

# SEQUENTIAL CIRCUITS

- NAND Latch
- NOR Latch
- SR, D, JK, T flip flop

# SR Flip Flop using NAND latch

Function Table

Clk	S	R	Output
0	X	X	No Change
1	0	0	No Change
1	0	1	Reset
1	1	0	Set
1	1	1	Indeterminate

Equation for SET and RESET:

	SET	RESET
0 → 0	1	1
1 → 1	0	1
1 → 0	1	0
0 → 1	0	1

Excitation Table

Clk	S	R	Q(t)	Q(t+1)	SET	RESET
0	0	0	0	0	1	X
0	0	0	1	1	X	1
0	0	1	0	0	1	X
0	0	1	1	1	X	1
0	1	0	0	0	1	X
0	1	0	1	1	X	1
0	1	1	0	0	1	X
0	1	1	1	1	X	1
1	0	0	0	0	1	X
1	0	0	1	1	X	1
1	0	1	0	0	1	X
1	0	1	1	0	1	0
1	1	0	0	0	0	1
1	1	0	1	1	X	1
1	1	1	0	X	X	X
1	1	1	1	X	X	X

NAND latch / p.

Circuit:

SET :-  $\overline{clk} \cdot \overline{S}$

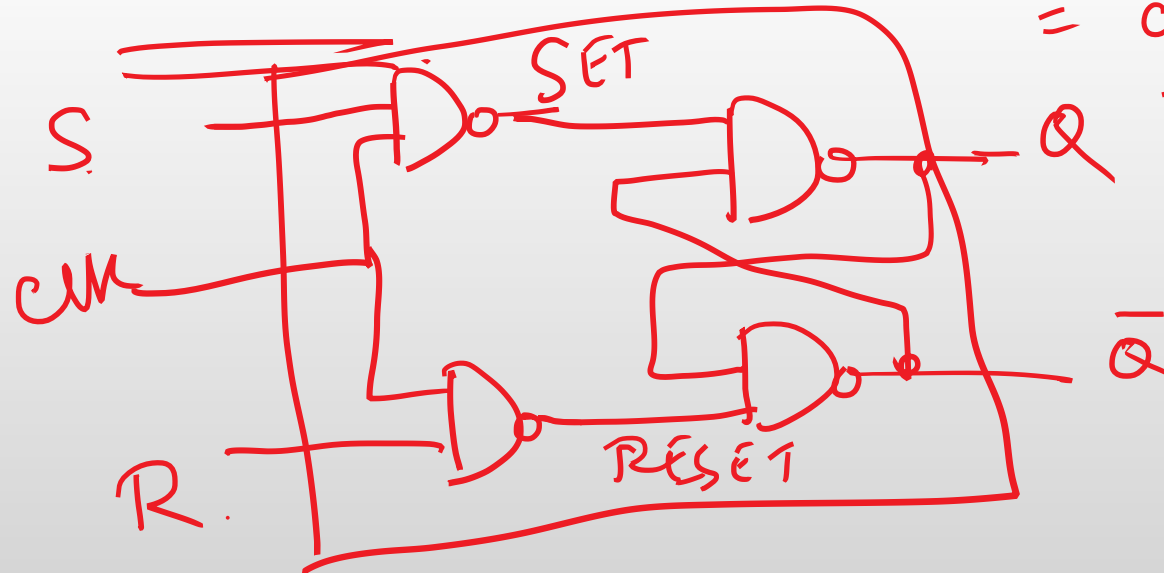
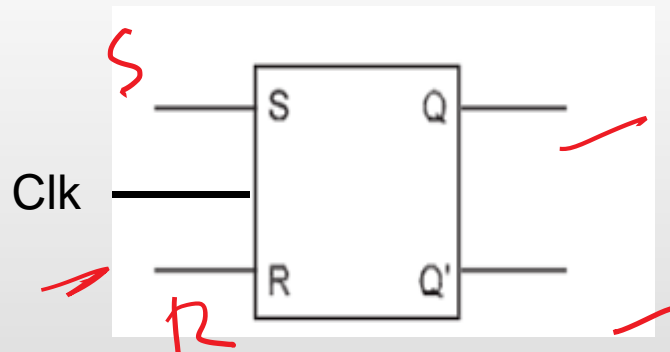
$\overline{clk} \backslash R$	00	01	11	10
00	1	X	X	1
01	1	X	X	1
11	0	X	X	X
10	1	X	1	1

RESET :-  $\overline{clk} \cdot \overline{R}$

$\overline{clk} \backslash R$	00	01	11	10
00	X	1	1	X
01	X	1	1	X
11	1	X	X	X
10	X	1	0	X

