

$n t_{PD}$  = delay final o/p.  
frequency of ck should  
be less, otherwise ripples  
overlap & some values are  
missed.

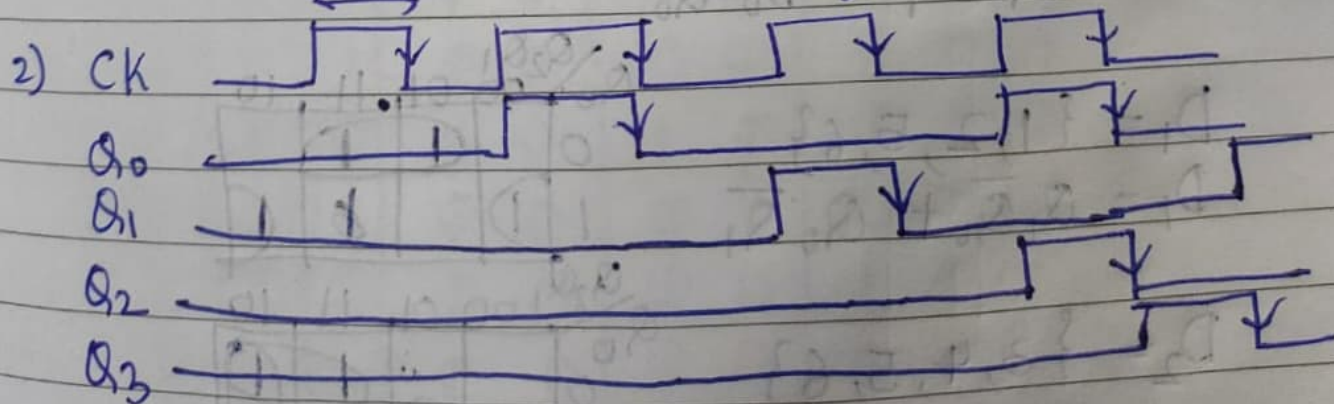
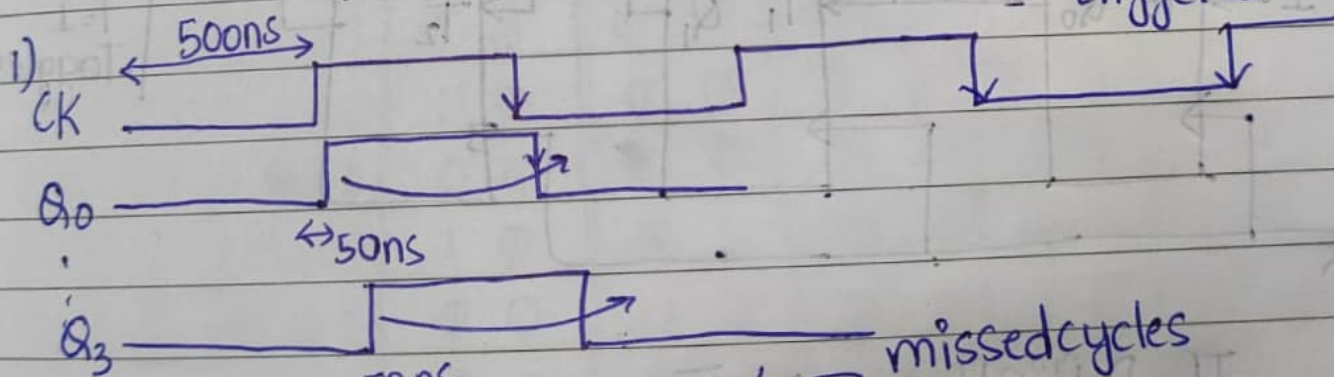
$$f_{max} = \frac{1}{N t_{PD}}$$

