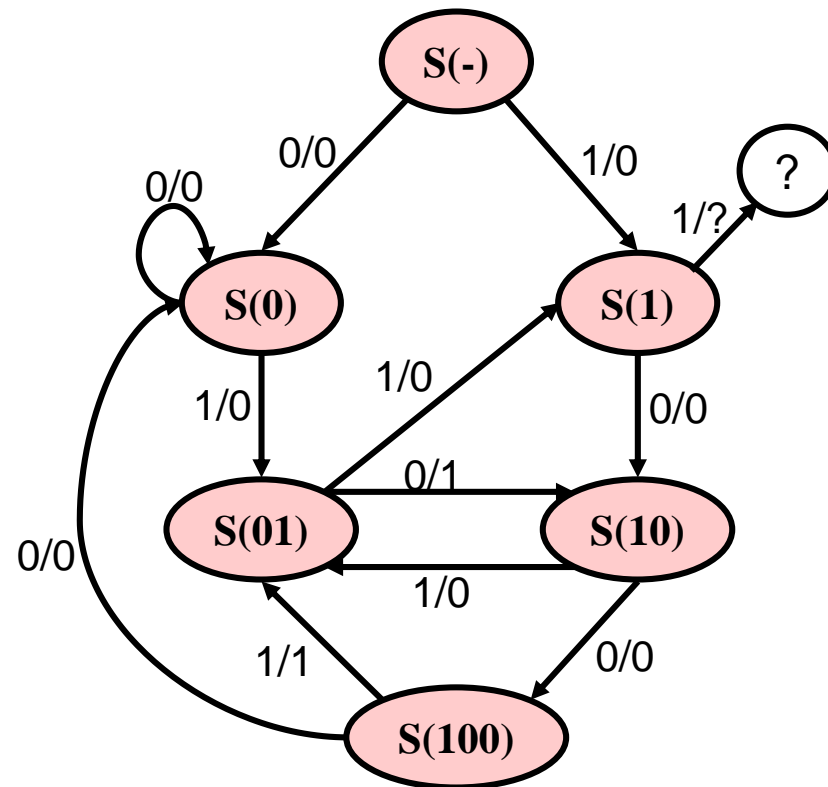
Target Sequences:
010
1001



Mealy Sequence Detector



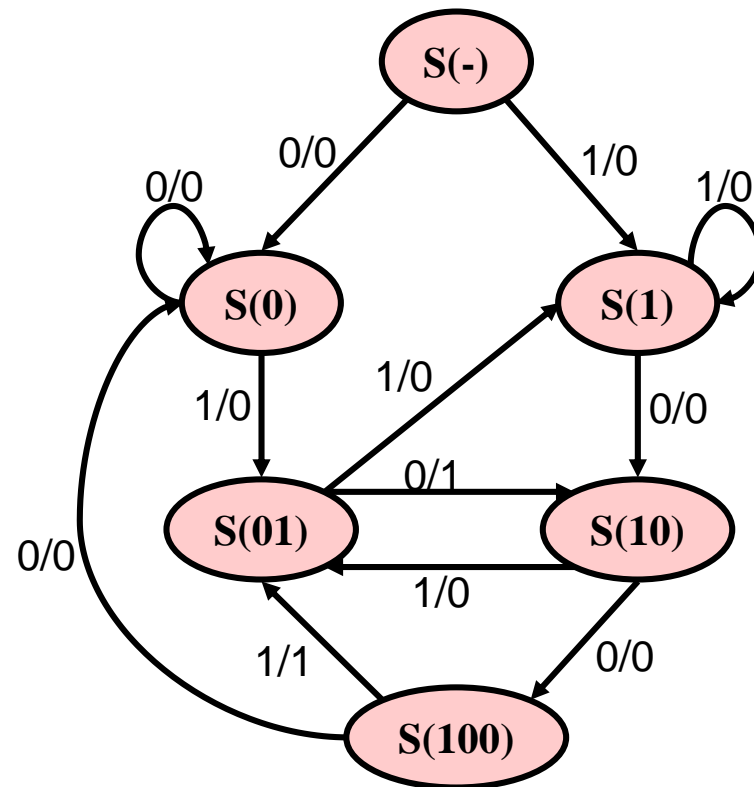
Target Sequences:
010
1001



Mealy Sequence Detector



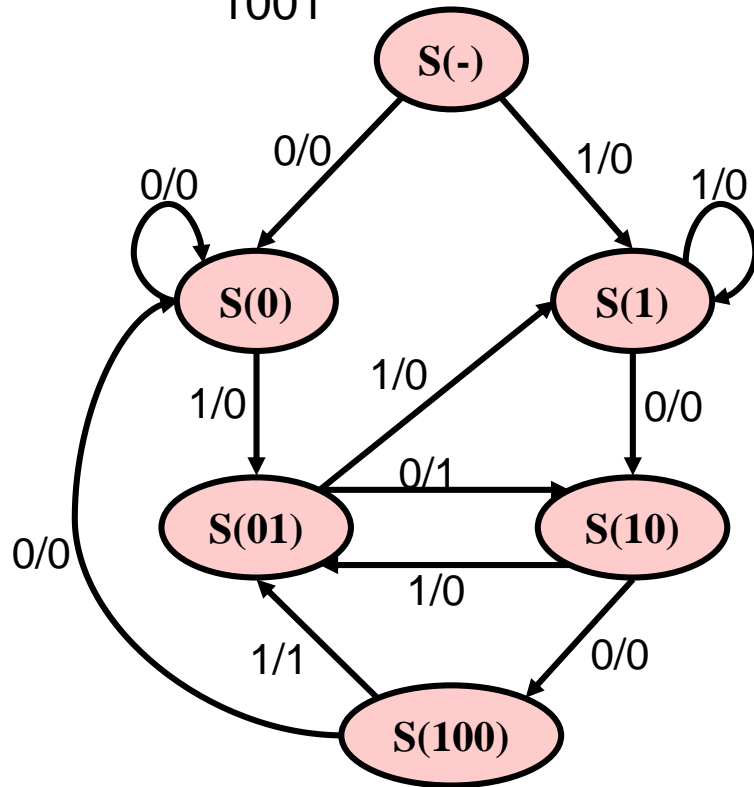
Target Sequences:
010
1001



Mealy Sequence Detector

Target Sequences:

010
1001



Present State	Next State		Output	
	X=0	X=1	X=0	X=1
S(-)	S(0)	S(1)	0	0
S(0)	S(0)	S(01)	0	0
S(1)	S(10)	S(1)	0	0
S(01)	S(10)	S(1)	1	0
S(10)	S(100)	S(01)	0	0
S(100)	S(0)	S(01)	0	1

Mealy Sequence Detector



Present State	Next State		Output	
	X=0	X=1	X=0	X=1
S(-)	S(0)	S(1)	0	0
S(0)	S(0)	S(01)	0	0
S(1)	S(10)	S(1)	0	0
S(01)	S(10)	S(1)	1	0
S(10)	S(100)	S(01)	0	0
S(100)	S(0)	S(01)	0	1

State	Code
	$Q_2Q_1Q_0$
S(-)	000
S(0)	001
S(1)	010
S(01)	011
S(10)	100
S(100)	101

Mealy Sequence Detector

Present State	Next State		Output	
	X=0	X=1	X=0	X=1
000	S(0)	S(1)	0	0
S(0)	S(0)	S(01)	0	0
S(1)	S(10)	S(1)	0	0
S(01)	S(10)	S(1)	1	0
S(10)	S(100)	S(01)	0	0
S(100)	S(0)	S(01)	0	1

State	Code Q ₂ Q ₁ Q ₀
S(-)	000
S(0)	001
S(1)	010
S(01)	011
S(10)	100
S(100)	101

Mealy Sequence Detector



Present State	Next State		Output	
	X=0	X=1	X=0	X=1
000	001	S(1)	0	0
001	001	S(01)	0	0
S(1)	S(10)	S(1)	0	0
S(01)	S(10)	S(1)	1	0
S(10)	S(100)	S(01)	0	0
S(100)	001	S(01)	0	1