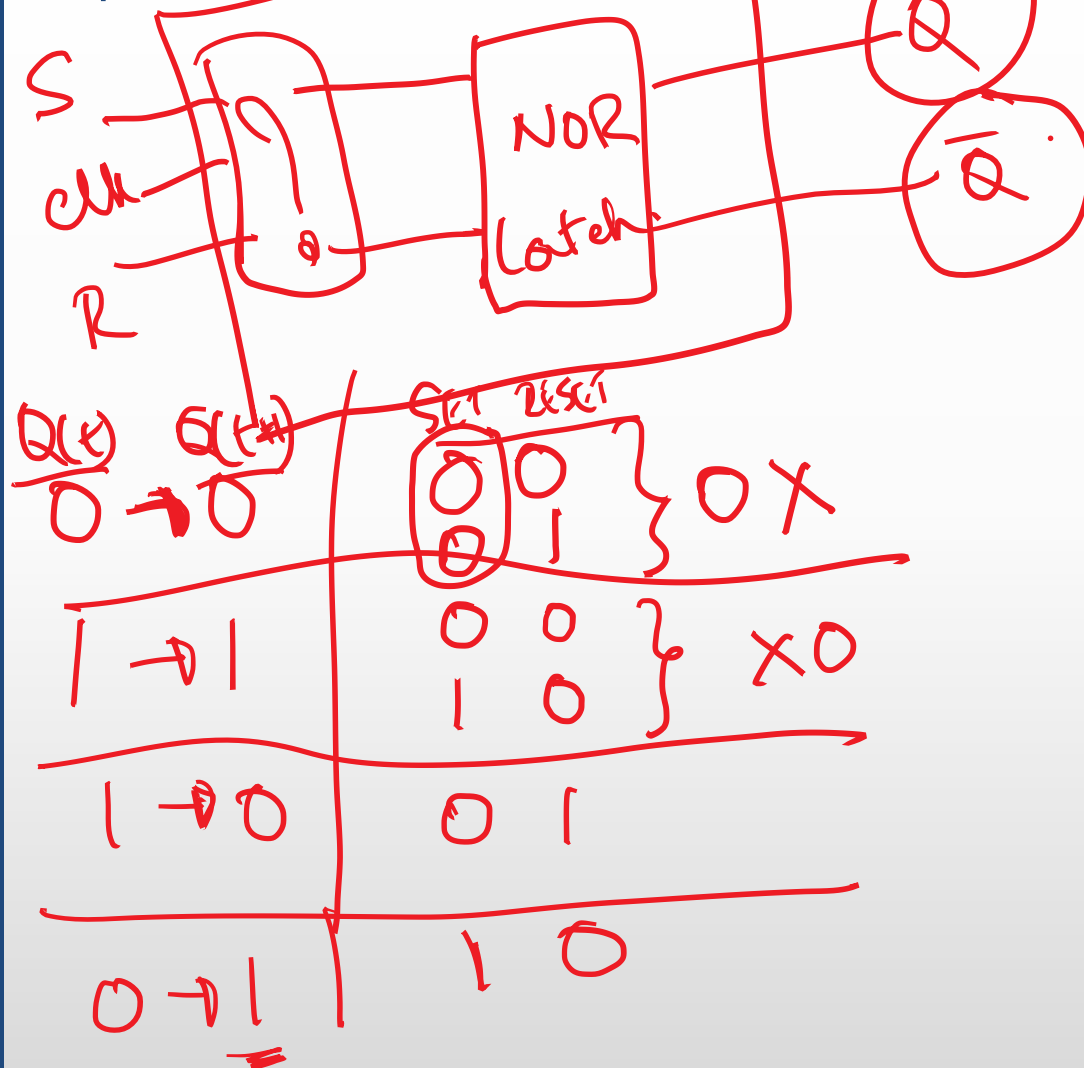
$$SET = \overline{clk} + \overline{S} = \overline{clk \cdot S}$$

$$RESET = \overline{R} + \overline{clk} = \overline{clk \cdot R}$$



# SR Flip Flop using NOR latch

Equation for SET and RESET



Excitation Table

Clk	S	R	Q(t)	Q(t+1)	SET	RESET
0	0	0	0	0	0	x
0	0	0	1	1	x	0
0	0	1	0	0	0	x
0	0	1	1	1	x	0
0	1	0	0	0	0	x
0	1	0	1	1	x	0
0	1	1	0	0	0	x
0	1	1	1	1	x	0
1	0	0	0	0	0	x
1	0	0	1	1	x	0
1	0	1	0	0	0	x
1	0	1	1	0	0	1
1	1	0	0	1	1	0
1	1	0	1	1	x	0
1	1	1	0	x	x	x
1	1	1	1	x	x	x

