EEE205 – Digital Electronics (II)

Lecture 12

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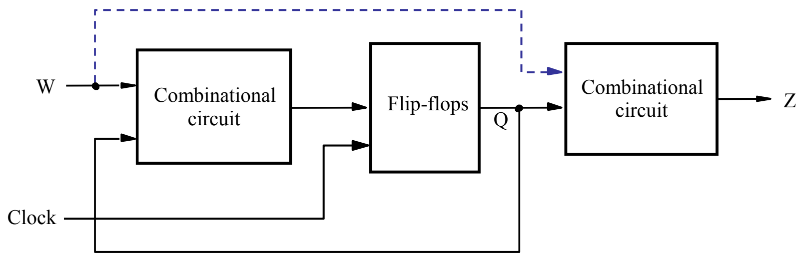
In This Session

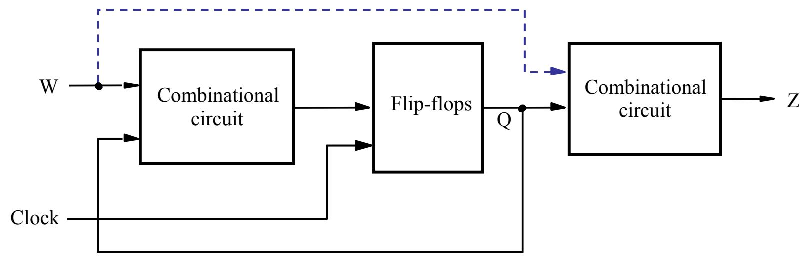
- Moore and Mealy Sequential Circuits
- State Tables and Graphs
- Derivation of State Tables

General Form of A Sequential Circuit.



- Sequential circuits are called **finite state machines (FSM)**.
- Combinational circuit 1 has inputs from the input W and the state Q of the flip-flops.
- The output Z always depends on the state Q of the flip-flops and possibly on the input W.

General Form of A Sequential Circuit.



- The sequential circuits whose outputs depend only on the state of the circuit are of **Moore type**.
- Those whose outputs depend on both the state and the inputs are of **Mealy type**.

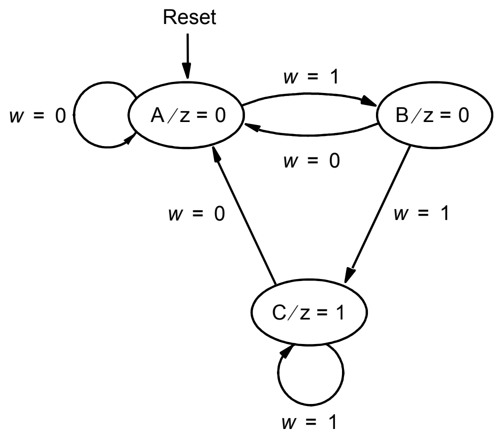
State Tables and Graphs

- A **state table**, also called a *state transition table*, specifies the next state and output of a sequential circuit in terms of its present state and input

Present state	Next state		Output
	$w = 0$	$w = 1$	z
A	A	B	0
B	A	C	0
C	A	C	1

State Tables and Graphs

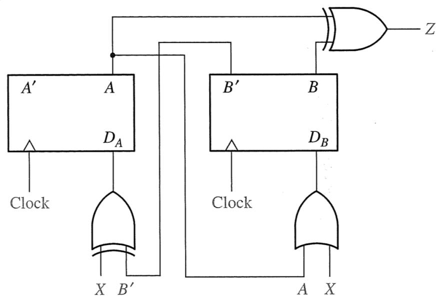
- A **state graph** is a graphical representation of the state table, in which each *node* represents a state and the *arc* joining the nodes is labelled with the input causing the state change.



State Tables and Graphs

The method to construct the state table and graph from a given circuit:

A Moore sequential circuit



1. Determine the flip-flop input equations and the output equations from the circuit.

$$D_A = X \oplus B' \qquad D_B = X + A \qquad Z = A \oplus B$$

State Tables and Graphs

D flip flop

D	Q^+
0	0
1	1

$Q^+ = D$

D-CE flip flop

CE	D	Q^+
0	X	Q
1	0	0
1	1	1

$Q^+ = D \cdot CE + Q \cdot CE'$

T flip flop

T	Q^+
0	Q
1	Q’

