Upgrade

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Fundamentals of Logic Design

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Explanation

Verified

Step 1

Next-state equations

We note that there are two K flip-flops with outputs Q_1 and Q_2, thus the states of the machine are the bit strings of length 2.

$$\begin{aligned}
J_1 &= [(XQ_2')'(Q_2X')']' \\
&= [(X'+Q_2)(Q_2'+X)]' && \text{DeMorgan's law} \\
&= XQ_2' + Q_2X' && \text{DeMorgan's law} \\
K_1 &= [(Q_2X')']' \\
&= Q_2X' && \text{Involution law} \\
J_2 &= (X'+Q_1)' \\
&= XQ_1' && \text{DeMorgan's law} \\
K_2 &= J_2 = XQ_1' \\
Z &= (Q_1'+Q_2')' \\
&= Q_1Q_2 && \text{DeMorgan's law}
\end{aligned}$$

The next-state equation for a J-K flip-flop is $Q^+ = JQ' + K'Q$.

$$\begin{aligned}
Q_1^+ &= J_1Q_1' + K_1'Q_1 \\
&= XQ_1'Q_2' + X'Q_1'Q_2 + (Q_2X')'Q_1 \\
&= XQ_1'Q_2' + X'Q_1'Q_2 + (Q_2'+X)Q_1 && \text{DeMorgan's law} \\
&= XQ_1'Q_2' + X'Q_1'Q_2 + Q_1Q_2' + Q_1X && \text{Distributive law} \\
Q_2^+ &= J_2Q_2' + K_2'Q_2 \\
&= XQ_1'Q_2' + (XQ_1')'Q_2 \\
&= XQ_1'Q_2' + (X'+Q_1)Q_2 && \text{DeMorgan's law} \\
&= XQ_1'Q_2' + X'Q_2 + Q_1Q_2 && \text{Distributive law}
\end{aligned}$$

Step 2

Transition table

Let us use the next-state equations to determine the next state based on the current state and the input X.

Similarly, we will use the output equation to determine the output corresponding to each current state.

	Present state Q_1Q_2	Next state $Q_1^+Q_2^+$ $X=0$	$X=1$	Z
S_0	00	00	11	0
S_1	01	11	00	0
S_2	10	10	10	0
S_3	11	01	11	1

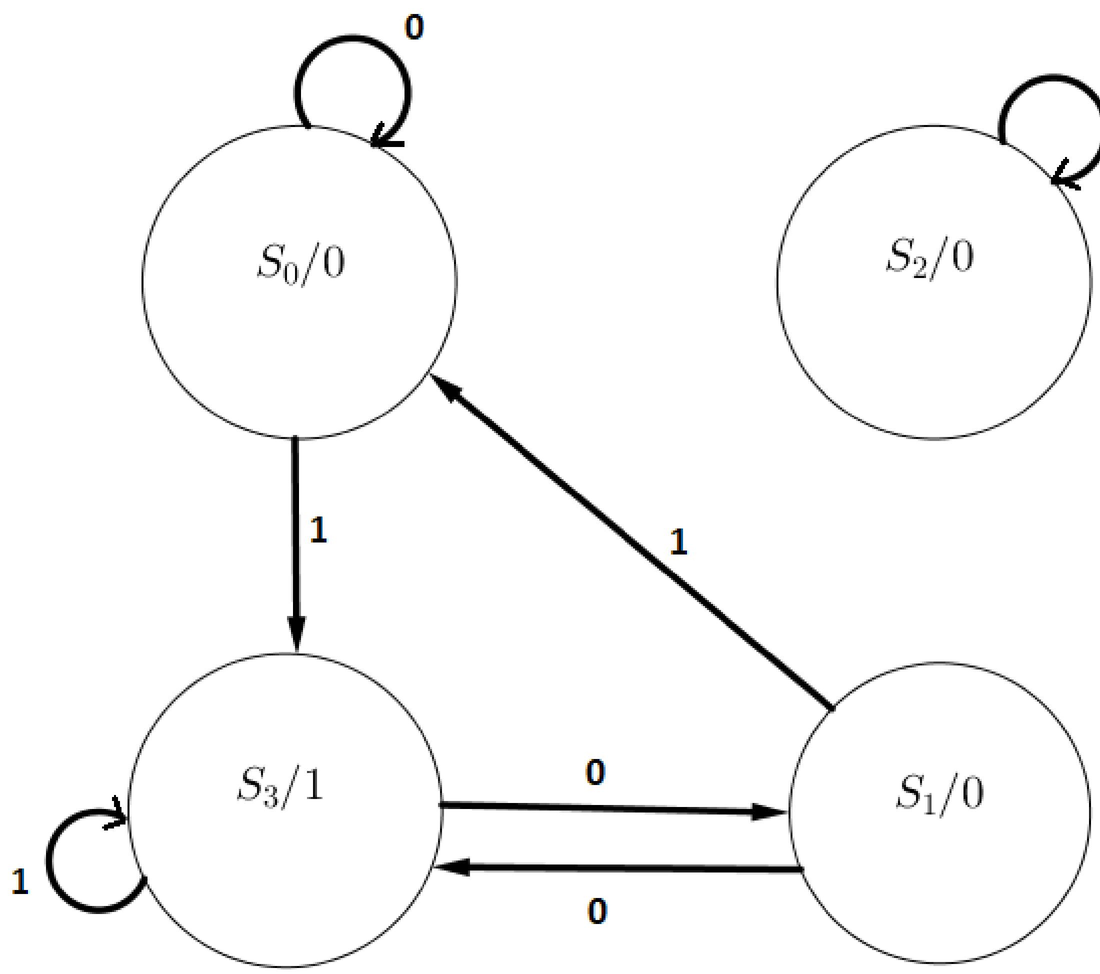
Step 3

State graph

There are four states S_0 to S_3 mentioned in the present state column, thus we need to draw four states.

