Digital Circuits - Conversion of Flip-Flops

In previous chapter, we discussed the four flip-flops, namely SR flip-flop, D flip-flop, JK flip-flop & T flip-flop. We can convert one flip-flop into the remaining three flip-flops by including some additional logic. So, there will be total of twelve **flip-flop conversions**.

Follow these **steps** for converting one flip-flop to the other.

- Consider the **characteristic table** of desired flip-flop.
- Fill the excitation values $inputs$ of given flip-flop for each combination of present state and next state. The **excitation table** for all flip-flops is shown below.

Present State	**Next State**	**SR flip-flop inputs**		**D flip-flop input**	**JK flip-flop inputs**		**T flip-flop input**
Q t	**Q** $t+1$	**S**	**R**	**D**	**J**	**K**	**T**
0	0	0	x	0	0	x	0
0	1	1	0	1	1	x	1
1	0	0	1	0	x	1	1
1	1	x	0	1	x	0	0

- Get the **simplified expressions** for each excitation input. If necessary, use Kmaps for simplifying.
- Draw the **circuit diagram** of desired flip-flop according to the simplified expressions using given flip-flop and necessary logic gates.

Now, let us convert few flip-flops into other. Follow the same process for remaining flipflop conversions.

SR Flip-Flop to other Flip-Flop Conversions

Following are the three possible conversions of SR flip-flop to other flip-flops.

- SR flip-flop to D flip-flop
- SR flip-flop to JK flip-flop
- SR flip-flop to T flip-flop

SR flip-flop to D flip-flop conversion

Here, the given flip-flop is SR flip-flop and the desired flip-flop is D flip-flop. Therefore, consider the following **characteristic table** of D flip-flop.

D flip-flop input	Present State	Next State
D	**Q** t	**Q** $t+1$
0	0	0
0	1	0
1	0	1
1	1	1

We know that SR flip-flop has two inputs S & R. So, write down the excitation values of SR flip-flop for each combination of present state and next state values. The following table shows the characteristic table of D flip-flop along with the **excitation inputs** of SR flip-flop.

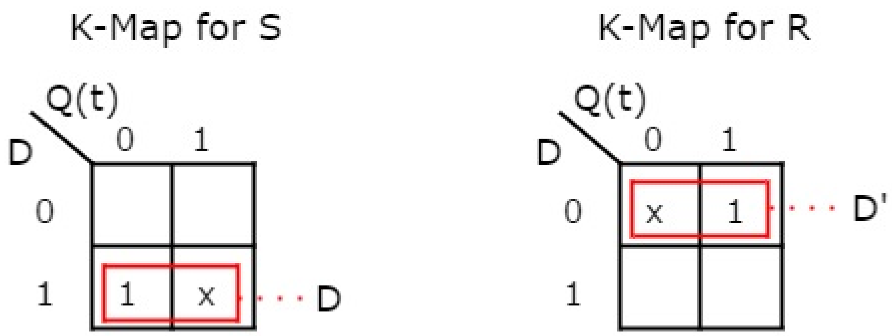
D flip-flop input	Present State	Next State	SR flip-flop inputs	
D	**Q** t	**Q** $t+1$	**S**	**R**
0	0	0	0	x
0	1	0	0	1
1	0	1	1	0
1	1	1	x	0

From the above table, we can write the **Boolean functions** for each input as below.