$Q^+ = T \oplus Q$

State Tables and Graphs

S-R flip flop

S	R	Q^+
0	0	Q
1	0	1
0	1	0

$Q^+ = S + R'Q$

J-K flip flop

J	K	Q^+
0	0	Q
1	0	1
0	1	0
1	1	Q'

$Q^+ = JQ' + K'Q$

State Tables and Graphs

2. Derive the next-state equation for each flip-flop from its input equations, using one of the these:

D flip-flop	$Q^+ = D$
D-CE flip-flop	$Q^+ = D \cdot CE + Q \cdot CE'$
T flip-flop	$Q^+ = T \oplus Q$
S-R flip-flop	$Q^+ = S + R'Q$
J-K flip-flop	$Q^+ = JQ' + K'Q$

The next-state equations for the flip-flops are:

$$A^+ = X \oplus B' \qquad B^+ = X + A$$

State Tables and Graphs

3. Form the state table.

$$A^+ = X \oplus B' \qquad B^+ = X + A \qquad Z = A \oplus B$$

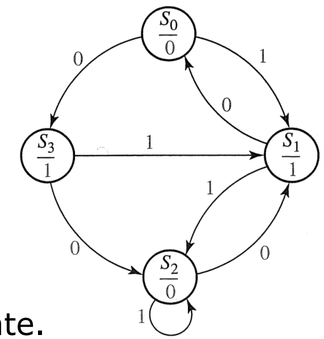
	A^+B^+		
AB	$X = 0$	$X = 1$	Z
00	10	01	0
01	00	11	1
11	01	11	0
10	11	01	1

State Tables and Graphs

4. Replace each combination of states with a single symbol. Draw the state graph.

Replacing 00 with S_0, 01 with S_1, 11 with S_2, and 10 with S_3.

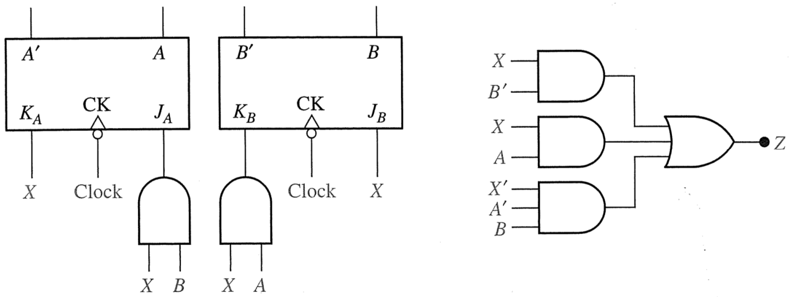
Present State	Next State $X = 0$	Next State $X = 1$	Present Output (Z)
S_0	S_3	S_1	0
S_1	S_0	S_2	1
S_2	S_1	S_2	0
S_3	S_2	S_1	1



In a Moore state graph, the output is written with the state.

State Tables and Graphs

Another example for a Mealy sequential circuit:



J_A = XB K_A = X J_B = X K_B = XA

Z = XB' + XA + X'A'B

State Tables and Graphs

The next-state and output equations are:

$$A^+ = J_A A' + K'_A A = XBA' + X'A$$
$$B^+ = J_B B' + K'_B B = XB' + (AX)'B = XB' + X'B + A'B$$
$$Z = X'A'B + XB' + XA$$

Recall that Q+ = JQ' + K'Q for J-K flip flops

J_A = XB K_A = X J_B = X K_B = XA

State Tables and Graphs

$$A^+ = J_A A' + K'_A A = XBA' + X'A$$
$$B^+ = J_B B' + K'_B B = XB' + (AX)'B = XB' + X'B + A'B$$
$$Z = X'A'B + XB' + XA$$

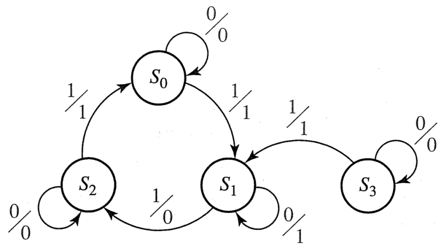
AB	A^+B^+ $X = 0$	1	Z $X = 0$	1
00	00	01	0	1
01	01	11	1	0
11	11	00	0	1
10	10	01	0	1

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

State Tables and Graphs

AB	A^+B^+ $X = 0$	1	Z $X = 0$	1
00	00	01	0	1
01	01	11	1	0
11	11	00	0	1
10	10	01	0	1

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



- The labels on the arcs are X/Z, where X is the input and Z is the output.
- In a Mealy state graph, the output is written with the transition.