1)  $T = 1000 \text{ ns}$

$T_{PD} = 50 \text{ ns}$

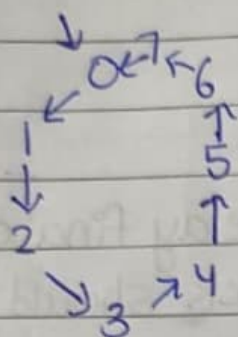
2)  $T = 100 \text{ ns}$

$T_{PD} = 50 \text{ ns}$

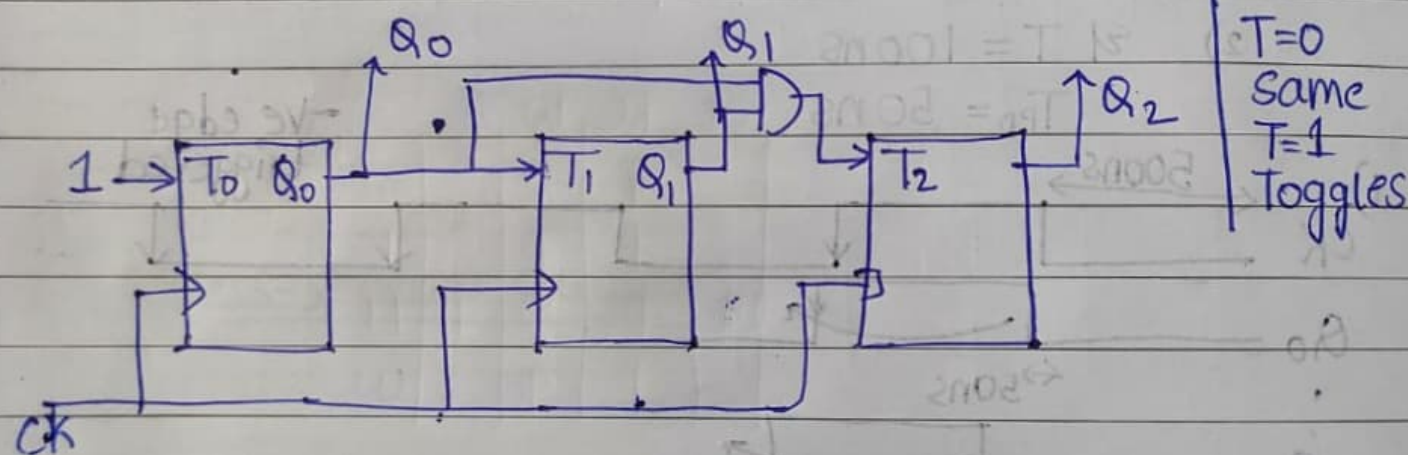


Synchronous counters  $\rightarrow$  3 bit binary up-counter

State Transition diagram

State Transition Table ( $D_t = N_t$ )

PS	NS	$D_2$	$D_1$	$D_0$
$Q_2 Q_1 Q_0$	$Q_2 Q_1 Q_0$			
0 0 0	0 0 1	0	0	1
0 0 1	0 1 0	0	1	0
0 1 0	0 1 1	0	1	1
0 1 1	1 0 0	1	0	0
1 0 0	1 0 1	1	0	1
1 0 1	1 1 0	1	1	0
1 1 0	1 1 1	1	1	1
1 1 1	0 0 0	0	0	0

Toggle flip flop  $\rightarrow JK=1$ If D flip flop  $\rightarrow D_0 = \bar{Q}_0$ 

$$D_1 = \{1, 2, 5, 6\}$$

$$D_1 = Q_1 \bar{Q}_0 + Q_0 \bar{Q}_1$$

$$D_2 = \{3, 4, 5, 6\}$$

$$= \bar{Q}_2 Q_1 Q_0 + Q_2 \bar{Q}_0 + Q_2 \bar{Q}_1$$

$Q_2 Q_1$	00	01	11	10
$Q_0$	0	1	1	0
$Q_0$	1	1	0	1

$Q_2 Q_1$	00	01	11	10
$Q_0$	0	1	1	0
$Q_0$	1	1	0	1



$D^+ = NS$ $T^+ =$			PS	NS	J-K
			$Q$	$Q^+$	$\phi$ $\phi$ J K
excitation -ion Table	0	0	0	0	1 0 0 $\phi$
	0	1	1	1	1 $\phi$
	1	0	1	0	$\phi$ 1
	1	1	0	1	$\phi$ 0

