

## Sequential Logic Circuit Design Module III (Lec-3,4)

# Flip Flop

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## Flip Flops Classification

[1] SR Flip Flop

[3] D Flip Flop

[2] JK Flip Flop

[4] T Flip Flop

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## Procedure for Designing of Flip Flops

[1] Truth Table

[3] Characteristic Equation

[2] Characteristic Table

[4] Excitation Table

# SR Flip Flop

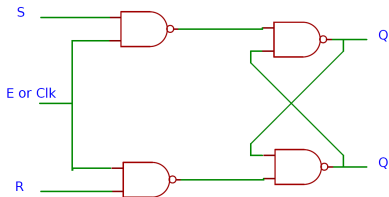
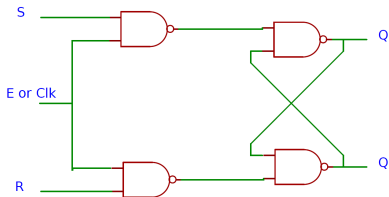


Table: Truth Table for SR Flip Flop

Clk	S	R	Q
0	×	×	Previous state
1	0	0	Previous state
1	0	1	0 (Reset State)
1	1	0	1 (Set State)
1	1	1	Invalid state

# SR Flip Flop



**Table:** Truth Table for SR Flip Flop

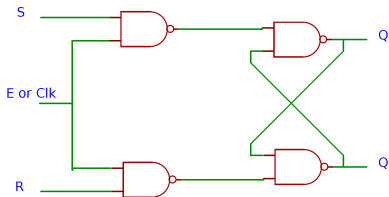
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- The control input (E or Clk) acts as an enable signal or clocked pulse for the two inputs.
- When **E=0**, the circuit remains in the previous state.
- When **E goes to 1**, information from the S or R input is allowed to get the output.

# SR Flip Flop

**Table: Characteristic Table**  
for SR Flip Flop

<b>S</b>	<b>R</b>	$Q_n$	$Q_{n+1}$
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	×
1	1	1	×

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0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	×
1	1	1	×

**Table: Excitation Table** for SR  
Flip Flop

$Q_n$	$Q_{n+1}$	S	R
0	0	0	×
0	1	1	0
1	0	0	1
1	1	×	0

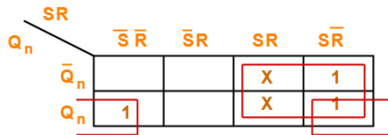
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0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	×
1	1	1	×

**Table: Excitation Table for SR Flip Flop**

$Q_n$	$Q_{n+1}$	S	R
0	0	0	×
0	1	1	0
1	0	0	1
1	1	×	0



K Map

# SR Flip Flop

**Table: Characteristic Table**  
for SR Flip Flop

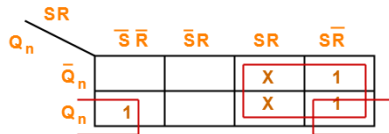
S	R	$Q_n$	$Q_{n+1}$
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	×
1	1	1	×

**Characteristic Equation**

$$Q_{n+1} = S + \bar{R}Q_n$$

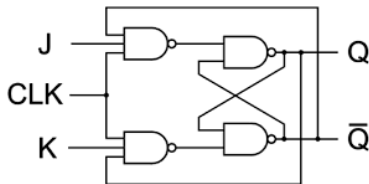
**Table: Excitation Table** for SR  
Flip Flop

$Q_n$	$Q_{n+1}$	S	R
0	0	0	×
0	1	1	0
1	0	0	1
1	1	×	0



K Map

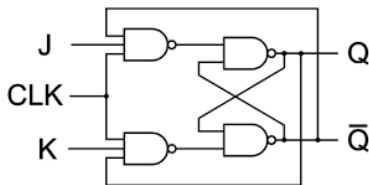
# JK Flip Flop



**Table:** Truth Table for JK Flip Flop

Clk	J	K	Q
0	×	×	Hold ( $Q_n$ )
1	0	0	Hold ( $Q_n$ )
1	0	1	0
1	1	0	1
1	1	1	Toggle ( $\bar{Q}_n$ )

# JK Flip Flop

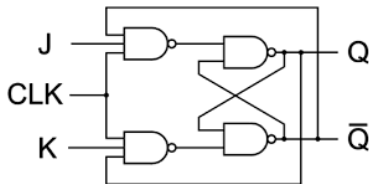


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- The JK FF is used to avoid the invalid state in the SR FF.

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- When **Clk=0**, the circuit remains in the previous state.
- When **Clk goes to 1**, information from the J and K input is allowed to get the output.