State	Code $Q_2Q_1Q_0$
S(-)	000
S(0)	001
S(1)	010
S(01)	011
S(10)	100
S(100)	101

Mealy Sequence Detector



Present State	Next State		Output	
	X=0	X=1	X=0	X=1
000	001	010	0	0
001	001	S(01)	0	0
010	S(10)	010	0	0
S(01)	S(10)	010	1	0
S(10)	S(100)	S(01)	0	0
S(100)	001	S(01)	0	1

State	Code Q ₂ Q ₁ Q ₀
S(-)	000
S(0)	001
S(1)	010
S(01)	011
S(10)	100
S(100)	101

Mealy Sequence Detector

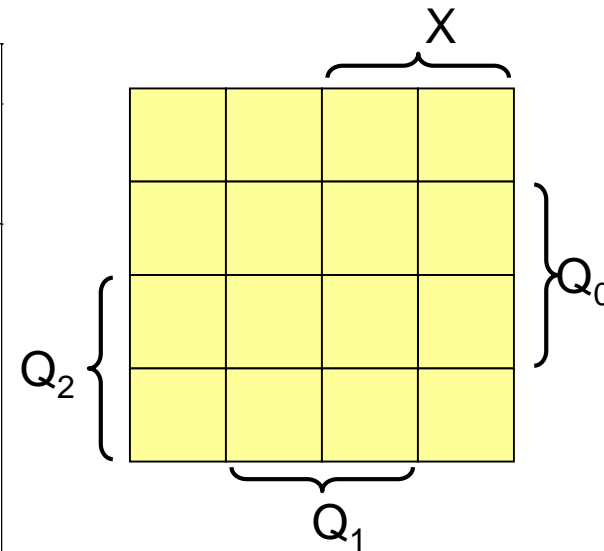


Present State	Next State		Output	
	X=0	X=1	X=0	X=1
000	001	010	0	0
001	001	011	0	0
010	S(10)	010	0	0
011	S(10)	010	1	0
S(10)	S(100)	011	0	0
S(100)	001	011	0	1

State	Code $Q_2Q_1Q_0$
S(-)	000
S(0)	001
S(1)	010
S(01)	011
S(10)	100
S(100)	101

Mealy Sequence Detector

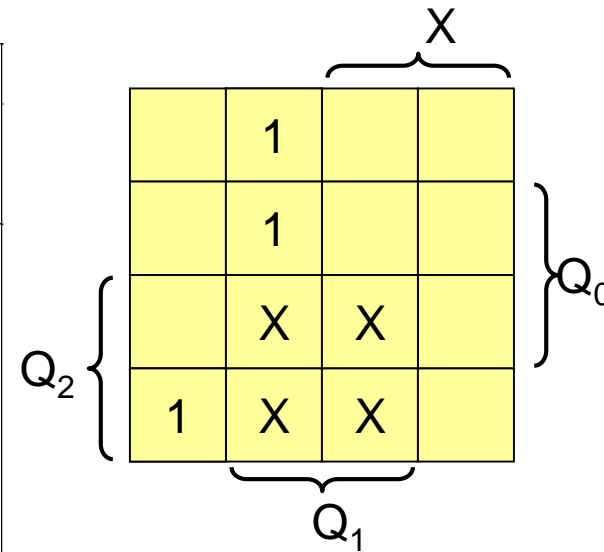
Present State $Q_2Q_1Q_0$	Next State		Output	
	$X=0$ $Q_2^+Q_1^+Q_0^+$	$X=1$ $Q_2^+Q_1^+Q_0^+$	$X=0$	$X=1$
000	001	010	0	0
001	001	011	0	0
010	100	010	0	0
011	100	010	1	0
100	101	011	0	0
101	001	011	0	1



Which Karnaugh map cells are don't cares?