## Circuit and Block Diagram

~~SET =  $\overline{clk} S$~~

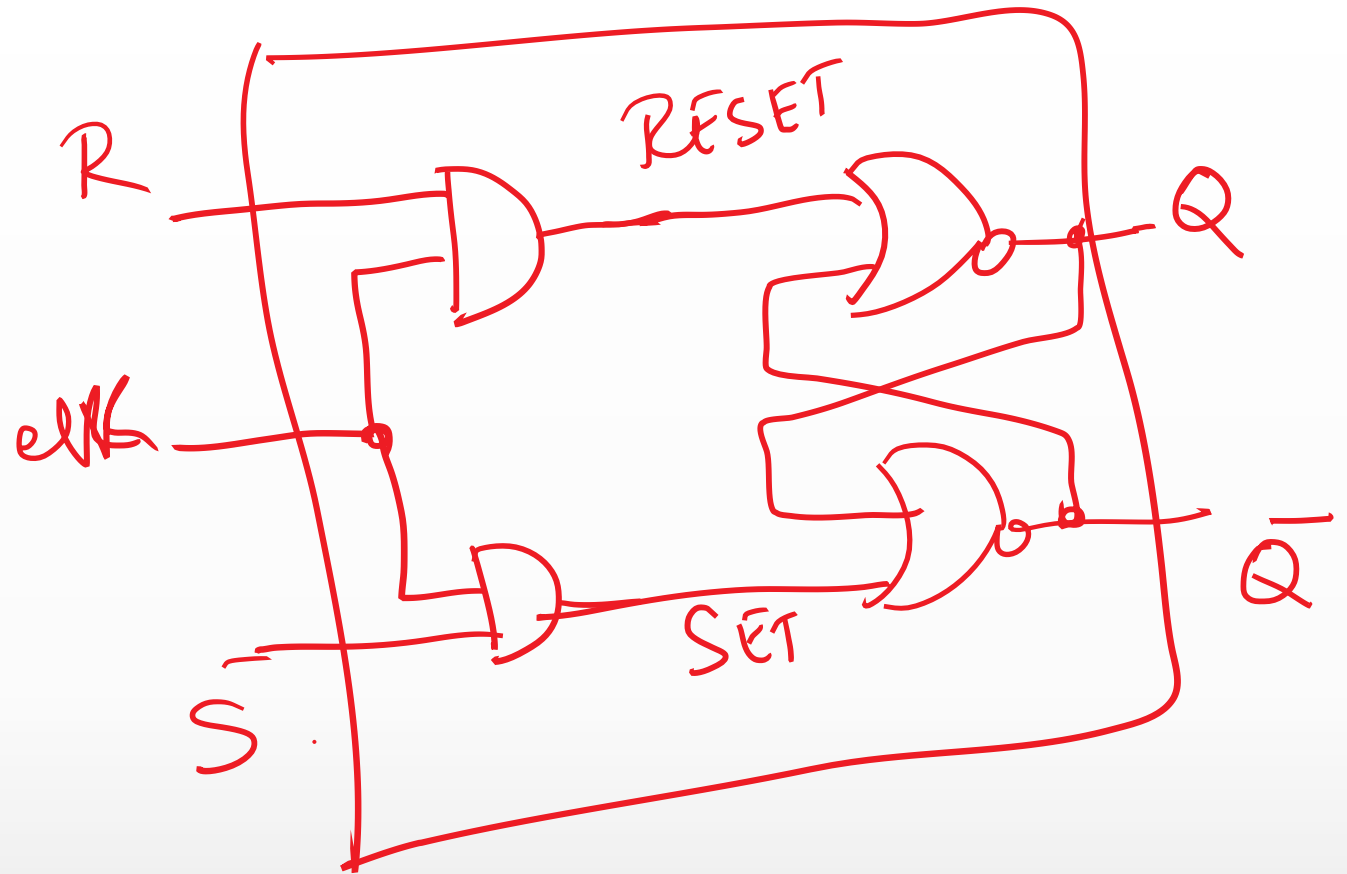
<del>clk</del>	<del>R</del>	<del>Q</del>	00	01	11	10
00	0	X	X	0		
01	0	X	X	0		
11	1	X	X	X		
10	0	X	0	0		

SET =  $\overline{clk} S$

~~RESET =  $\overline{clk} R$~~

<del>clk</del>	<del>R</del>	<del>Q</del>	00	01	11	10
00	X	0	0	X		
01	X	0	0	X		
11	0	0	X	X		
10	X	0	1	X		

RESET =  $\overline{clk} R$



SR - FF

Characteristic Table			
S	R	Q(t)	Q(t+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	X
1	1	1	X

Characteristic equation:

$Q(t+1)$

$S \backslash R Q(t)$

	00	01	11	10
0	0	1	0	0
1	1	1	X	X

$$Q(t+1) = S + \bar{R}Q(t)$$

When  $S=R=1$  does not occur.

# D Flip Flop using NAND latch

NAND latch

Function Table		
Clk	D	Output
0	X	No change
1	0	Reset 0
1	1	Set 1

Equation for SET and RESET

	SET	RESET
0 → 0	1	1
1 → 1	0	1
1 → 0	1	0
0 → 1	0	1

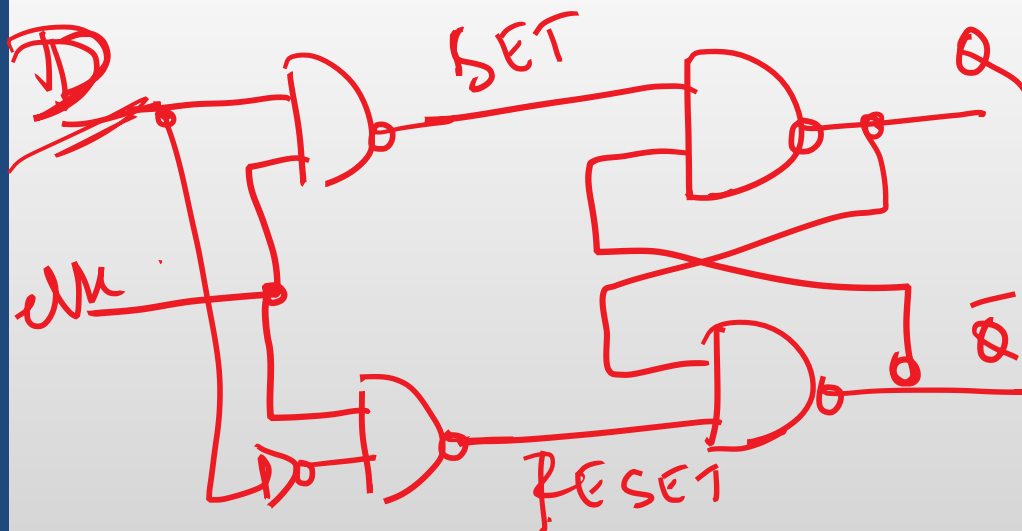
Excitation Table					
Clk	D	Q(t)	Q(t+1)	SET	RESET
0	0	0	0	1	X
0	0	1	1	X	1
0	1	0	0	1	X
0	1	1	1	X	1
1	0	0	0	1	X
1	0	1	0	1	0
1	1	0	1	0	1
1	1	1	1	X	1