When the output b is mentioned in the row starting with S_i, then we mention S_i/b in the corresponding state.

When the state S_j is mentioned in the row starting with S_i and in the next-state column with input $X = a$, then we draw an arc from state S_i to state S_j and label the arc with a.



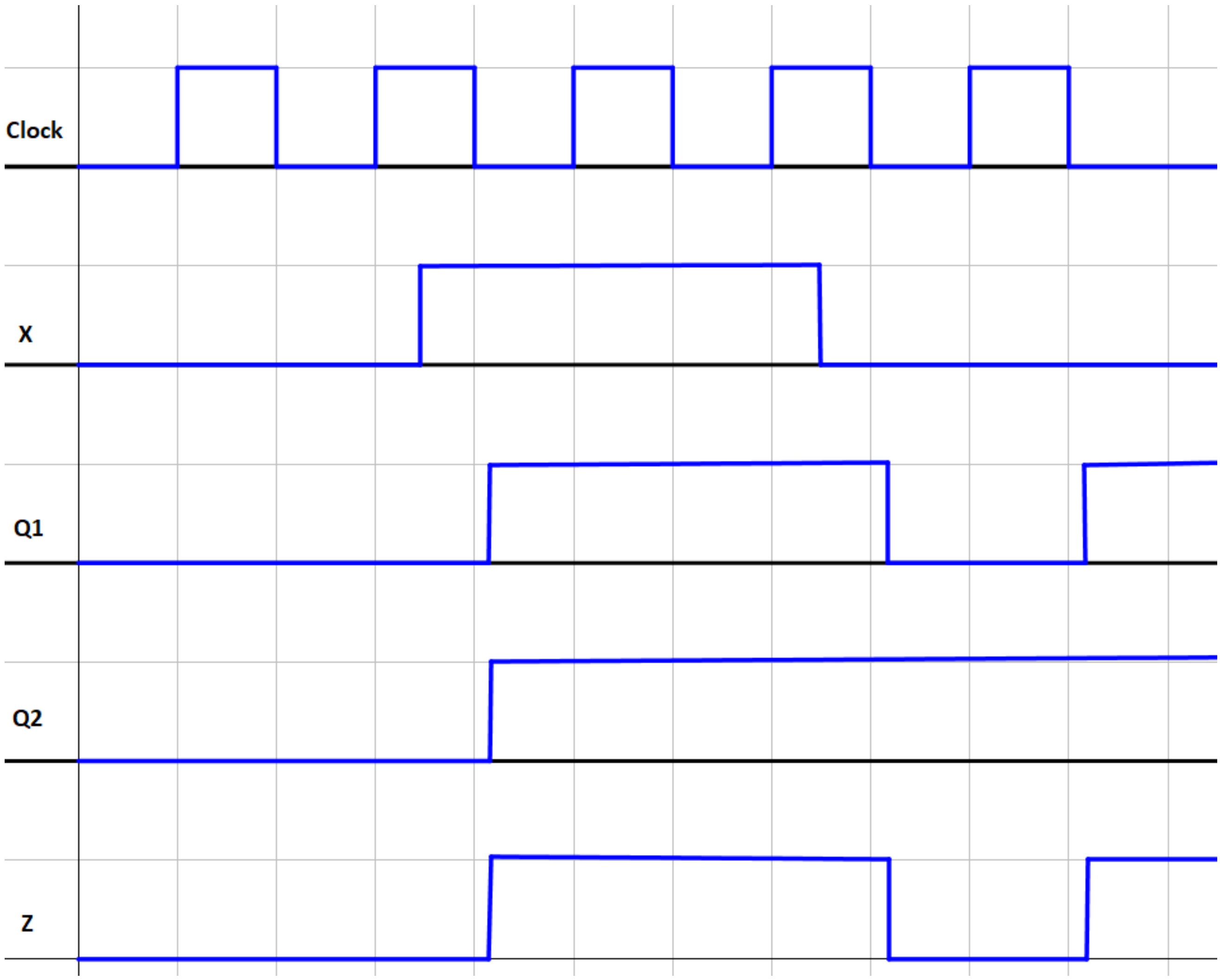
Step 4

(b) **Timing diagram**

We know that the input X is 01100, while any changes in X need to occur in the middle between rising and falling clock edges.

We assume that the initial state is $Q_1Q_2 = 00$.

Since the clock is inverted, any changes in the states Q_1, Q_2, and Z will occur right after the falling edge of the clock. Moreover, the next-states and output can be found in the transition table.



Step 5

(c)

$$X = 01100$$

Output sequence

Since $Q_1 = Q_2 = 0$ initially, we start at state S_0.

The first input is $X = 0$ and the present state is S_0, thus we remain at state S_0 with output $Z = 0$.

$$Z = 0$$

The second input is $X = 1$ and the present state is S_0, thus we move to state S_3 with output $Z = 1$.

$$Z = 1$$

The third input is $X = 1$ and the present state is S_3, thus we remain at state S_3 with output $Z = 1$.

$$Z = 1$$

The fourth input is $X = 0$ and the present state is S_3, thus we move to state S_1 with output $Z = 0$.

$$Z = 0$$

The fifth input is $X = 0$ and the present state is S_1, thus we move to state S_3 with output $Z = 1$.

$$Z = 1$$

Thus we then note that the output sequence is $Z = 01101$.

Result

(a)

	Present state Q_1Q_2	Next state $Q_1^+Q_2^+$ $X=0$	$X=1$	Z
S_0	00	00	11	0
S_1	01	11	00	0
S_2	10	10	10	0
S_3	11	01	11	1

(b) No false outputs

(c) $Z = 01101$

Exercise 19

Exercise 21