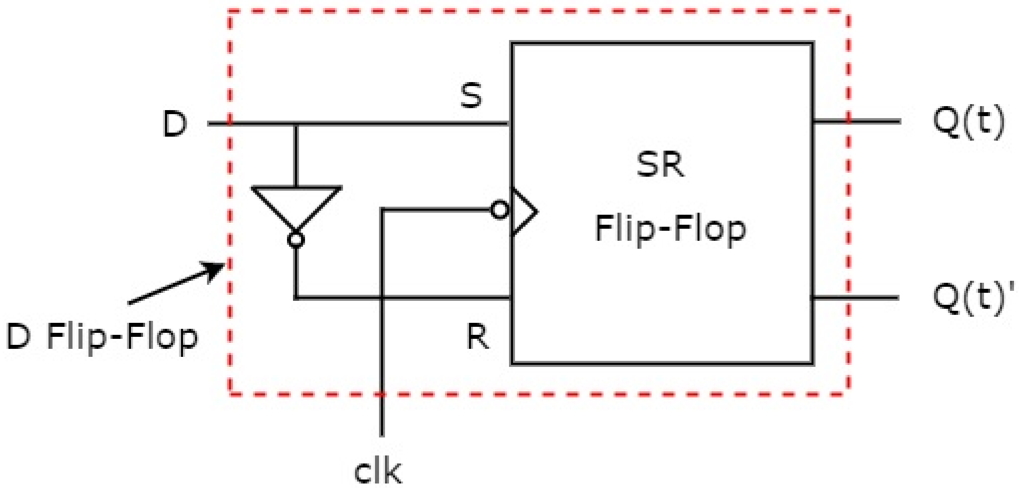
$$S = m_2 + d_3$$

$$R = m_1 + d_0$$

We can use 2 variable K-Maps for getting simplified expressions for these inputs. The **k-Maps** for S & R are shown below.



So, we got S = D & R = D' after simplifying. The **circuit diagram** of D flip-flop is shown in the following figure.



This circuit consists of SR flip-flop and an inverter. This inverter produces an output, which is complement of input, D. So, the overall circuit has single input, D and two outputs Q t & Q t '. Hence, it is a **D flip-flop**. Similarly, you can do other two conversions.

D Flip-Flop to other Flip-Flop Conversions

Following are the three possible conversions of D flip-flop to other flip-flops.

- D flip-flop to T flip-flop
- D flip-flop to SR flip-flop
- D flip-flop to JK flip-flop

D flip-flop to T flip-flop conversion

Here, the given flip-flop is D flip-flop and the desired flip-flop is T flip-flop. Therefore, consider the following **characteristic table** of T flip-flop.

T flip-flop input	Present State	Next State
T	**Q** t	**Q** $t+1$
0	0	0
0	1	1
1	0	1
1	1	0

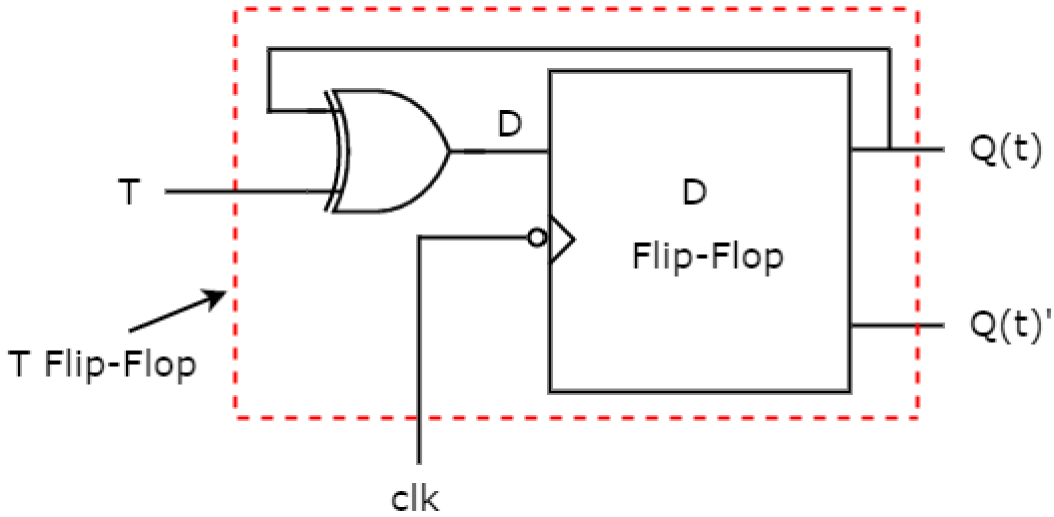
We know that D flip-flop has single input D. So, write down the excitation values of D flip-flop for each combination of present state and next state values. The following table shows the characteristic table of T flip-flop along with the **excitation input** of D flip-flop.