# Circuit and block diagram of D Flip Flop

Truth Table for D Flip Flop:

clk	D	Q
0	0	1
0	1	X
1	0	0
1	1	1

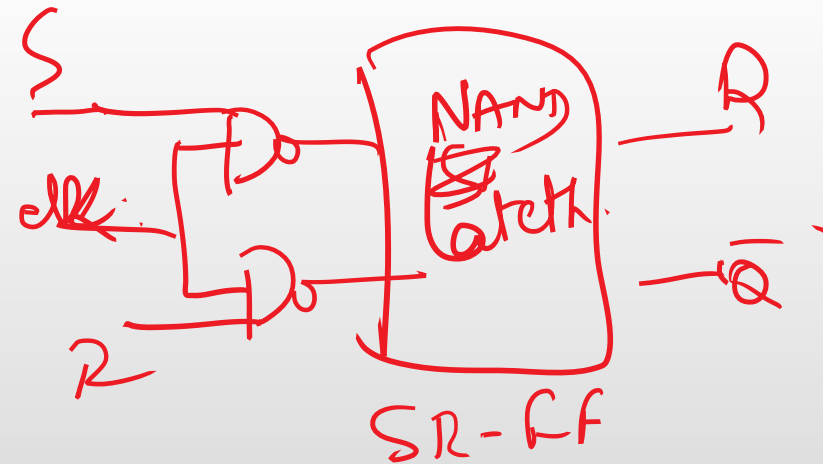
$$SET = \overline{clk} \cdot \overline{D} = \overline{clk \cdot D}$$



Truth Table for D Flip Flop (Handwritten):

clk	D	Q
0	0	1
0	1	X
1	0	0
1	1	1

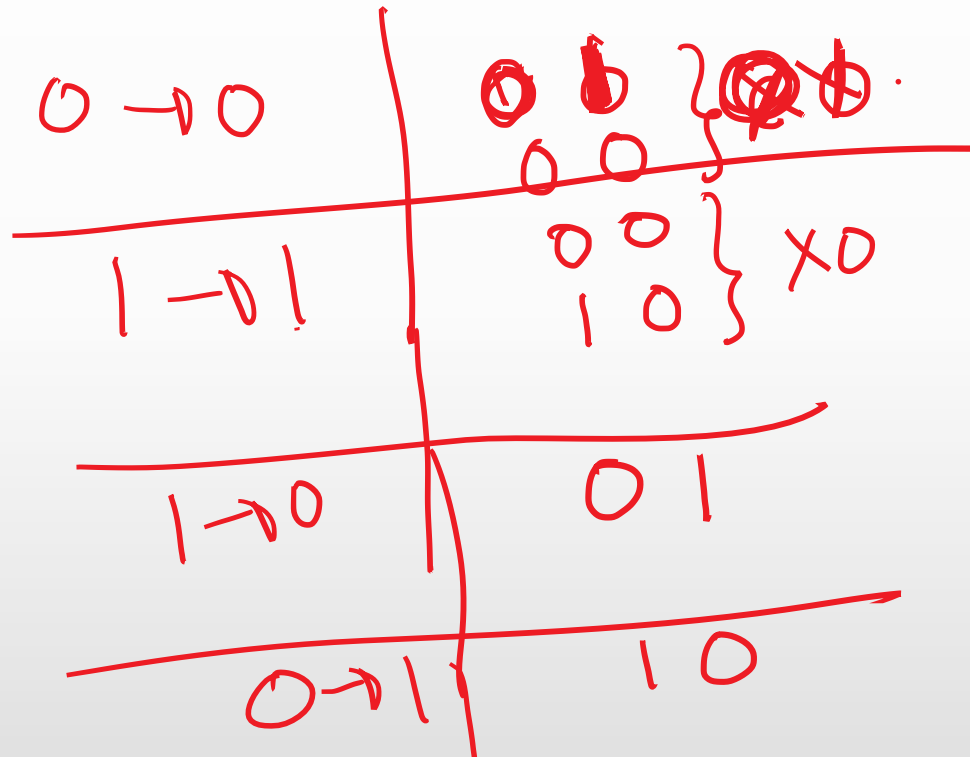
$$RESET = \overline{clk} \cdot D = \overline{clk \cdot \overline{D}}$$