4-bit up counter

flipflop inputs

PS	NS	$J_3 K_3$	$J_2 K_2$	$J_1 K_1$	$J_0 K_0$
$Q_3 Q_2 Q_1 Q_0$	$Q_3 Q_2 Q_1 Q_0$				
0 0 0 0	0 0 0 1	0 $\phi$	0 $\phi$	0 $\phi$	1 $\phi$
1 0 0 0	0 0 1 0	0 $\phi$	0 $\phi$	1 $\phi$	$\phi$ 1
2 0 0 1	0 0 1 1	0 $\phi$	0 $\phi$	$\phi$ 0	1 $\phi$
3 0 0 1	0 1 0 0	0 $\phi$	1 $\phi$	$\phi$ 1	$\phi$ 1
4 0 1 0	0 1 0 1	0 $\phi$	$\phi$ 0	$\phi$ 0	1 $\phi$
5 0 1 0	0 1 1 0	0 $\phi$	$\phi$ 0	1 $\phi$	$\phi$ 1
6 0 1 1	0 1 1 1	0 $\phi$	$\phi$ 0	$\phi$ 0	1 $\phi$
7 0 1 1	1 0 0 0	1 $\phi$	$\phi$ 1	$\phi$ 1	$\phi$ 1
8 1 0 0	1 0 0 1	$\phi$ 0	0 $\phi$	$\phi$ 0	1 $\phi$
9 1 0 0	1 0 1 0	$\phi$ 0	0 $\phi$	1 $\phi$	$\phi$ 1
10 1 0 1	1 0 1 1	$\phi$ 0	0 $\phi$	$\phi$ 0	1 $\phi$
11 1 0 1	1 1 0 0	$\phi$ 0	1 $\phi$	$\phi$ 1	$\phi$ 1
12 1 1 0	1 1 0 1	$\phi$ 0	$\phi$ 0	0 $\phi$	1 $\phi$
13 1 1 0	1 1 1 0	$\phi$ 0	$\phi$ 0	1 $\phi$	$\phi$ 1
14 1 1 1	1 1 1 1	$\phi$ 0	$\phi$ 0	$\phi$ 0	1 $\phi$
15 1 1 1	0 0 0 0	$\phi$ 1	$\phi$ 1	$\phi$ 1	$\phi$ 1

$J_3$

$Q_3 Q_2$	00	01	11	10
$Q_1 Q_0$				
00			$\phi$	$\phi$
01			$\phi$	$\phi$
11		1	$\phi$	$\phi$
10			$\phi$	$\phi$

$$= Q_2 Q_1 Q_0$$

$K_3$

$Q_3 Q_2$	00	01	11	10
$Q_1 Q_0$				
00	$\phi$	$\phi$		
01	$\phi$	$\phi$		
11	$\phi$	$\phi$	1	
10	$\phi$	$\phi$		

$$= Q_2 Q_1 Q_0$$

$J_2$

$Q_3 Q_2$	00	01	11	10
$Q_1 Q_0$				
00		$\phi$	$\phi$	
01		$\phi$	$\phi$	
11	1	$\phi$	$\phi$	$\phi$
10		$\phi$	$\phi$	

$$= Q_1 Q_0$$

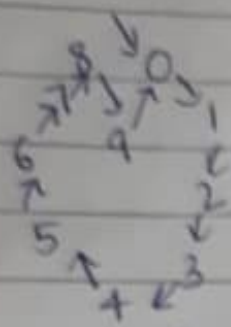
$K_2$

$Q_3 Q_2$	00	01	11	10
$Q_1 Q_0$				
00	$\phi$			$\phi$
01	$\phi$		1	$\phi$
11	$\phi$	1	1	$\phi$
10	$\phi$			$\phi$

$$= Q_1 Q_0$$

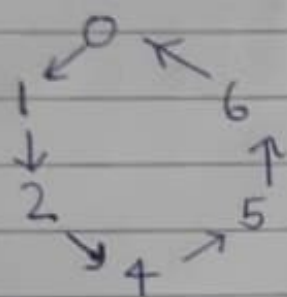
$$J_0 = K_0 = 1$$



BCD up counter

Same as before, except everything after 9 in present state - JK are don't cares & NS of 9 in PS is 0000

ex:



but  $\begin{matrix} 3 \\ \nearrow \\ 7 \end{matrix}$  may happen, To avoid  $\begin{matrix} 3 \rightarrow 0 \\ \nearrow \\ 2 \end{matrix}$

