

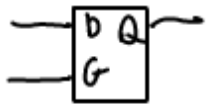
① Latches \leftarrow level sensitive (output changes whenever an input is at a certain value)

② Flip flops \leftarrow edge sensitive / edge triggered.

(output changes whenever an input makes a transition from $0 \rightarrow 1$ or $1 \rightarrow 0$)

↑ ↑
rising edge falling edge

Latch



Q changes according to D while $G=1$

FlipFlop



Q changes according to D, when G transitions from $0 \rightarrow 1$.

Flipflop input is not called gate, but rather a clock.

Types of flipflops

DFF



characteristic table (describes how the flipflop works)

$D(t)$	$Q(t+1)$
0	0
1	1

characteristic eqn:
 $Q(t+1) = D(t)$

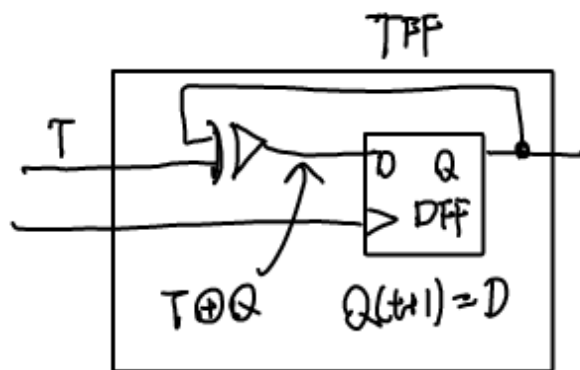
TFF "toggle" flip-flop



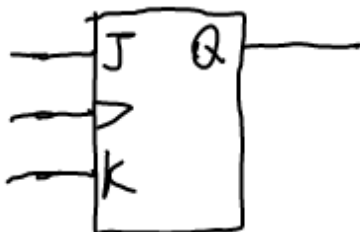
$T(t)$	$Q(t+1)$
0	$Q(t)$
1	$\overline{Q(t)}$

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

$$= T \oplus Q$$



JKFF

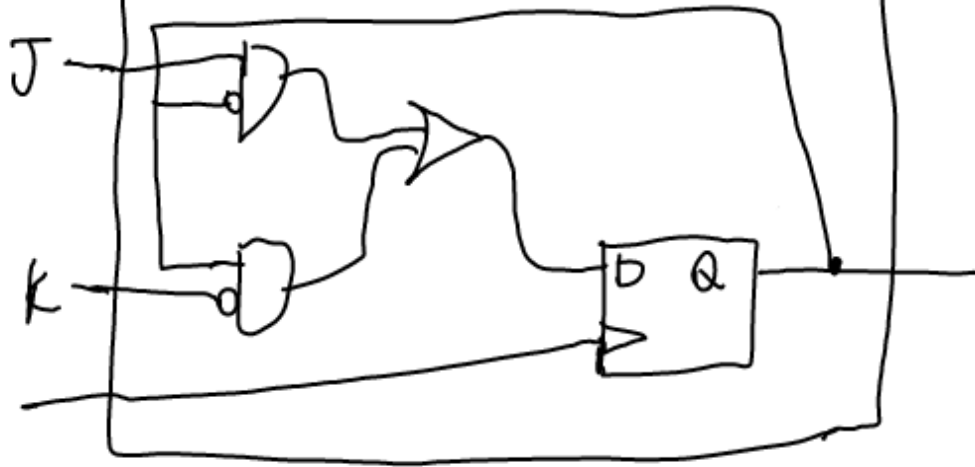


$J(t)$	$K(t)$	$Q(t+1)$
0	0	$Q(t)$
0	1	0
1	0	1
1	1	$\overline{Q(t)}$

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

t			$t+1$
J	K	Q	Q
{			{

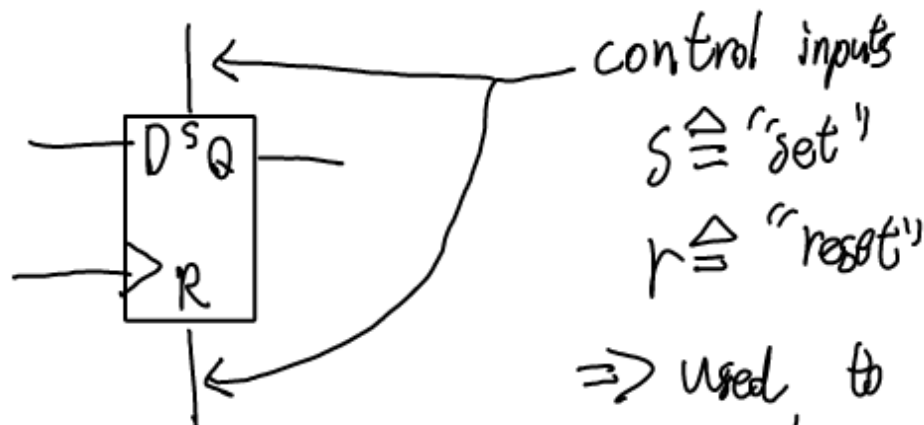
obtain eqn from
K-map.