# D Flip Flop using NOR Latch

Equation for SET and RESET

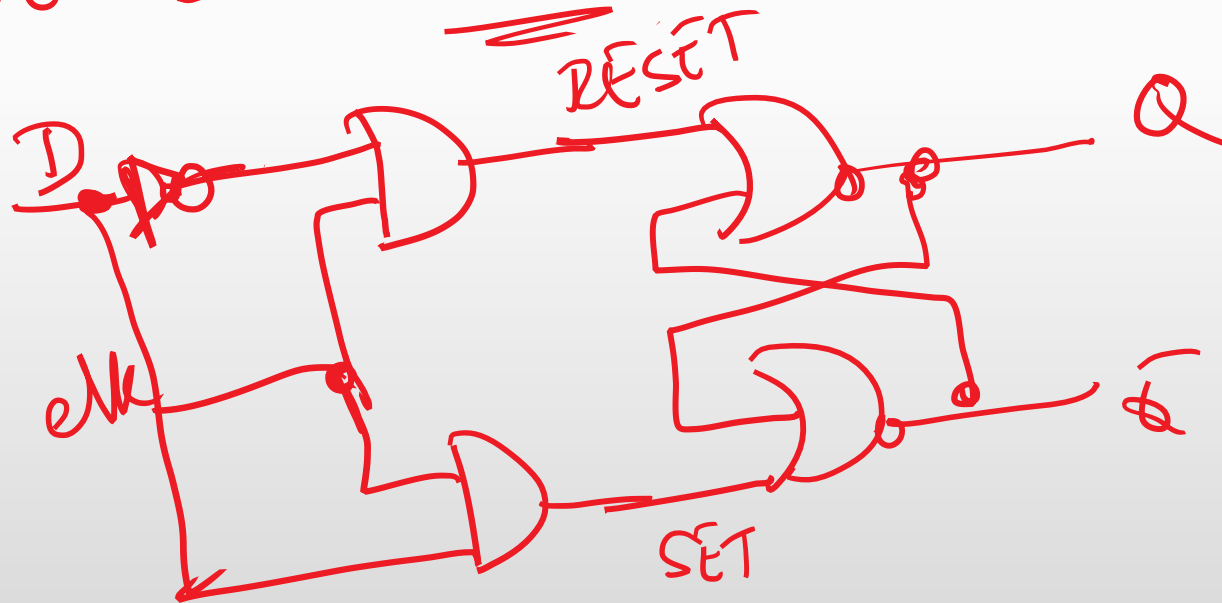


Excitation Table					
Clk	D	Q(t)	Q(t+1)	SET	RESET
0	0	0 → 0	0	0	X
0	0	1 → 1	1	X	0
0	1	0 → 0	0	0	X
0	1	1 → 1	1	X	0
1	0	0 → 0	0	0	X
1	0	1 → 0	0	0	1
1	1	0 → 1	1	1	0
1	1	1 → 1	1	X	0

# Circuit and block diagram of D Flip Flop

clk \ D Q(t)	00	01	11	10
0	0	X	X	0
1	0	0	X	1

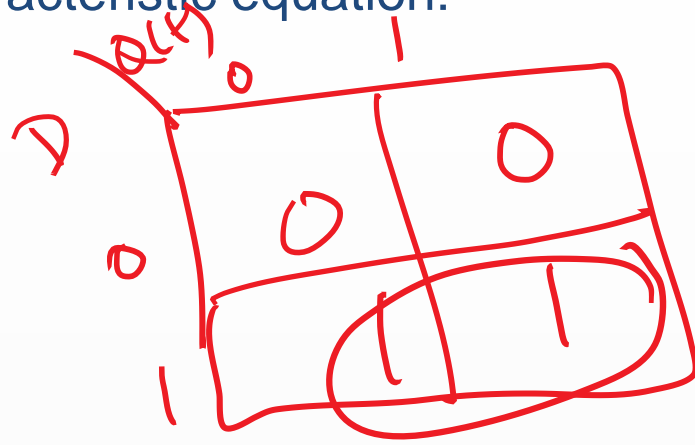
$$\text{SET} = \text{clk} \cdot \underline{\underline{\text{D}}}$$



clk \ D Q(t)	00	01	11	10
0	X	0	0	X
1	X	1	0	0

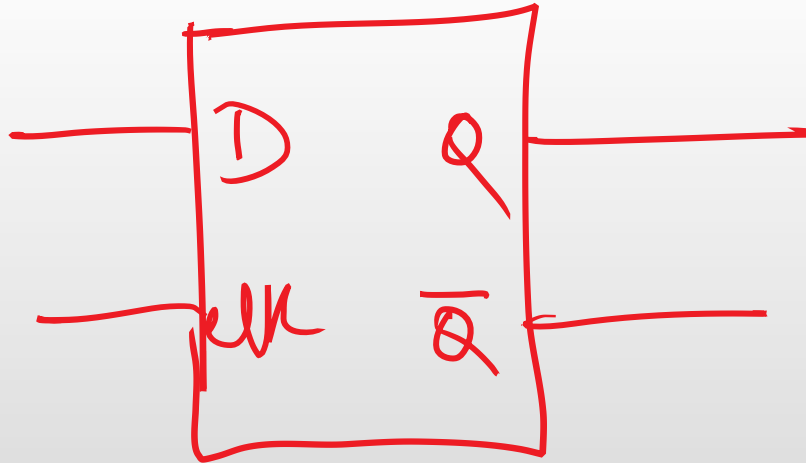
$$\text{RESET} = \underline{\underline{\text{clk} \cdot \text{D}}}$$

Characteristic equation:



$$Q(t+1) = D$$

Characteristic Table		
D	Q(t)	Q(t+1)
0	0	0
0	1	0
1	0	1
1	1	1



# JK Flip Flop using NAND latch

Function Table			
Clk	J	K	Output
0	X	X	No Change
1	0	0	No Change
1	0	1	Reset
1	1	0	Set
1	1	1	Toggle

Equation for SET and RESET

	SET	RESET	SET	RESET
0 → 0	1	1	1	X
1 → 1	1	0	X	1
1 → 0	1	0		
0 → 1	0	1		

Excitation Table						
Clk	J	K	Q(t)	Q(t+1)	SET	RESET
0	0	0	0	0	1	X
0	0	0	1	1	X	1
0	0	1	0	0	1	X
0	0	1	1	1	X	1
0	1	0	0	0	1	X
0	1	0	1	1	X	1
0	1	1	0	0	1	X
0	1	1	1	1	X	1
1	0	0	0	0	1	X
1	0	0	1	1	X	1
1	0	1	0	0	1	X
1	0	1	1	0	1	0
1	1	0	0	1	0	1
1	1	0	1	1	X	1
1	1	1	0	1	0	1
1	1	1	1	0	1	0