PS	NS	Flip-flop input			
$Q_3 Q_2 Q_1 Q_0$	$Q_3 Q_2 Q_1 Q_0$	$J_3 K_3$	$J_2 K_2$	$J_1 K_1$	$J_0 K_0$
0 0 0 0	0 0 0 1	0 $\phi$	0 $\phi$	0 $\phi$	1 $\phi$
1 0 0 0	0 0 1 0	0 $\phi$	0 $\phi$	1 $\phi$	$\phi$ 1
2 0 0 1	0 0 1 1	0 $\phi$	0 $\phi$	$\phi$ 0	1 $\phi$
3 0 0 1	0 1 0 0	0 $\phi$	1 $\phi$	$\phi$ 1	$\phi$ 1
4 0 1 0	0 1 0 1	0 $\phi$	$\phi$ 0	$\phi$ 0	1 $\phi$
5 0 1 0	0 1 1 0	0 $\phi$	$\phi$ 0	1 $\phi$	$\phi$ 1
6 0 1 1	0 1 1 1	0 $\phi$	$\phi$ 0	$\phi$ 0	1 $\phi$
7 0 1 1	$\phi$ 0 0 0	1 $\phi$	$\phi$ 1	$\phi$ 1	$\phi$ 1
8 1 0 0	1 0 0 1	$\phi$ 0	0 $\phi$	0 $\phi$	1 $\phi$
9 1 0 0	0 0 0 0	$\phi$ 1	0 $\phi$	0 $\phi$	$\phi$ 1
1 0 1 0	<del>1 0 1 1</del>	$\phi$ $\phi$	$\phi$ $\phi$	$\phi$ $\phi$	$\phi$ $\phi$
1 0 1 1	<del>1 1 0 0</del>				
1 $\phi$ 0 0	—				
1 1 0 1	—				
1 1 1 0	—				

$Q_3 Q_2$

$Q_1 Q_0$	00	01	11	10
00			$\phi$	$\phi$
01			$\phi$	$\phi$
11		1	$\phi$	$\phi$
10			$\phi$	$\phi$

$$= Q_2 Q_1 Q_0 = J_3$$

$K_3$   $Q_3 Q_2$

$Q_1 Q_0$	00	01	11	10
00	$\phi$	$\phi$	$\phi$	
01	$\phi$	$\phi$	$\phi$	1
11	$\phi$	$\phi$	$\phi$	$\phi$
10	$\phi$	$\phi$	$\phi$	$\phi$

$$= Q_0$$

$K_1$   $Q_3 Q_2$

$Q_1 Q_0$	00	01	11	10
00	$\phi$	$\phi$	$\phi$	$\phi$
01	$\phi$	$\phi$	$\phi$	$\phi$
11	1	1	$\phi$	$\phi$
10			$\phi$	$\phi$

$$= Q_0$$

$J_2$   $Q_3 Q_2$

$Q_1 Q_0$	00	01	11	10
00		$\phi$	$\phi$	
01		$\phi$	$\phi$	
11	$\phi$	$\phi$	$\phi$	$\phi$
10	1	$\phi$	$\phi$	$\phi$

$$= Q_1$$

$$J_0 = K_0 = 1$$

$K_2$   $Q_3 Q_2$

$Q_1 Q_0$	00	01	11	10
00	$\phi$		$\phi$	$\phi$
01	$\phi$		$\phi$	$\phi$
11	$\phi$	1	$\phi$	$\phi$
10	$\phi$		$\phi$	$\phi$

$$= Q_1 Q_0$$

$J_1$   $Q_3 Q_2$

$Q_1 Q_0$	00	01	11	10
00		$\phi$	$\phi$	
01	1	1	$\phi$	
11	$\phi$	$\phi$	$\phi$	$\phi$
10	$\phi$	$\phi$	$\phi$	$\phi$

$$= \overline{Q_3} Q_0$$

PS				NS				FlipFlop			
$Q_3 Q_2 Q_1 Q_0$				$Q_3 Q_2 Q_1 Q_0$				$J_3 K_3$	$J_2 K_2$	$J_1 K_1$	$J_0 K_0$
0	0	0	0	0	0	0	1	0 $\phi$	0 $\phi$	0 $\phi$	1 $\phi$
1	0	0	0	0	0	1	0	0 $\phi$	0 $\phi$	1 $\phi$	$\phi$ 1
2	0	0	1	0	1	0	0	0 $\phi$	1 $\phi$	$\phi$ 1	0 $\phi$
3	0	0	1	0	0	0	0	0 $\phi$	0 $\phi$	$\phi$ 1	$\phi$ 1
4	0	1	0	0	1	0	1	0 $\phi$	$\phi$ 0	0 $\phi$	1 $\phi$
5	0	1	0	0	1	1	0	0 $\phi$	$\phi$ 0	1 $\phi$	$\phi$ 1
6	0	1	1	0	0	0	0	0 $\phi$	$\phi$ 1	$\phi$ 1	0 $\phi$
7	0	1	1	0	0	0	0	0 $\phi$	$\phi$ 1	$\phi$ 1	$\phi$ 1
8								$\phi$ $\phi$	$\phi$ $\phi$	$\phi$ $\phi$	$\phi$ $\phi$

