F/F characteristic equation :-

⇒ S-R F/F

S	R	Q_n	Q_{n+1}	
0	0	0	0	} previous
0	0	1	1	
0	1	0	0	} Reset
0	1	1	0	
1	0	0	1	} set
1	0	1	1	
1	1	0	?	
1	1	1	?	

Q_{n+1}	$\bar{R}\bar{Q}_n$	$\bar{R}Q_n$	RQ_n	$R\bar{Q}_n$
$\bar{S}$	0	1	0	0
S	1	1	X	X

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

$SR = 0$

Both S and R can not equal to 1 simultaneously

⇒ D F/F

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

$Q_{n+1} = D$

⇒ JK F/F

J	K	Q_n	Q_{n+1}	
0	0	0	0	} Q_n
0	0	1	1	
0	1	0	0	} Reset
0	1	1	0	
1	0	0	1	} Set
1	0	1	1	
1	1	0	1	} Toggle
1	1	1	0	

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

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

⇒ T F/F

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

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

Excitation table :- provide Q_n formation to the inputs with Q_n and Q_{n+1}

⇒ SR FlF

S	R	Q_n	Q_{n+1}
0	0	0	Q_n
0	0	1	Q_n
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	?
1	1	1	?

⇒

Q_n	Q_{n+1}	S	R
0	0	0	X
0	1	1	0
1	0	0	1
1	1	X	0

⇒ JK FlF

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

⇒

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

→ D FlF

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

⇒

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

→ T FlF

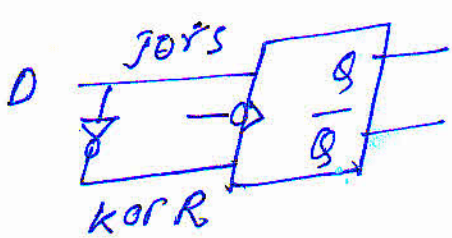
T	Q_n	Q_{n+1}
0	0	0
0	1	1
1	0	1
1	1	0

⇒

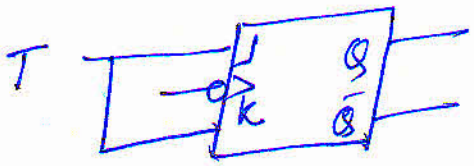
Q_n	Q_{n+1}	T
0	0	0
0	1	1
1	0	1
1	1	0

Jn for connection of FlFs. :-

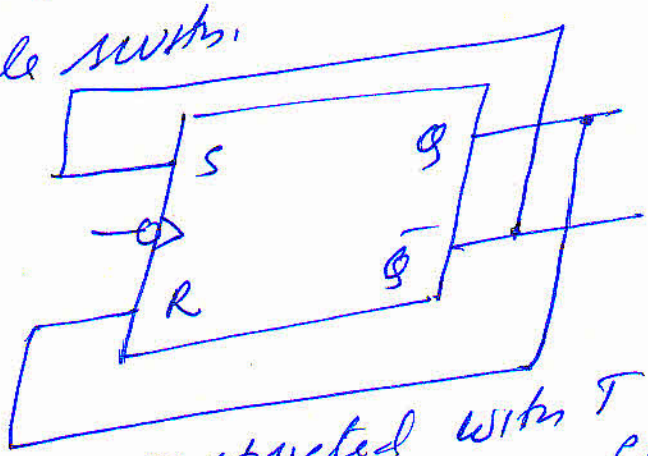
⇒ JK/RS into D



⇒ J.K into T



⇒ SR as Toggle switch.

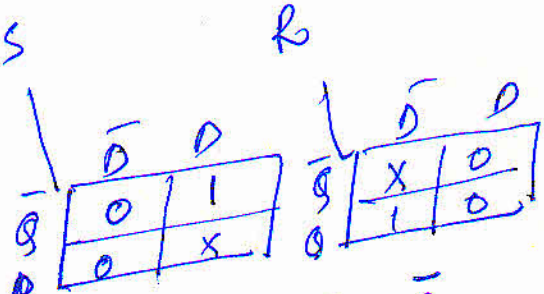


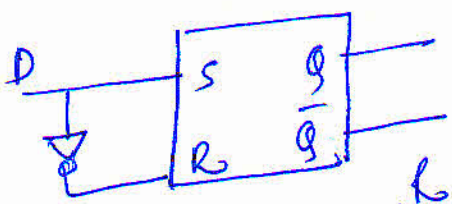
SR F/F can't be constructed with T F/F since S=R=1 is forbidden, however ckt shown act as a Toggle switch, Q changes with each clk pulse.