NAND latch

# Circuit and block diagram of JK flip flop:

clk \ J \ K	00	01	11	10
00	1	X	X	1
01	1	X	X	1
11	0	X	1	0
10	1	X	1	1

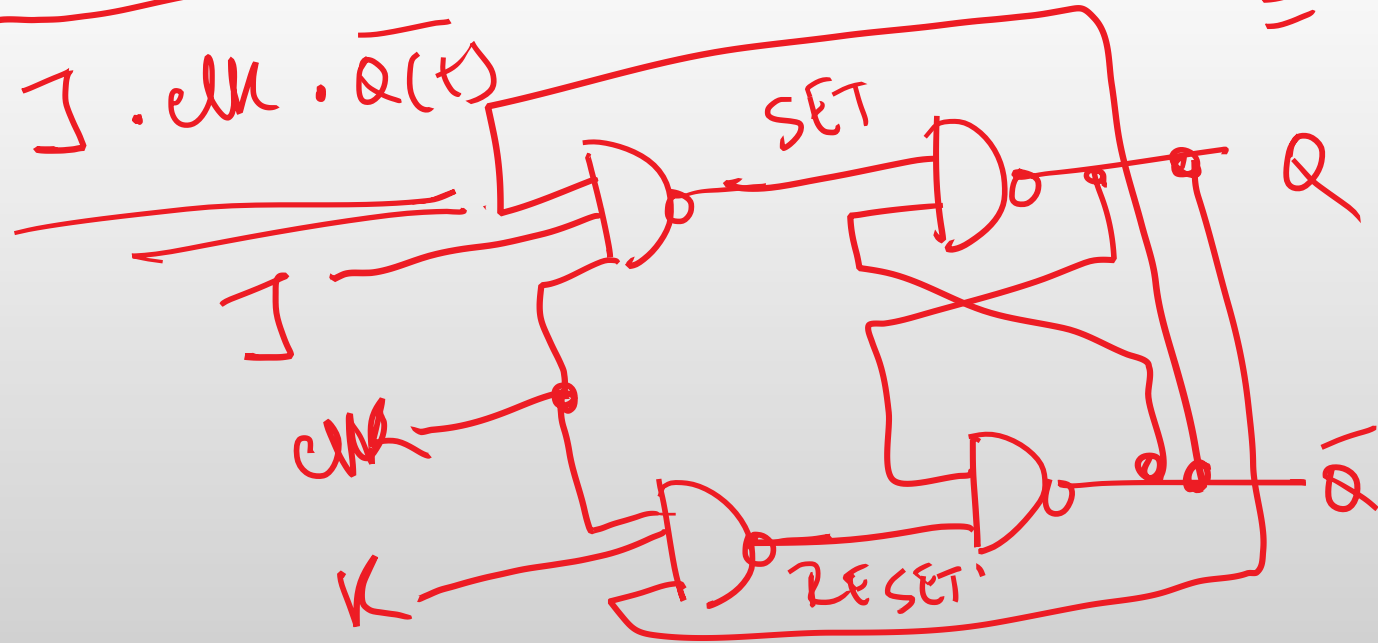
clk \ J \ K	00	01	11	10
00	X	1	1	X
01	X	1	1	X
11	1	1	0	1
10	X	1	0	X

$$\text{SET} = \overline{J} + Q(t) + \overline{\text{CLK}}$$

$$= J \cdot \text{CLK} \cdot \overline{Q(t)}$$

$$\text{RESET} = \overline{Q(t)} + \overline{\text{CLK}} + \overline{K}$$

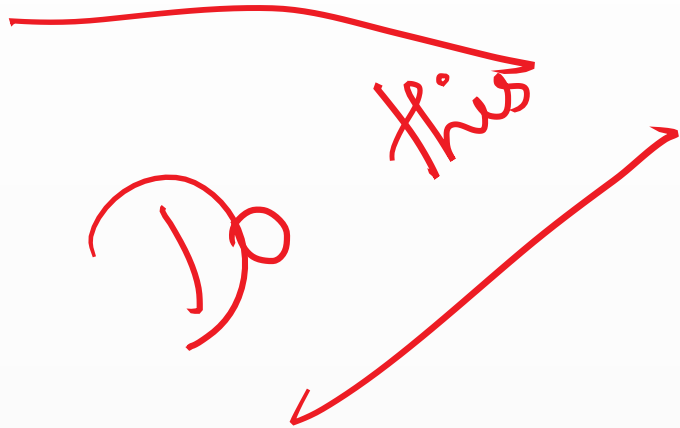
$$= \overline{K \cdot \text{CLK} \cdot Q(t)}$$



# JK Flip Flop using NOR latch

Equation for SET and RESET

*Do this*

Handwritten red arrows and text. A curved arrow points from the text 'Do this' towards the right. Another curved arrow points from the text 'Do this' towards the bottom right.