T flip-flop input	Present State	Next State	D flip-flop input
T	**Q** t	**Q** $t+1$	**D**
0	0	0	0
0	1	1	1
1	0	1	1
1	1	0	0

From the above table, we can directly write the **Boolean function** of D as below.

$$D = T \oplus Q\left(t\right)$$

So, we require a two input Exclusive-OR gate along with D flip-flop. The **circuit diagram** of T flip-flop is shown in the following figure.



This circuit consists of D flip-flop and an Exclusive-OR gate. This Exclusive-OR gate produces an output, which is Ex-OR of T and Q t . So, the overall circuit has single input, T and two outputs Q t & Q t ’. Hence, it is a **T flip-flop**. Similarly, you can do other two conversions.

JK Flip-Flop to other Flip-Flop Conversions

Following are the three possible conversions of JK flip-flop to other flip-flops.

- JK flip-flop to T flip-flop
- JK flip-flop to D flip-flop
- JK flip-flop to SR flip-flop

JK flip-flop to T flip-flop conversion

Here, the given flip-flop is JK flip-flop and the desired flip-flop is T flip-flop. Therefore, consider the following **characteristic table** of T flip-flop.

T flip-flop input	Present State	Next State
T	**Q** t	**Q** $t+1$
0	0	0
0	1	1
1	0	1
1	1	0

We know that JK flip-flop has two inputs J & K. So, write down the excitation values of JK flip-flop for each combination of present state and next state values. The following table shows the characteristic table of T flip-flop along with the **excitation inputs** of JK flipflop.

T flip-flop input	Present State	Next State	JK flip-flop inputs	
T	**Q** t	**Q** $t+1$	**J**	**K**
0	0	0	0	x
0	1	1	x	0
1	0	1	1	x
1	1	0	x	1

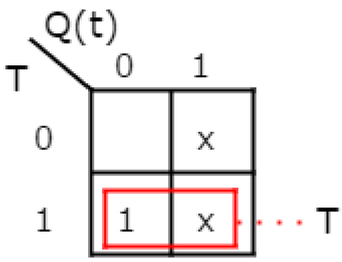
From the above table, we can write the **Boolean functions** for each input as below.

$$J = m_2 + d_1 + d_3$$

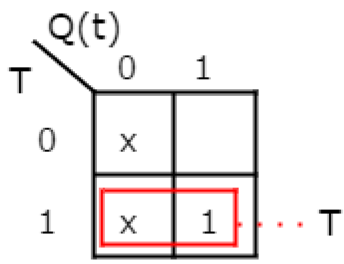
$$K = m_3 + d_0 + d_2$$

We can use 2 variable K-Maps for getting simplified expressions for these two inputs. The **k-Maps** for J & K are shown below.