 $J_3$ 

$Q_3 Q_2$	00	01	11	10
$Q_1 Q_0$				
00			$\phi$ $\phi$	
01			$\phi$ $\phi$	
11			$\phi$ $\phi$	
10			$\phi$ $\phi$	

similar for  $K_3$  so,  $J_3 = K_3 = 0$ 

$J_2$	$Q_3 Q_2$	00	01	11	10
$Q_1 Q_0$					
00			$\phi$ $\phi$ $\phi$		
01			$\phi$ $\phi$ $\phi$		
11			$\phi$ $\phi$ $\phi$		
10			$\phi$ $\phi$ $\phi$		

$= Q_1 \bar{Q}_0$

$K_2$	$Q_3 Q_2$	00	01	11	10
$Q_1 Q_0$					
00			$\phi$ $\phi$		
01			$\phi$ $\phi$		
11			$\phi$ 1 $\phi$ $\phi$		
10			$\phi$ 1 $\phi$ $\phi$		

$= Q_1$



$J_1 Q_1 Q_0$

$Q_1 Q_0$	00	01	11	10
00			$\phi$	$\phi$
01	1	1	$\phi$	$\phi$
11	$\phi$	$\phi$	$\phi$	$\phi$
10	$\phi$	$\phi$	$\phi$	$\phi$

$= Q_0$

$K_1 Q_1 Q_0$

$Q_1 Q_0$	00	01	11	10
00	$\phi$	$\phi$	$\phi$	$\phi$
01	$\phi$	$\phi$	$\phi$	$\phi$
11	1	1	$\phi$	$\phi$
10	1	1	$\phi$	$\phi$

$= 1$

$J_0 Q_3 Q_2$

$Q_3 Q_2$	00	01	11	10
00	1	1	$\phi$	$\phi$
01	$\phi$	$\phi$	$\phi$	$\phi$
11	$\phi$	$\phi$	$\phi$	$\phi$
10			$\phi$	$\phi$

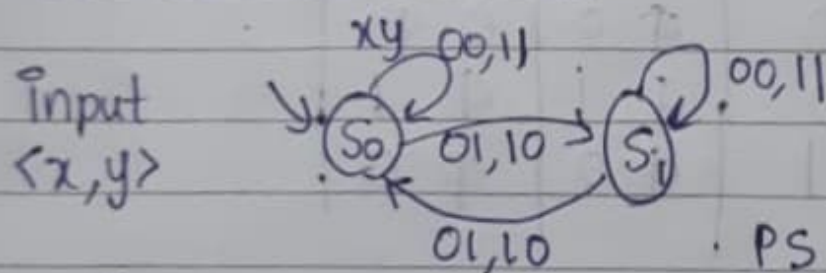
$= \bar{Q}_1$

$K_0 Q_3 Q_2$

$Q_3 Q_2$	00	01	11	10
00	$\phi$	1	$\phi$	$\phi$
01	1	$\phi$	$\phi$	$\phi$
11	1	$\phi$	$\phi$	$\phi$
10	$\phi$	1	$\phi$	$\phi$

$= 1$

Clks with external inputs



$S_0 = 0$  } state  
 $S_1 = 1$  } encoding

$\log(\text{no. of states})$   
 $= \text{no. of flipflops}$   
 $= 1 \text{ (here)}$

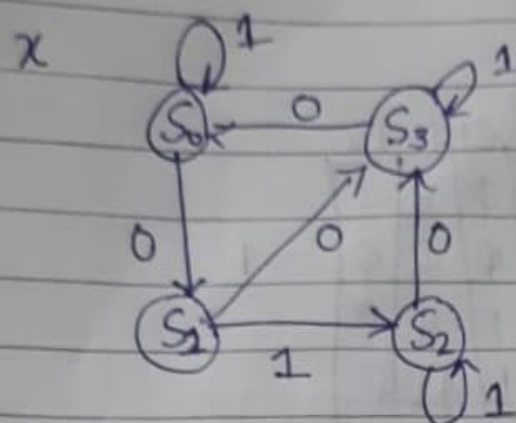
$Q_0 x$

$Q_0$	00	01	11	10
0		1		1
1	1		1	

$D = Q_0 \oplus x \oplus y$

	PS	i/p	NS	D flip
	$Q_0$	$x \ y$	$Q^+$	
$S_0$	0	0 0	0	0
	0	0 1	1	1
	0	1 0	1	1
	0	1 1	0	0
$S_1$	1	0 0	1	1
	1	0 1	0	0
	1	1 0	0	0
	1	1 1	1	1