Excitation Table						
Clk	J	K	Q(t)	Q(t+1)	SET	RESET
0	0	0	0			
0	0	0	1			
0	0	1	0			
0	0	1	1			
0	1	0	0			
0	1	0	1			
0	1	1	0			
0	1	1	1			
1	0	0	0			
1	0	0	1			
1	0	1	0			
1	0	1	1			
1	1	0	0			
1	1	0	1			
1	1	1	0			
1	1	1	1			

## Circuit and Block Diagram

Solve this

Characteristic Table

J	K	Q(t)	Q(t+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

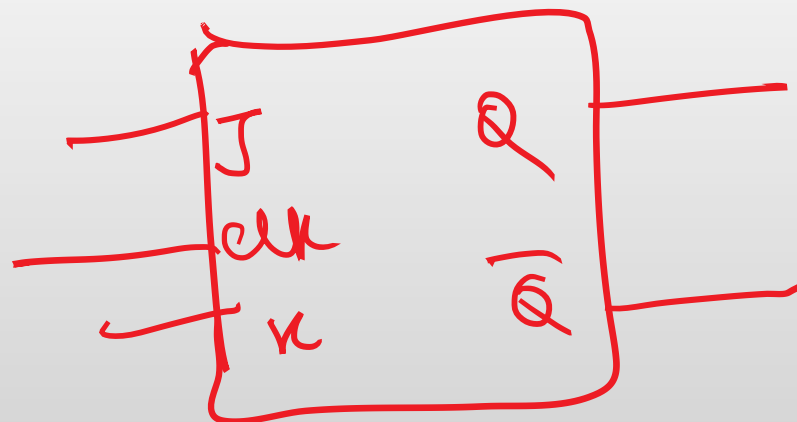
Characteristic equation:

Handwritten Karnaugh map for the characteristic equation:

J \ K Q(t)	00	01	11	10
0	0	1	0	0
1	1	1	0	1

Red circles and lines indicate groupings for the characteristic equation.

$$Q(t+1) = J \bar{K} + \bar{K} Q(t) + J Q(t)$$





# T Flip Flop using NAND latch

NAND latch

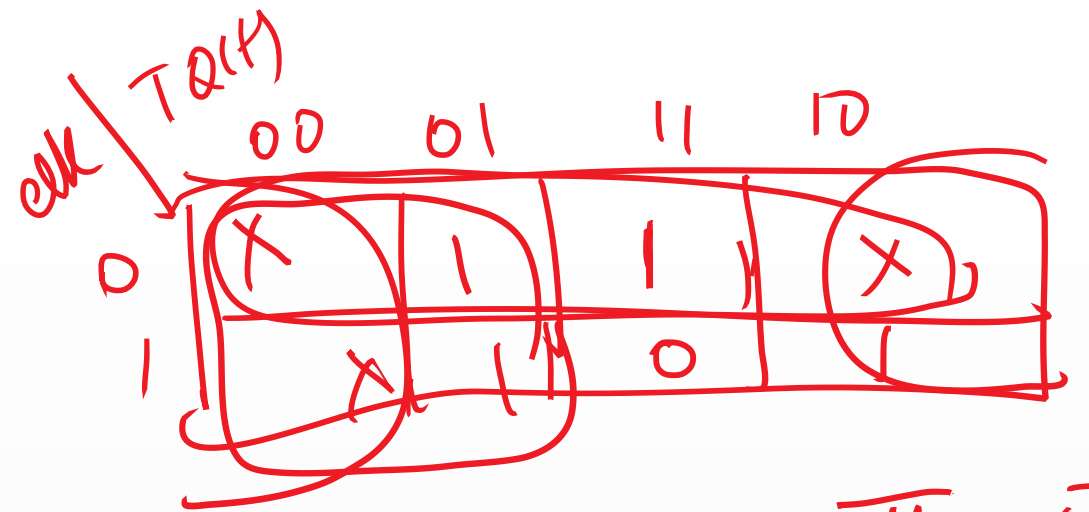
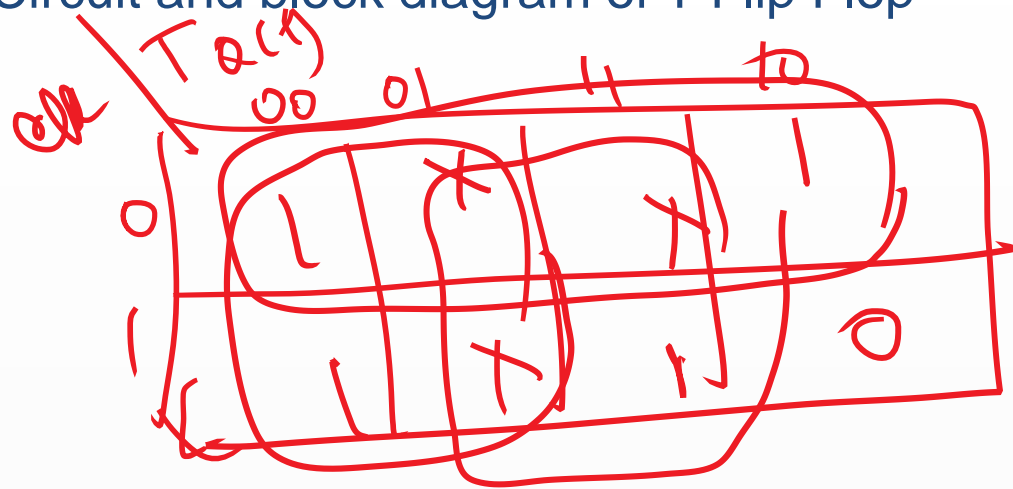
Function Table $Q(k+1)$		
Clk	T	Output
0	X	No change
1	0	No Change
1	1	<del>Q(k)</del> Toggle