Conversion of F/Fs :-

⇒ SR into D

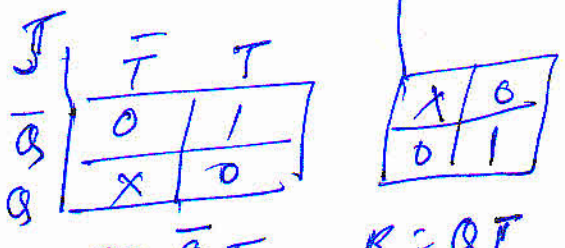
Inputs		Transition	O/Ps	
Q	D	$Q_n \to Q_{n+1}$	S	R
0	0	0 → 0	0	X
0	1	0 → 1	1	0
1	0	1 → 0	0	1
1	1	1 → 1	X	0

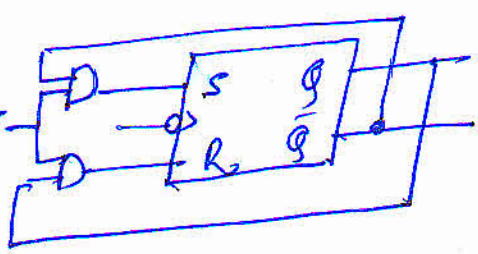




⇒ SR into T

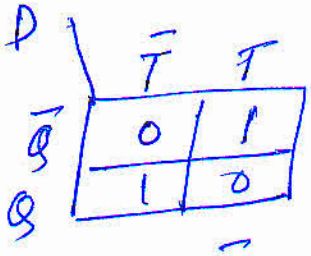
Inputs		Transition		
Q	T	$Q_n \to Q_{n+1}$	S	R
0	0	0 → 0	0	X
0	1	0 → 1	1	0
1	0	1 → 1	X	0
1	1	1 → 0	0	1