Mealy Sequence Detector

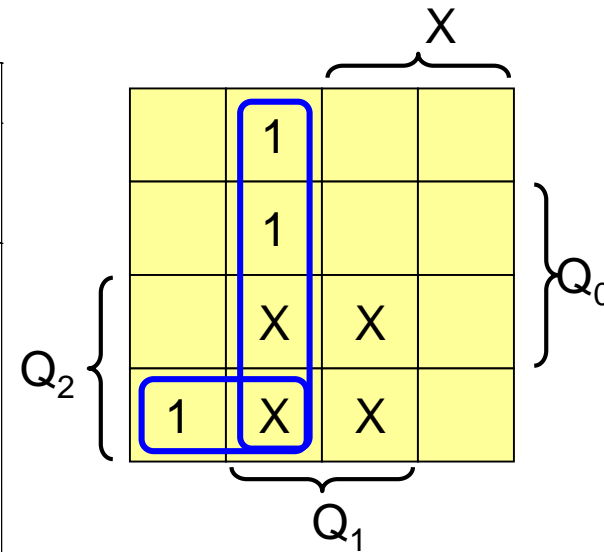
Present State $Q_2Q_1Q_0$	Next State		Output	
	$X=0$ $Q_2^+Q_1^+Q_0^+$	$X=1$ $Q_2^+Q_1^+Q_0^+$	$X=0$	$X=1$
000	001	010	0	0
001	001	011	0	0
010	100	010	0	0
011	100	010	1	0
100	101	011	0	0
101	001	011	0	1



$$D_2 =$$

Mealy Sequence Detector

Present State $Q_2Q_1Q_0$	Next State		Output	
	X=0 $Q_2^+Q_1^+Q_0^+$	X=1 $Q_2^+Q_1^+Q_0^+$	X=0	X=1
000	001	010	0	0
001	001	011	0	0
010	100	010	0	0
011	100	010	1	0
100	101	011	0	0
101	001	011	0	1

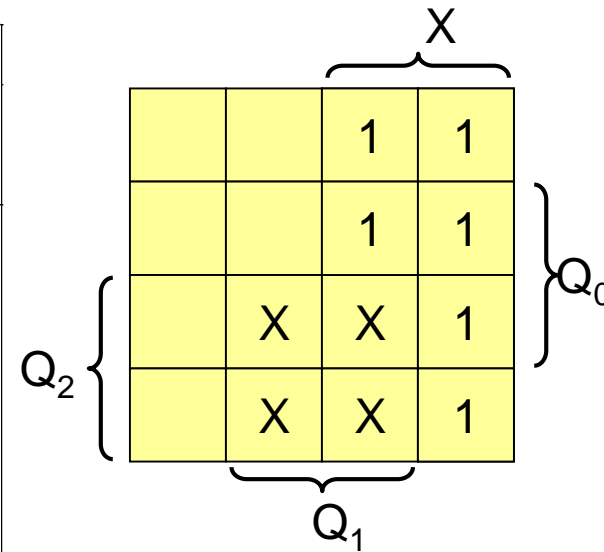


$$D_2 = Q_1X' + Q_2Q_0'X'$$

Mealy Sequence Detector



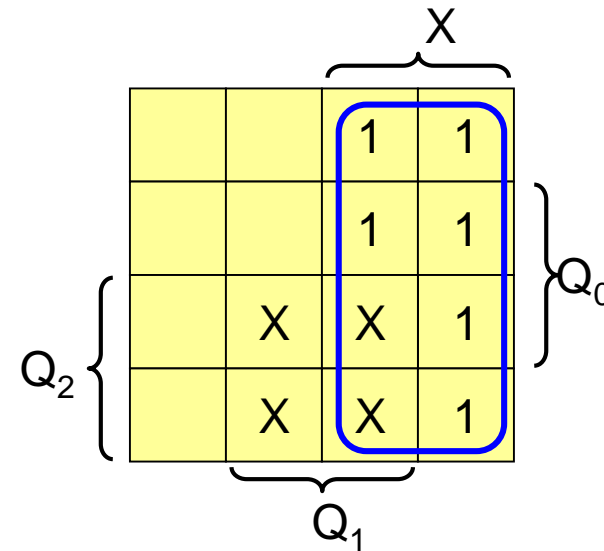
Present State $Q_2Q_1Q_0$	Next State		Output	
	$X=0$ $Q_2^+Q_1^+Q_0^+$	$X=1$ $Q_2^+Q_1^+Q_0^+$	$X=0$	$X=1$
000	001	010	0	0
001	001	011	0	0
010	100	010	0	0
011	100	010	1	0
100	101	011	0	0
101	001	011	0	1