# JK Flip Flop

**Table: Characteristic Table**  
for JK Flip Flop

J	K	$Q_n$	$Q_{n+1}$
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

# JK Flip Flop

**Table: Characteristic Table**  
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J	K	$Q_n$	$Q_{n+1}$
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

**Table: Excitation Table** for JK  
Flip Flop

$Q_n$	$Q_{n+1}$	J	K
0	0	0	×
0	1	1	×
1	0	×	1
1	1	×	0

# JK Flip Flop

**Table: Characteristic Table**  
for JK Flip Flop

J	K	$Q_n$	$Q_{n+1}$
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

**Table: Excitation Table** for JK  
Flip Flop

$Q_n$	$Q_{n+1}$	J	K
0	0	0	×
0	1	1	×
1	0	×	1
1	1	×	0

K Map

		JK			
		$\bar{J}\bar{K}$ $\bar{J}K$ $JK$ $J\bar{K}$			
$Q_n$	$\bar{Q}_n$			1	1
	$Q_n$	1			1

K Map

# JK Flip Flop

**Table: Characteristic Table for JK Flip Flop**

J	K	$Q_n$	$Q_{n+1}$
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

**Characteristic Equation**

$$Q_{n+1} = J\bar{Q}_n + \bar{K}Q_n$$

**Table: Excitation Table for JK Flip Flop**

$Q_n$	$Q_{n+1}$	J	K
0	0	0	×
0	1	1	×
1	0	×	1
1	1	×	0

	$\bar{J}\bar{K}$	$\bar{J}K$	$J\bar{K}$	$JK$
$\bar{Q}_n$			1	1
$Q_n$	1			1

**K Map**

# D Flip Flop

- Delayed Flip Flop is one of the simple FF to store data. It is also called transparent FF.

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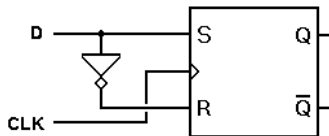
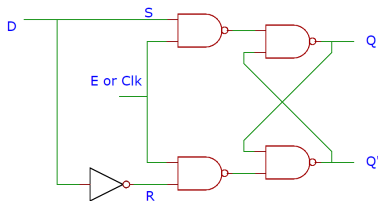
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- Ensure that inputs S and R are **never equal to 1** at the same time.

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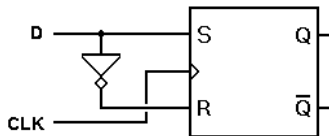
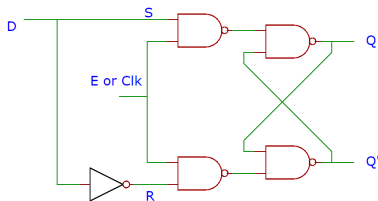
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Table: Truth Table for D Latch

<b>E</b>	<b>D</b>	<b>Q</b>
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1	0	0; Reset
1	1	1; Set

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Table: **Characteristic Table**  
for D Flip Flop

<b>D</b>	$Q_n$	$Q_{n+1}$
0	0	0
0	1	0
1	0	1
1	1	1

# D Flip Flop

**Table:** Truth Table for D Latch

E	D	Q
0	×	Previous state
1	0	0; Reset
1	1	1; Set

## Characteristic Equation

$$Q_{n+1} = D$$

Therefore it is also called as transparent latch or flip flop.

**Table:** Characteristic Table  
for D Flip Flop

D	$Q_n$	$Q_{n+1}$
0	0	0
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**Table:** Truth Table for D Latch

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**Table:** Excitation Table for D  
Flip Flop

$Q_n$	$Q_{n+1}$	D
0	0	0
0	1	1
1	0	0
1	1	1

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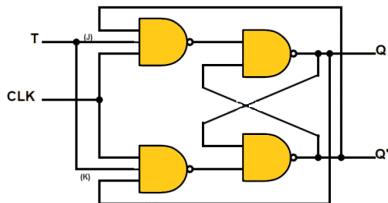


# T Flip Flop

- T- FF is also known as toggle FF.
- This is the another way to eliminate the undesirable condition of the invalid state in the SR latch.
- We can design the T-FF by making simple modifications to the JK FF.
- The T- FF is a single input device and hence by connecting J and K inputs together we can convert a JK FF into T-FF.

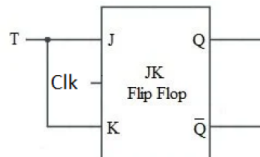
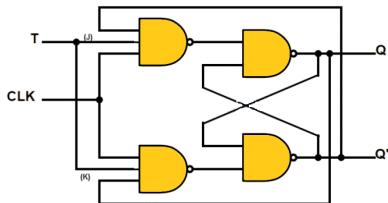
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# T Flip Flop