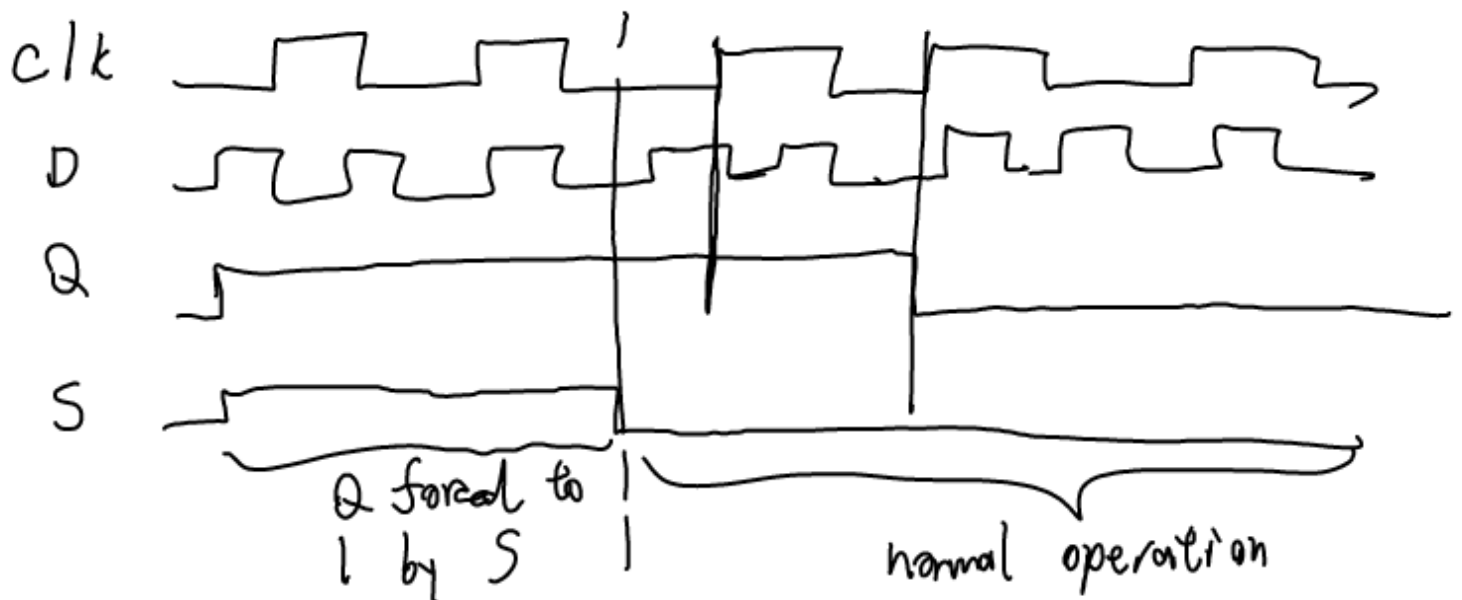
JK FlipFlop

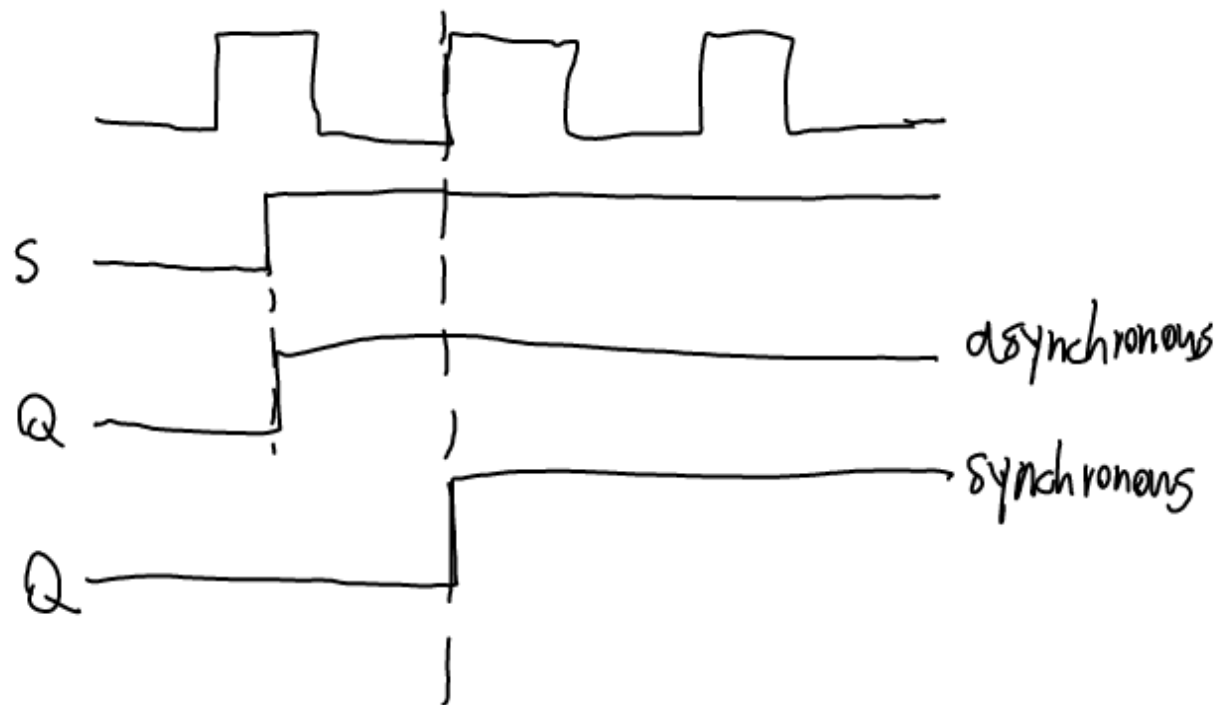
Q: what about the output of a flipflop at $t=0$?

- could be either 0 or 1
- You don't necessarily know the initial condition.



$S \equiv \text{"set"}$
 $R \equiv \text{"reset"}$
 \Rightarrow used to force output to 1 or 0 regardless of the clock.

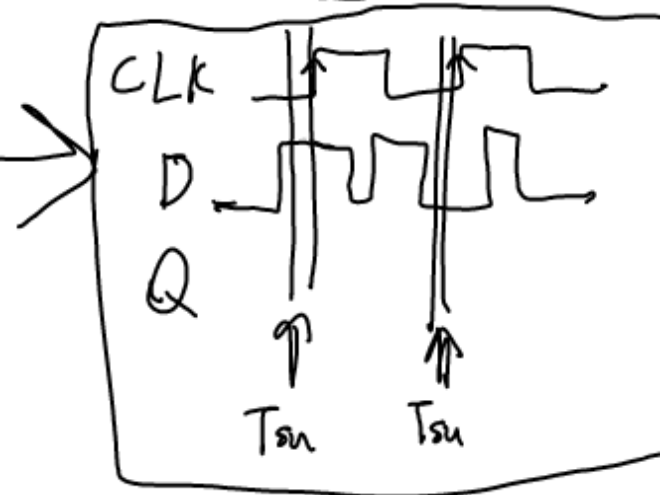
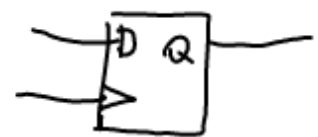