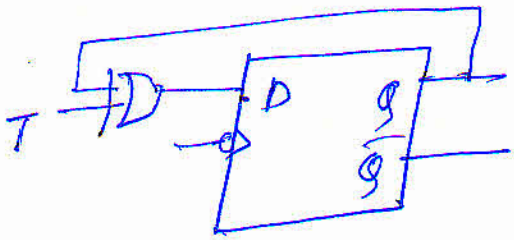


⇒ D into T

Q	T	$Q_n \to Q_{n+1}$	D
0	0	0 → 0	0
0	1	0 → 1	1
1	0	1 → 1	1
1	1	1 → 0	0

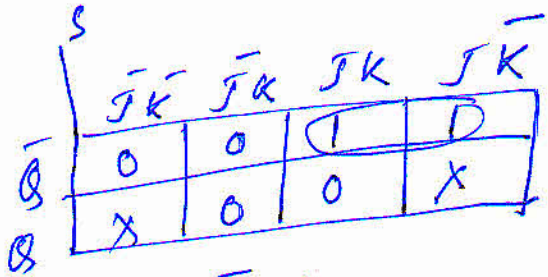


$D = Q\bar{T} + \bar{Q}T = Q \oplus T$

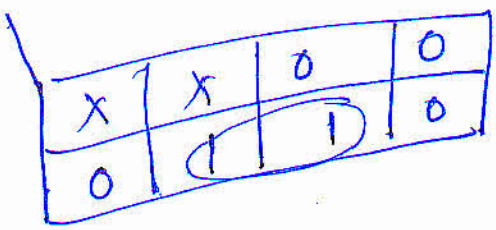


⇒ SR into JK

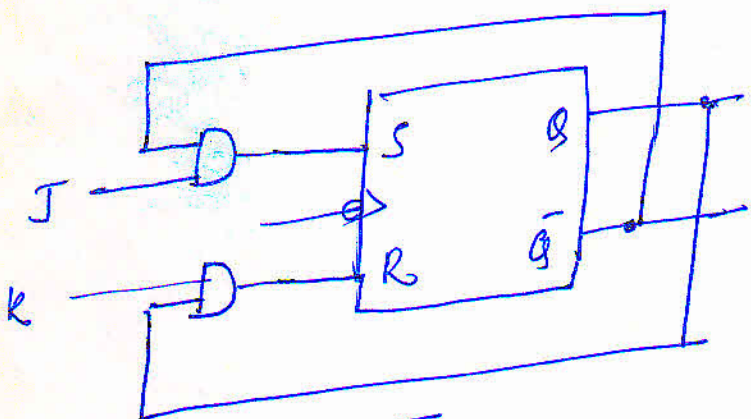
Q	J	K	$Q_n \to Q_{n+1}$	S	R
0	0	0	0 → 0	0	X
0	0	1	0 → 0	0	X
0	1	0	0 → 1	1	0
0	1	1	0 → 1	1	0
1	0	0	1 → 1	X	0
1	0	1	1 → 0	0	1
1	1	0	1 → 1	X	0
1	1	1	1 → 0	0	1



R $S = \bar{Q}J$

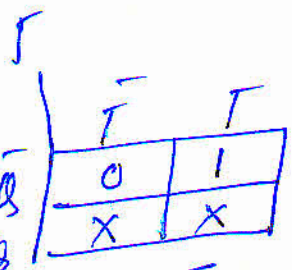


$R = QK$

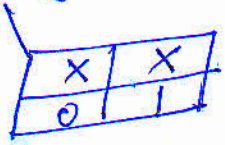


⇒ JK to T

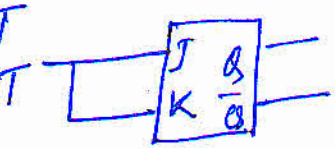
Q	T	$Q_n \to Q_{n+1}$	J	K
0	0	0 → 0	0	X
0	1	0 → 1	1	X
1	0	1 → 1	X	0
1	1	1 → 0	X	1



K $J = T$



$K = T$



⇒ in XY F/F truth table is given below is to implemented using JK F/F from J S K respectively

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

JK to XY F/F.

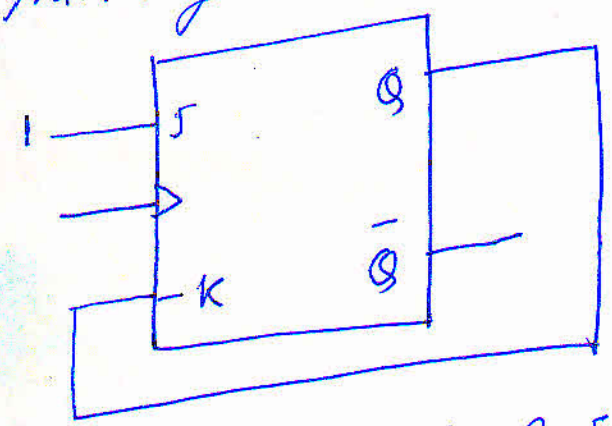
Q_n	x	y	$Q_n \to Q_{n+1}$	J	K
0	0	0	0 → 1	1	X
0	0	1	0 → 0	0	X
0	1	0	0 → 1	1	X
0	1	1	0 → 0	0	X
1	0	0	1 → 1	X	0
1	0	1	1 → 1	X	0
1	1	0	1 → 0	X	1
1	1	1	1 → 0	X	1

J

Q_n	$\bar{x}\bar{y}$	$\bar{x}y$	xy	$x\bar{y}$
$\bar{Q}_n$	1	0	0	1
Q_n	X	x	x	x

$J = \bar{y}$ Similarly $K = x$.