Equation for SET and RESET

	SET	RESET	
$0 \rightarrow 0$	1	0	1x
$1 \rightarrow 1$	0	1	x1
$0 \rightarrow 1$	0	1	
$1 \rightarrow 0$	1	0	

Excitation Table					
Clk	T	Q(t)	Q(t+1)	SET	RESET
0	0	0 $\rightarrow$ 0		1	x
0	0	1 $\rightarrow$ 1		x	1
0	1	0 $\rightarrow$ 0		1	x
0	1	1 $\rightarrow$ 1		x	1
1	0	0 $\rightarrow$ 0		1	x
1	0	1 $\rightarrow$ 1		x	1
1	1	0 $\rightarrow$ 1		0	1
1	1	1 $\rightarrow$ 0		1	0

# Circuit and block diagram of T Flip Flop

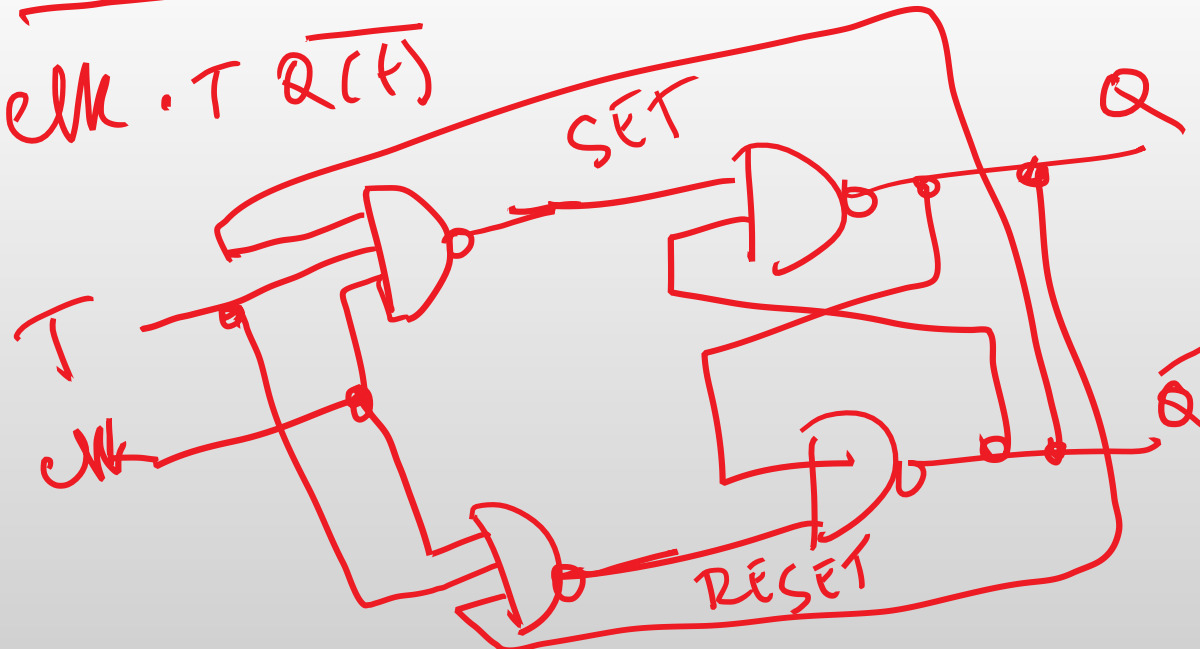


$$\text{RESET} = \overline{T} + \overline{\text{CLK}} + \overline{Q(t)}$$

$$= \overline{T \cdot \text{CLK} \cdot Q(t)}$$

$$\text{SET} = \overline{\text{CLK}} + \overline{T} + Q(t)$$

$$= \overline{\text{CLK} \cdot T \cdot \overline{Q(t)}}$$



# T Flip Flop using NOR Latch

Equation for SET and RESET

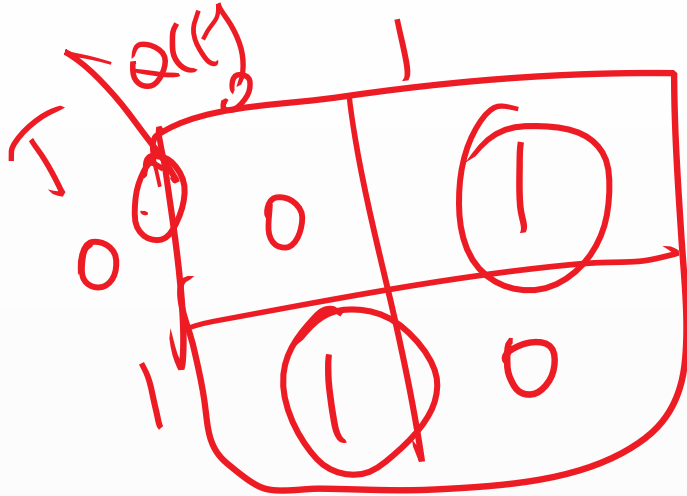
Do this

Excitation Table					
Clk	T	Q(t)	Q(t+1)	SET	RESET
0	0	0			
0	0	1			
0	1	0			
0	1	1			
1	0	0			
1	0	1			
1	1	0			
1	1	1			

## Circuit and block diagram of T Flip Flop

Do this

Characteristic equation:



Characteristic Table		
T	Q(t)	Q(t+1)
0	0	0
0	1	1
1	0	1
1	1	0

$$Q(t+1) = T \overline{Q(t)} + \overline{T} Q(t)$$
$$= \underline{\underline{T \oplus Q(t)}}$$