$$D_1 =$$

Mealy Sequence Detector

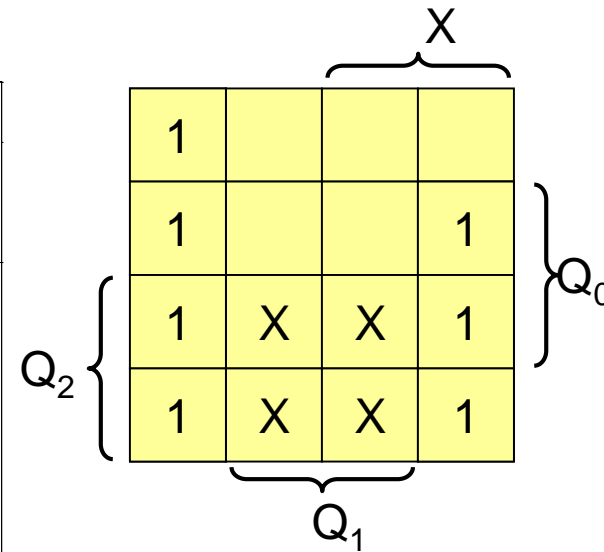
Present State $Q_2Q_1Q_0$	Next State		Output	
	X=0 $Q_2^+Q_1^+Q_0^+$	X=1 $Q_2^+Q_1^+Q_0^+$	X=0	X=1
000	001	010	0	0
001	001	011	0	0
010	100	010	0	0
011	100	010	1	0
100	101	011	0	0
101	001	011	0	1



$$D_1 = X$$

Mealy Sequence Detector

Present State $Q_2Q_1Q_0$	Next State		Output	
	X=0 $Q_2^+Q_1^+Q_0^+$	X=1 $Q_2^+Q_1^+Q_0^+$	X=0	X=1
000	001	010	0	0
001	001	011	0	0
010	100	010	0	0
011	100	010	1	0
100	101	011	0	0
101	001	011	0	1

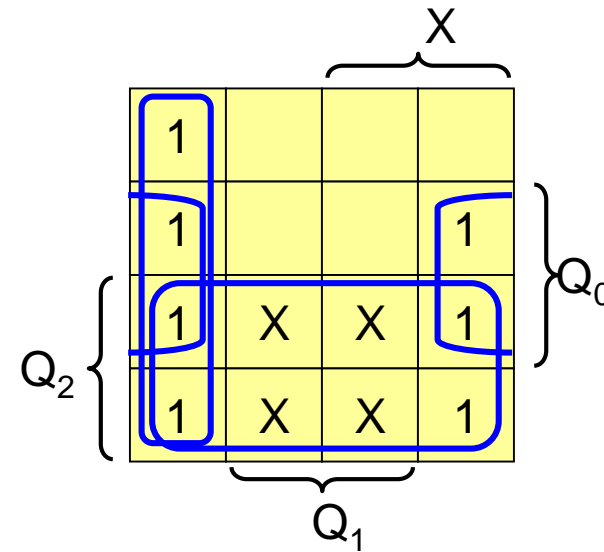


$D_0 =$

Mealy Sequence Detector



Present State $Q_2Q_1Q_0$	Next State		Output	
	$X=0$	$X=1$	$X=0$	$X=1$
	$Q_2^+Q_1^+Q_0^+$	$Q_2^+Q_1^+Q_0^+$		
000	001	010	0	0
001	001	011	0	0
010	100	010	0	0
011	100	010	1	0
100	101	011	0	0
101	001	011	0	1