⇒ If initially Q o/p is zero after 6 clk pulses the o/p Q is



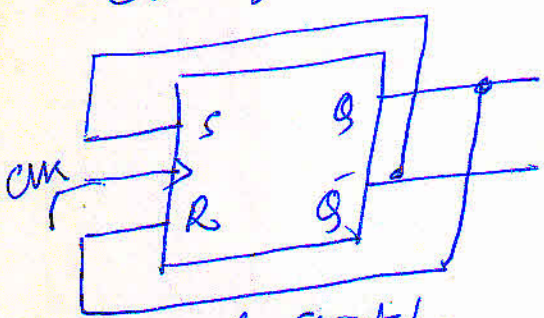
0

Since $K = \bar{Q}$

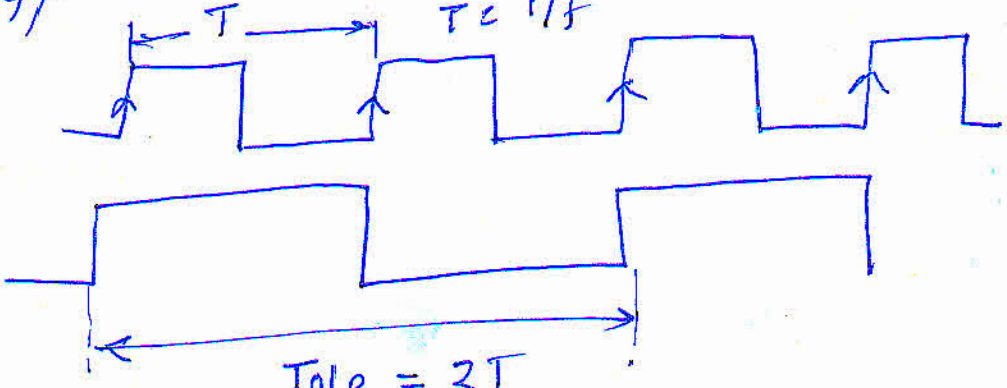
Q	J	K	Q_{n+1}
0	1	0	1
1	1	1	0
1	0	1	1
1	1	1	0
1	0	1	1
1	1	1	0

o/p

⇒ In +ve edge triggered SR F/F If $\bar{Q}$ connected to S i/p, Q is connected to R and clk of 10 kHz is applied from o/p freq Q is



Toggle switch.

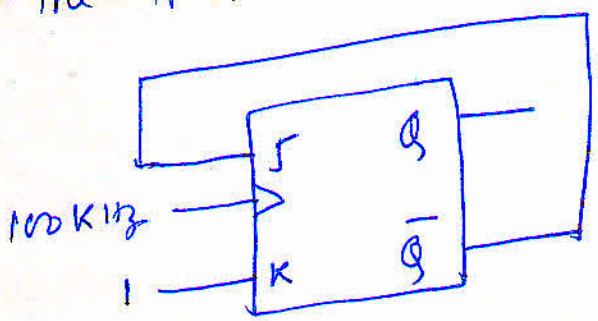


If initially $Q = 0$, $\bar{Q} = 1$ $R = 0$, $S = 1$ F/F is set

If $Q = 1$, $\bar{Q} = 0$ → $R = 1$, $S = 0$, Reset

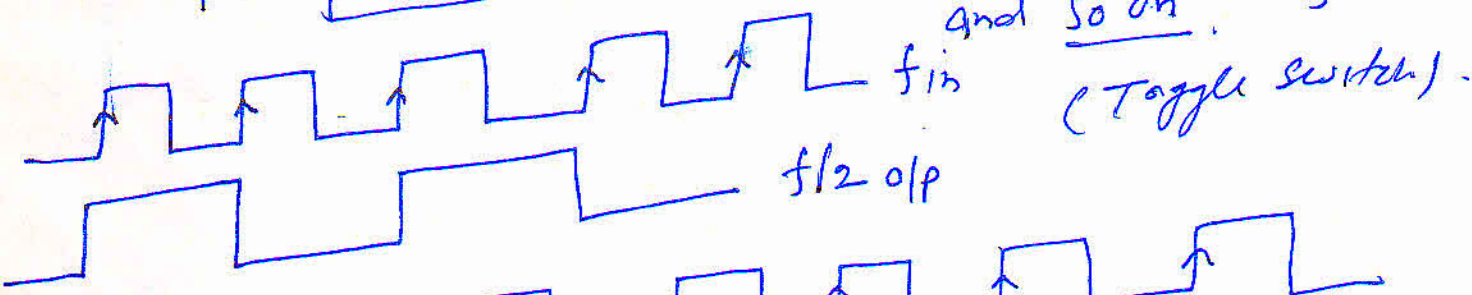
$$f_{o/p} = \frac{1}{T_{o/p}} = \frac{1}{2T} = \frac{f}{2} = \frac{10}{2} = 5\,kHz$$