Table: Truth Table for T FF

E	T	Q
0	×	Previous state
1	0	$Q_n$
1	1	$\bar{Q}_n$

# T Flip Flop

Table: Truth Table for T FF

E	T	Q
0	×	Previous state
1	0	$Q_n$
1	1	$\bar{Q}_n$

Table: Characteristic Table  
for T Flip Flop

T	$Q_n$	$Q_{n+1}$
0	0	0
0	1	1
1	0	1
1	1	0

# T Flip Flop

**Table:** Truth Table for T FF

E	T	Q
0	×	Previous state
1	0	$Q_n$
1	1	$\bar{Q}_n$

## Characteristic Equation

$$Q_{n+1} = \bar{T}Q_n + T\bar{Q}_n = T \oplus Q_n$$

**Table:** Excitation Table for T Flip Flop

$Q_n$	$Q_{n+1}$	T
0	0	0
0	1	1
1	0	1
1	1	0

**Table:** Characteristic Table for T Flip Flop

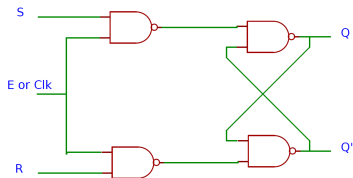
T	$Q_n$	$Q_{n+1}$
0	0	0
0	1	1
1	0	1
1	1	0

# Summary of Flip Flops

## Digital Logic Design

### Flip Flops

Summary of Flip Flops

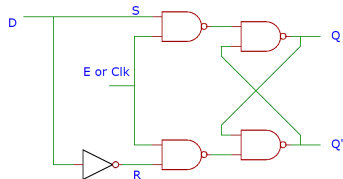
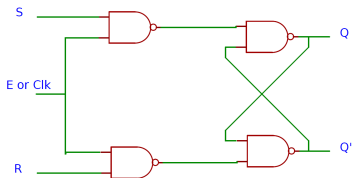


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Summary of Flip Flops



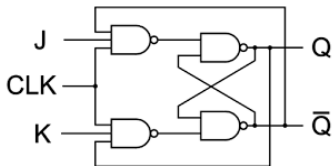
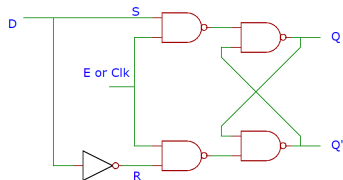
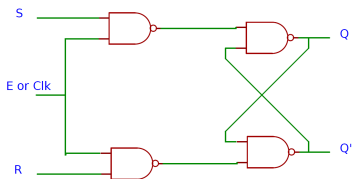


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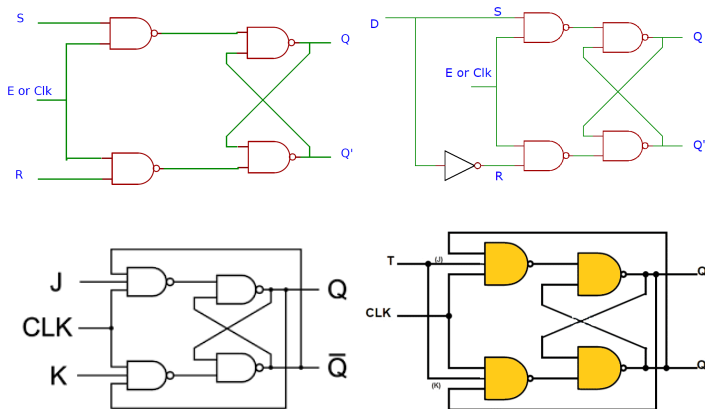


Figure: Logic Diagram of Flip flops

# Truth Tables of Flip Flops

Table: SR Flip Flop

<b>S</b>	<b>R</b>	$Q_{n+1}$
0	0	$Q_n$
0	1	0
1	0	1
1	1	Invalid

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1	0	1
1	1	Invalid

Table: JK Flip Flop

J	K	$Q_{n+1}$
0	0	$Q_n$
0	1	0
1	0	1
1	1	$\bar{Q}_n$

# Truth Tables of Flip Flops

Table: SR Flip Flop

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1	1	Invalid

Table: D Flip Flop

D	$Q_{n+1}$
0	0
1	1

Table: JK Flip Flop

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T	$Q_{n+1}$
0	$Q_n$
1	$\bar{Q}_n$

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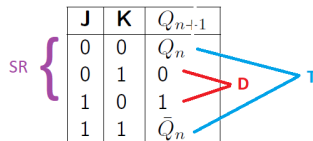
All tables are inside the JK FF

Table: D Flip Flop

D	$Q_{n+1}$
0	0
1	1

Table: T Flip Flop

T	$Q_{n+1}$
0	$Q_n$
1	$\bar{Q}_n$



Universal FF.

# Excitation Table and Characteristic Equations

**Table: Excitation Table for all Flip Flop**

$Q_n$	$Q_{n+1}$	<b>S</b>	<b>R</b>	<b>J</b>	<b>K</b>	<b>D</b>	<b>T</b>
0	0	0	×	0	×	0	0
0	1	1	0	1	×	1	1
1	0	0	1	×	1	0	1
1	1	×	0	×	0	1	0

## Characteristic Equations

$$\text{SR FF : } Q_{n+1} = S + R'Q_n$$

$$\text{JK FF : } Q_{n+1} = JQ'_n + K'Q_n$$

$$\text{D FF : } Q_{n+1} = D$$

$$\text{T FF : } Q_{n+1} = T \oplus Q_n$$