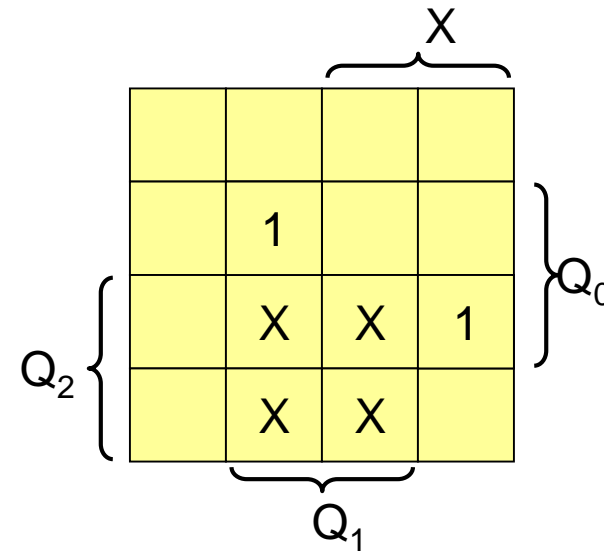


$$D_0 = Q_2 + Q_1'X' + Q_1'Q_0$$

Mealy Sequence Detector



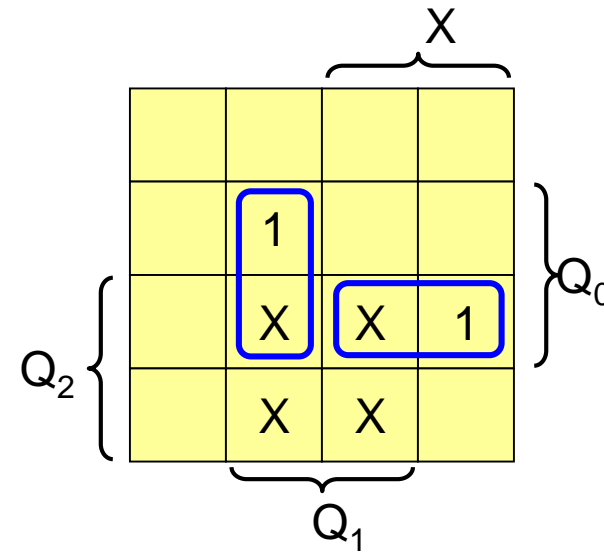
Present State $Q_2Q_1Q_0$	Next State		Output	
	X=0 $Q_2^+Q_1^+Q_0^+$	X=1 $Q_2^+Q_1^+Q_0^+$	X=0	X=1
000	001	010	0	0
001	001	011	0	0
010	100	010	0	0
011	100	010	1	0
100	101	011	0	0
101	001	011	0	1



Z =

Mealy Sequence Detector

Present State $Q_2Q_1Q_0$	Next State		Output	
	X=0 $Q_2^+Q_1^+Q_0^+$	X=1 $Q_2^+Q_1^+Q_0^+$	X=0	X=1
000	001	010	0	0
001	001	011	0	0
010	100	010	0	0
011	100	010	1	0
100	101	011	0	0
101	001	011	0	1



$$Z = Q_1Q_0X' + Q_2Q_0X$$

Mealy Sequence Detector Design Verification



Present State $Q_2Q_1Q_0$	Next State		Output	
	X=0 $Q_2^+Q_1^+Q_0^+$	X=1 $Q_2^+Q_1^+Q_0^+$	X=0	X=1
000	001	010	0	0
001	001	011	0	0
010	100	010	0	0
011	100	010	1	0
100	101	011	0	0
101	001	011	0	1
110	???	???	?	?
111	???	???	?	?