⇒ The o/p freq. is

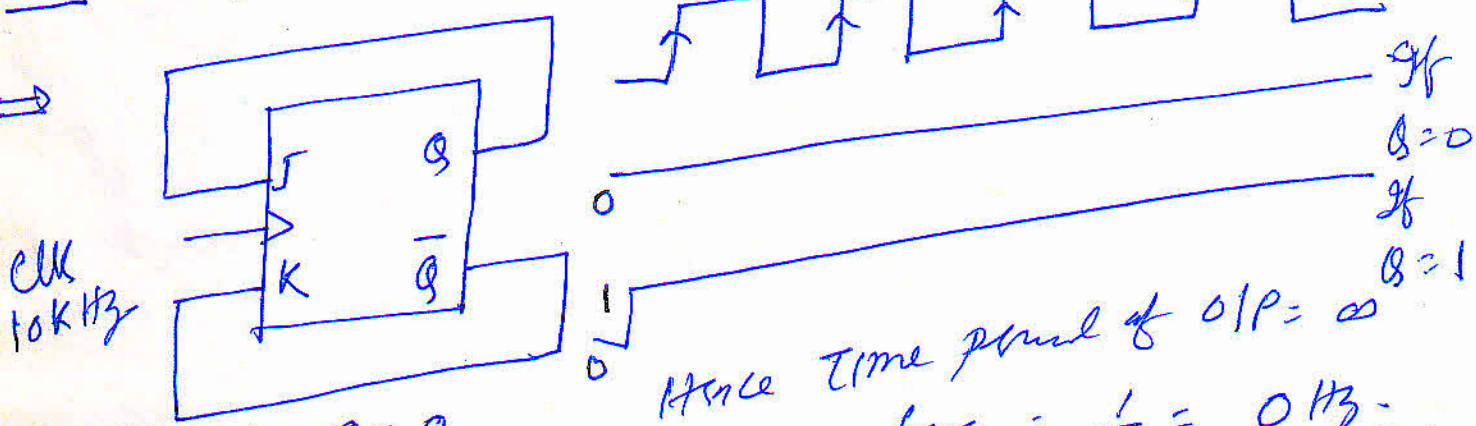


If initially
$Q = 0$, $\bar{Q} = 1$
$J = 1$, $K = 1$ Toggle $Q \to 1$
$\bar{Q} = 0$
If $Q = 1$
$J = 0$, $K = 1$ Reset $Q = 0$
$\bar{Q} = 1$

and so on.



⇒



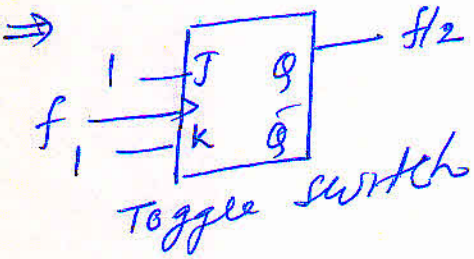
Hence Time period of o/p = ∞

freq. = $\frac{1}{\infty} = 0$ Hz.

If initially $Q = 0$
$\bar{Q} = 1$
$J = 0$ FF is Reset
$K = 1$ $Q = 0$ } always
$Q = 1$

If initially $Q = 1$
$\bar{Q} = 0$
$J = 1$ FF is Set
$K = 0$ $Q = 1$ } always.
$\bar{Q} = 0$

⇒



counters :- counters can be used as an instrument for measuring time and therefore period or freq. There are two types of counters.