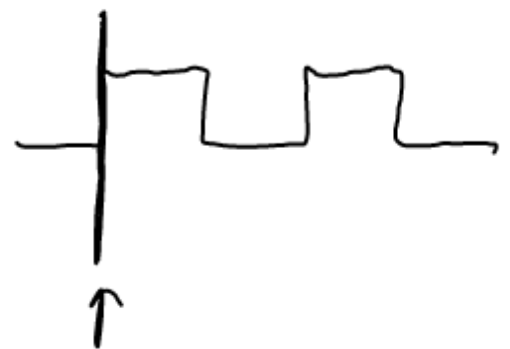




Timing Parameters for Flip flops

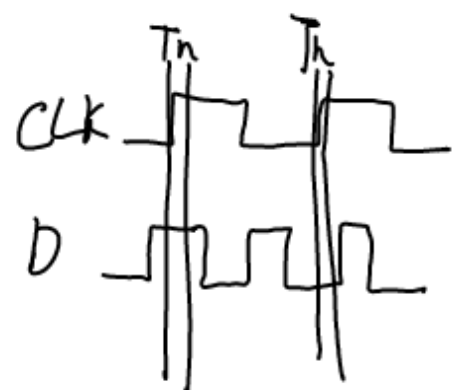
① Set up time: (T_{su})

Amount of time the data inputs must arrive & stop changing prior to the active clock edge.



② Hold Time (T_h)

Amount of time the data inputs must remain stable/constant after the arrival of the active clock edge.



③ Clock-to-output (T_{CO})

Amount of time for Q to change after the arrival of the active clock edge.