$$D_0 = Q_2 + Q_1'X' + Q_1'Q_0$$

$$D_1 = X$$

$$D_2 = Q_1X' + Q_2Q_0'X'$$

$$Z = Q_1Q_0X' + Q_2Q_0X$$

Mealy Sequence Detector Design Verification



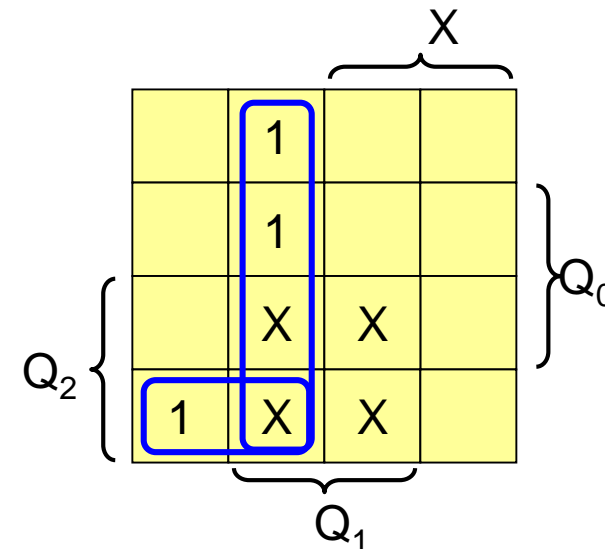
Present State $Q_2Q_1Q_0$	Next State		Output	
	X=0 $Q_2^+Q_1^+Q_0^+$	X=1 $Q_2^+Q_1^+Q_0^+$	X=0	X=1
000	001	010	0	0
001	001	011	0	0
010	100	010	0	0
011	100	010	1	0
100	101	011	0	0
101	001	011	0	1
110	1??	0??	?	?
111	1??	0??	?	?

$$D_0 = Q_2 + Q_1'X' + Q_1'Q_0$$

$$D_1 = X$$

$$D_2 = Q_1X' + Q_2Q_0'X'$$

$$X = Q_1Q_0X' + Q_2Q_0X$$



Mealy Sequence Detector Design Verification



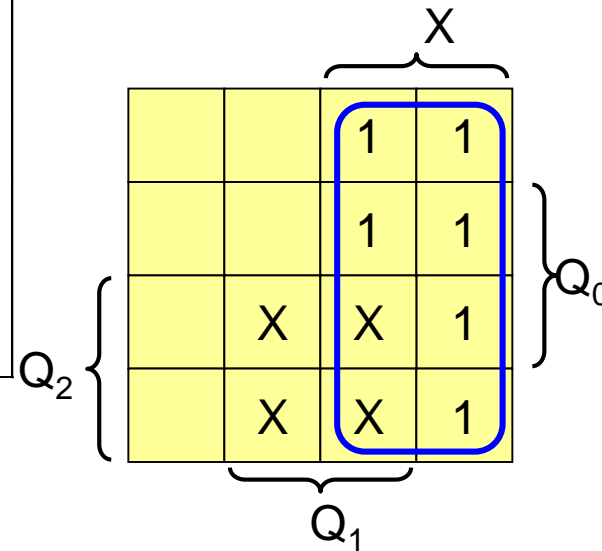
Present State $Q_2Q_1Q_0$	Next State		Output	
	X=0 $Q_2^+Q_1^+Q_0^+$	X=1 $Q_2^+Q_1^+Q_0^+$	X=0	X=1
000	001	010	0	0
001	001	011	0	0
010	100	010	0	0
011	100	010	1	0
100	101	011	0	0
101	001	011	0	1
110	10?	01?	?	?
111	10?	01?	?	?