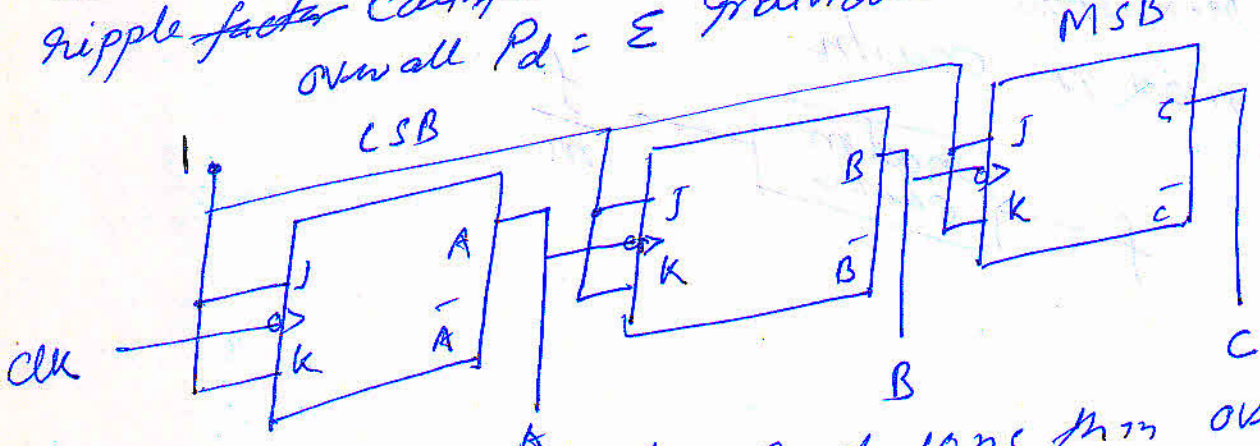
1) Syncronous
2) Asyncronous.

⇒ Asyncronous / Ripple / Serial counters :- Simple and straight forward in operation
* Require minimum hardware
* Has speed limitation
* Each FF is triggered by the previous FF and so the counter have cumulative settling time
* Suffer from glitch

⇒ parallel / syncronous counters :-
* Increase speed of operation
* Since FF is triggered by the clk in syncronous and so the settling time equals delay of the single FF
* Increase Hardware
* Glitch do not occur.

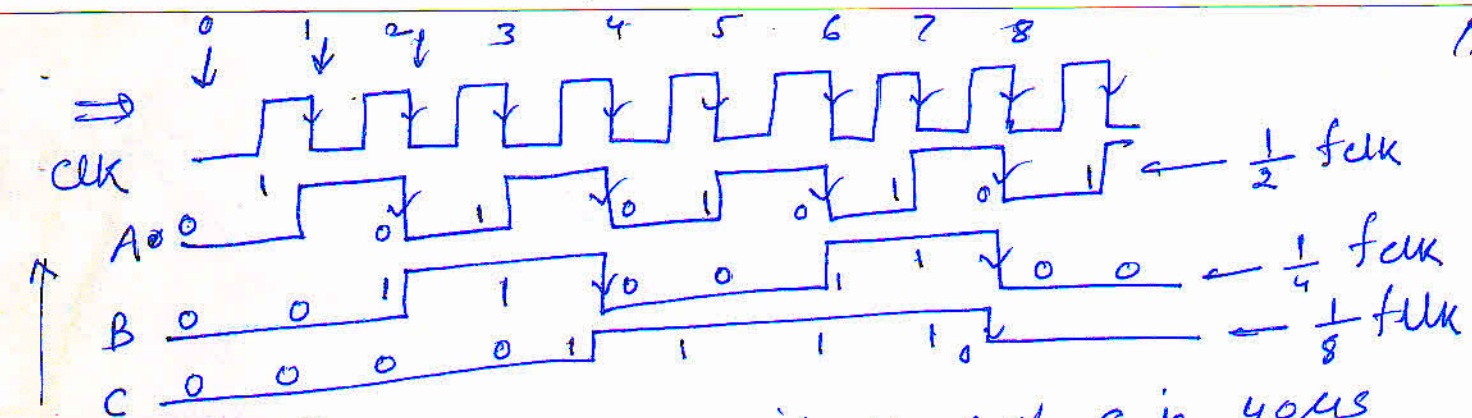
Ripple / Asyncronous counter :- when o/p of a FF is used as a clock for next stage FF. then it is called ripple counter.

overall Pd = Σ individual Pd of FFs.



CBA = 000 initially

If each FF has Pd of 10ns then overall Pd is 30ns. (LSB when external clk is applied).