State encoding

$S_0 = 00$

$S_1 = 01$

$S_2 = 10$

$S_3 = 11$

PS	in	NS	F/f input
$Q_1 Q_0$	$x$	$Q_1^+ Q_0^+$	$J_1 K_1 \quad J_0 K_0$
0 0	0	0 1	0 $\phi$ 1 $\phi$
1 0	1	0 0	0 $\phi$ 0 $\phi$
2 0 1	0	1 1	1 $\phi$ $\phi$ 0
3 0 1	1	1 0	1 $\phi$ $\phi$ 1
4 1 0	0	1 1	$\phi$ 0 1 $\phi$
5 1 0	1	1 0	$\phi$ 0 0 $\phi$
6 1 1	0	0 0	$\phi$ 1 $\phi$ 1
7 1 1	1	1 1	$\phi$ 0 $\phi$ 0

Truth table for  $J_1 = Q_0$ :

$x \backslash Q_1 Q_0$	00	01	11	10
00	0	1	$\phi$	$\phi$
11	0	1	$\phi$	$\phi$

$J_1 = Q_0$

Truth table for  $K_1 = \bar{x} Q_0$ :

$x \backslash Q_1 Q_0$	00	01	11	10
0	$\phi$	$\phi$	1	
1	$\phi$	$\phi$		

$K_1 = \bar{x} Q_0$

truth table for  $J_0$ :