$$D_0 = Q_2 + Q_1'X' + Q_1'Q_0$$

$$D_1 = X$$

$$D_2 = Q_1X' + Q_2Q_0'X'$$

$$X = Q_1Q_0X' + Q_2Q_0X$$



Mealy Sequence Detector Design Verification



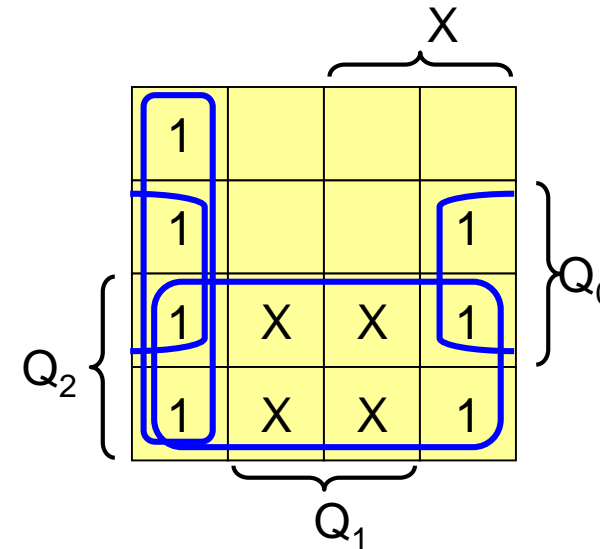
Present State $Q_2Q_1Q_0$	Next State		Output	
	X=0 $Q_2^+Q_1^+Q_0^+$	X=1 $Q_2^+Q_1^+Q_0^+$	X=0	X=1
000	001	010	0	0
001	001	011	0	0
010	100	010	0	0
011	100	010	1	0
100	101	011	0	0
101	001	011	0	1
110	101	011	?	?
111	101	011	?	?

$$D_0 = Q_2 + Q_1'X' + Q_1'Q_0$$

$$D_1 = X$$

$$D_2 = Q_1X' + Q_2Q_0'X'$$

$$X = Q_1Q_0X' + Q_2Q_0X$$



Mealy Sequence Detector Design Verification



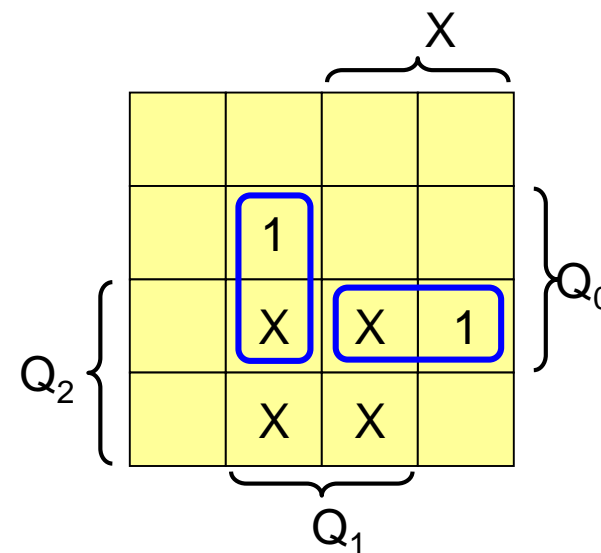
Present State $Q_2Q_1Q_0$	Next State		Output	
	X=0 $Q_2^+Q_1^+Q_0^+$	X=1 $Q_2^+Q_1^+Q_0^+$	X=0	X=1
000	001	010	0	0
001	001	011	0	0
010	100	010	0	0
011	100	010	1	0
100	101	011	0	0
101	001	011	0	1
110	101	011	0	0
111	101	011	1	1

$$D_0 = Q_2 + Q_1'X' + Q_1'Q_0$$

$$D_1 = X$$

$$D_2 = Q_1X' + Q_2Q_0'X'$$

$$X = Q_1Q_0X' + Q_2Q_0X$$



Reference

- mano BOOK

http://osp.mans.edu.eg/cs212/Seq_circuits_analysis.htm

Logic and Computer Design Fundamentals, Charles Kime & Thomas Kaminski

© 2008 Pearson Education, Inc.

(Edited by Dr. Muhamed Mudawar for COE 202 and EE 200 at KFUPM)

- <https://circuitdigest.com/tutorial/what-is-shift-register-types-applications>