Counting sequence

CLK transition	C B A
0	0 0 0
1	0 0 1
2	0 1 0
3	0 1 1
4	1 0 0
5	1 0 1
6	1 1 0
7	1 1 1
0	0 0 0

if period of C is 40μs

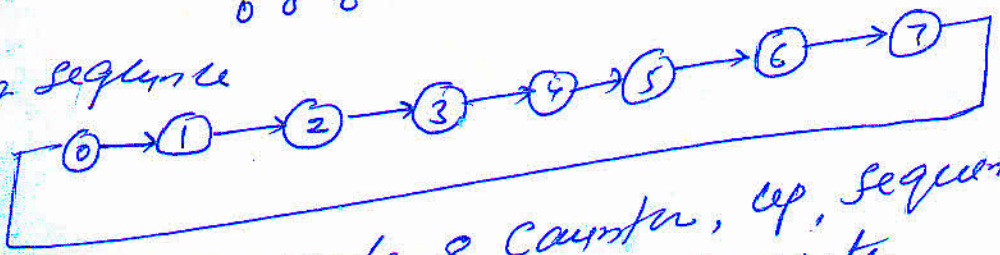
fclk = ?

$f_c = \frac{1}{40\times10^{-6}}$ =

$f_c = \frac{1}{8} f_{clk}$

$f_{clk} = 8 \times \frac{1}{40\times10^{-6}} = 200\ KHZ$

Counting sequence

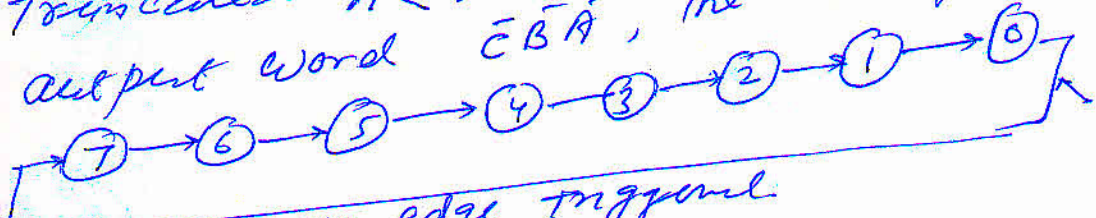


Count up mode →

* 8 states → Mode 8 counter, up, sequential. Regular
* Modular → No. of distinct states
* Sequential → states one is sequence 0, 1, 2, 3 - - -
* Regular → $n = 2^m$, n = no. of states / Mod of counter
  m → No. of F/Fs

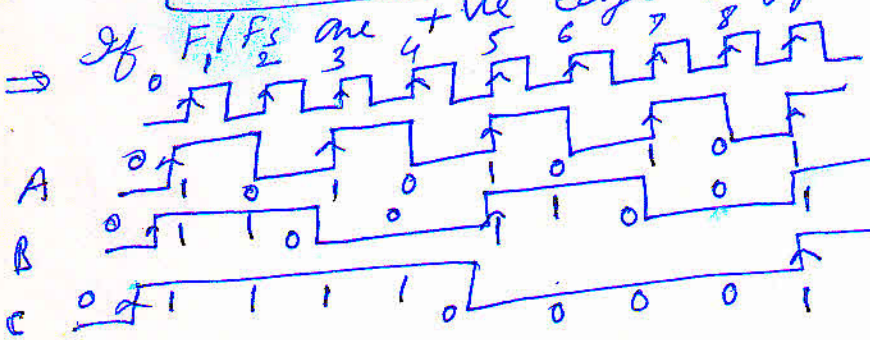
* Truncated $n < 2^m$

⇒ If output word $\bar{C}\bar{B}\bar{A}$, The Resulting sequence is

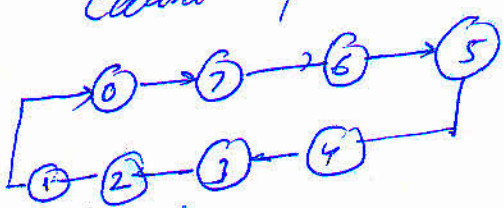


down sequential regular

⇒ If F/Fs are +ve edge triggered



count sequence



↓ down sequence

In Asynchronous counter

Cascade

Mod MN counter

In ripple counter Pd of each F/F is t_{pd} than time period of the clk

$$T_{clk} \geq n\, t_{pd\,FF}$$

$$f_{clk} \leq \frac{1}{n\, t_{pd}}$$

$$f_{max} = \frac{1}{n\, t_{pd}}$$

Max state = 2^n

For mod m counter