$x \backslash Q_1 Q_0$	00	01	11	10
0	1	0	0	1
1	0	0	0	0

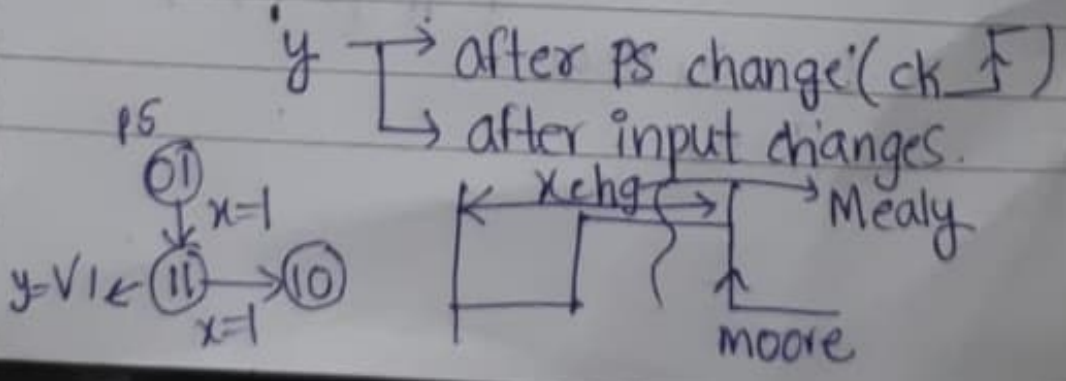
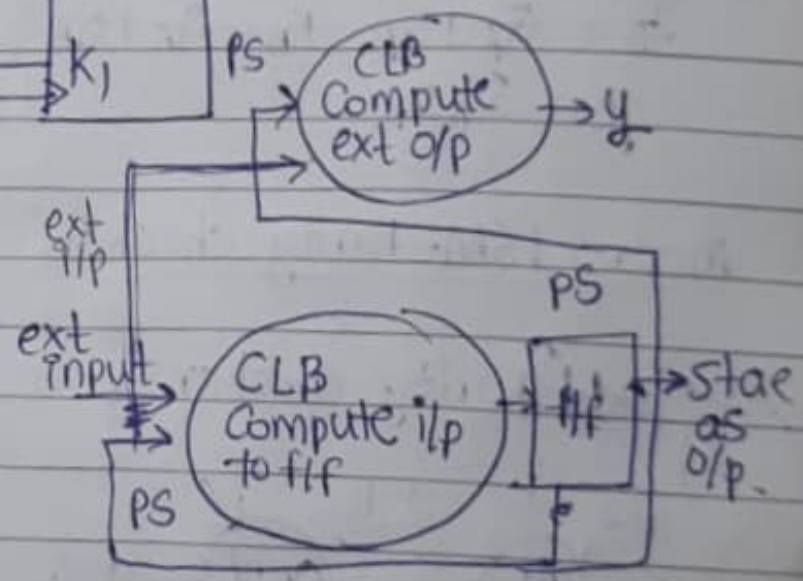
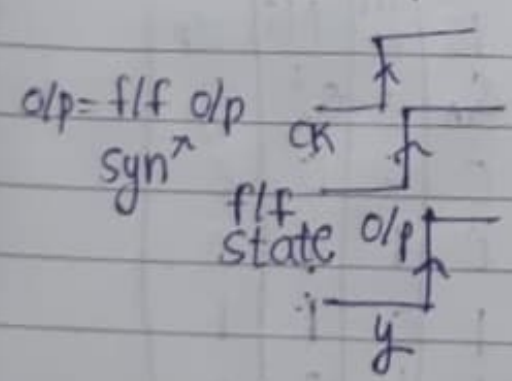
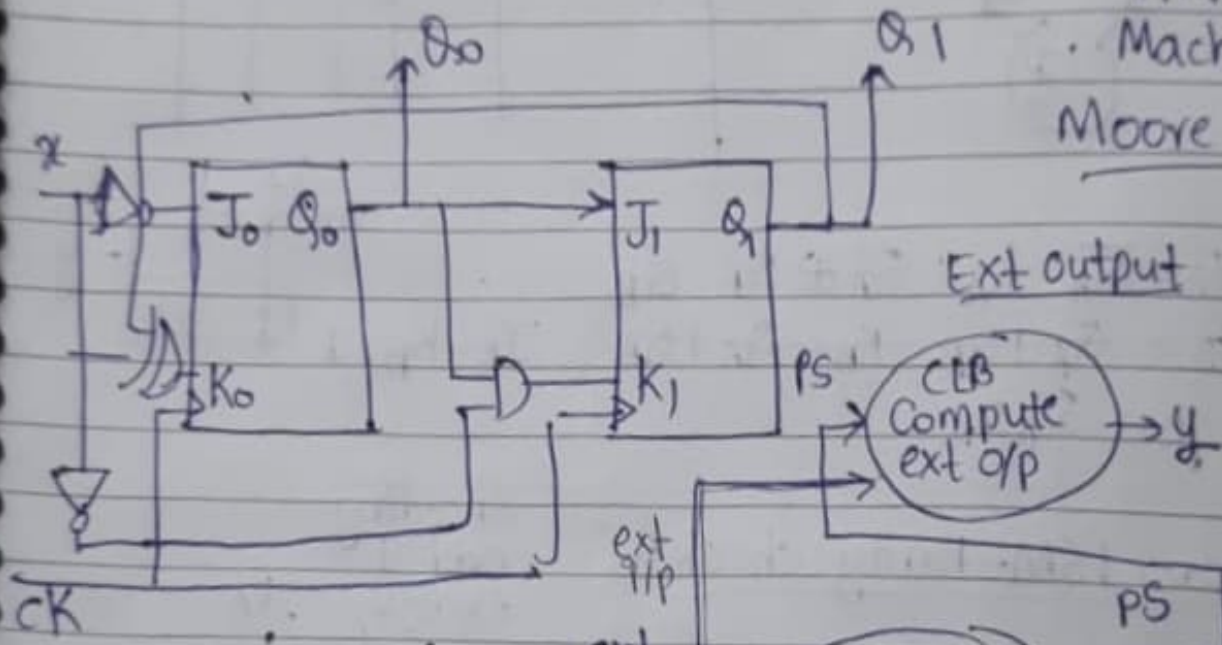
$$J_0 = \bar{x}$$

truth table for  $K_0$ :