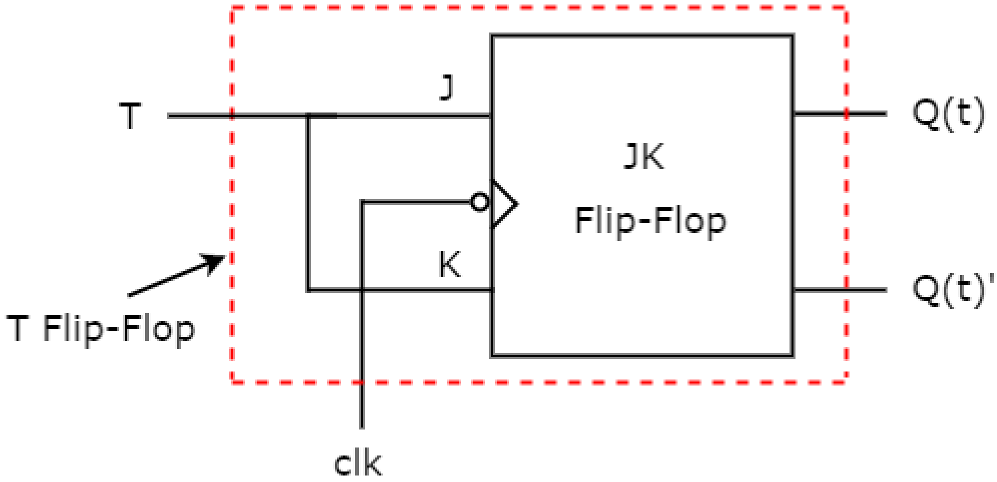
K-Map for J



K-Map for K



So, we got, J = T & K = T after simplifying. The **circuit diagram** of T flip-flop is shown in the following figure.



This circuit consists of JK flip-flop only. It doesn’t require any other gates. Just connect the same input T to both J & K. So, the overall circuit has single input, T and two outputs Q t & Q t ’.

Hence, it is a **T flip-flop**. Similarly, you can do other two conversions.

T Flip-Flop to other Flip-Flop Conversions

Following are the three possible conversions of T flip-flop to other flip-flops.

- T flip-flop to D flip-flop
- T flip-flop to SR flip-flop
- T flip-flop to JK flip-flop

T flip-flop to D flip-flop conversion

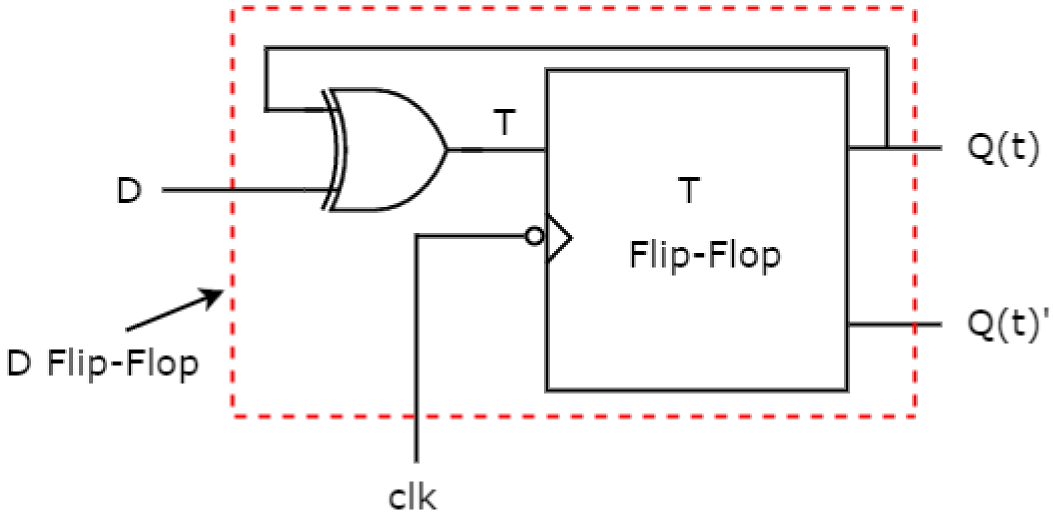
Here, the given flip-flop is T flip-flop and the desired flip-flop is D flip-flop. Therefore, consider the characteristic table of D flip-flop and write down the excitation values of T flip-flop for each combination of present state and next state values. The following table shows the **characteristic table** of D flip-flop along with the **excitation input** of T flip-flop.

D flip-flop input	Present State	Next State	T flip-flop input
D	**Q** t	**Q** $t+1$	**T**
0	0	0	0
0	1	0	1
1	0	1	1
1	1	1	0

From the above table, we can directly write the Boolean function of T as below.

$$T = D \oplus Q(t)$$

So, we require a two input Exclusive-OR gate along with T flip-flop. The **circuit diagram** of D flip-flop is shown in the following figure.



This circuit consists of T flip-flop and an Exclusive-OR gate. This Exclusive-OR gate produces an output, which is Ex-OR of D and Q t . So, the overall circuit has single input, D and two outputs Q t & Q t '. Hence, it is a **D flip-flop**. Similarly, you can do other two conversions.