$x \backslash Q_1 Q_0$	00	01	11	10
0	0	0	1	0
1	0	1	0	0

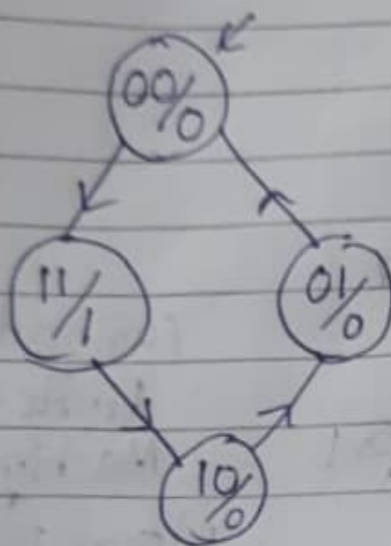
$$K_0 = \bar{Q}_1 x + Q_1 \bar{x} = x \oplus Q_1$$

(without ext ip)  
finite state  
Machine  
Moore FSMs





# Moose FSM



PS		NS		$J_A$	$K_A$	$J_B$	$K_B$	output $y$
$Q_A$	$Q_B$	$Q_A^+$	$Q_B^+$					
0	0	1	1	$\phi$	$\phi$	$\phi$	$\phi$	0
1	1	1	0	$\phi$	0	$\phi$	1	1
1	0	0	1	$\phi$	1	1	$\phi$	0
0	1	0	0	0	$\phi$	$\phi$	1	0

$$J_A = \bar{Q}_B \quad K_A = Q_A \oplus Q_B \quad \bar{Q}_B$$

$$J_B = Q_A + Q_B \quad K_B = Q_A + \bar{Q}_B$$

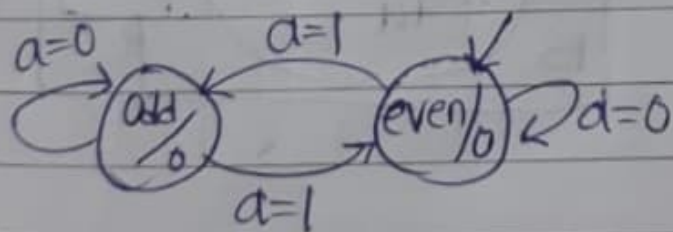
$$y = Q_A Q_B$$

$J_B = K_B = 1$

$Q_A$	$Q_B$	$y$
0	0	0
0	1	0
1	0	0
1	1	1

## Moore FSM - Parity checker

odd parity checker



encoding  
odd=1  
even=0

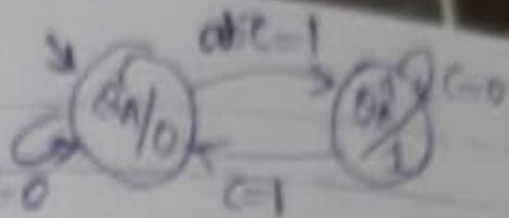
PS		NS		o/p
$Q_A$	$a$	$Q_A^+$	$y$	
0	0	0	0	
0	1	1	0	
1	0	1	1	
1	1	0	1	

$$D_A = Q_A \oplus a$$

$$y = Q_A$$

expressions

state encoding



3 inputs a, b, c

output y,  $y=1$  if  $abc=1$

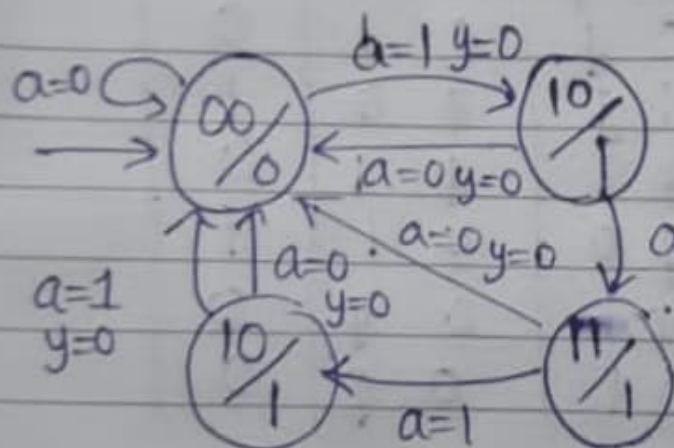
Remains as long as  $c=0$  or  $y=0$

PS	IP	NS=DA	O/P	$y = Q_A$
$Q_A$	a b c	$Q_A'$	y	$D_A = ab\bar{c} + Q_A\bar{c}$
0	1 1 0	1		
0				

i/p=1, machine does upcounting in grey code

i/p=0  $\Rightarrow$  o/p=0000

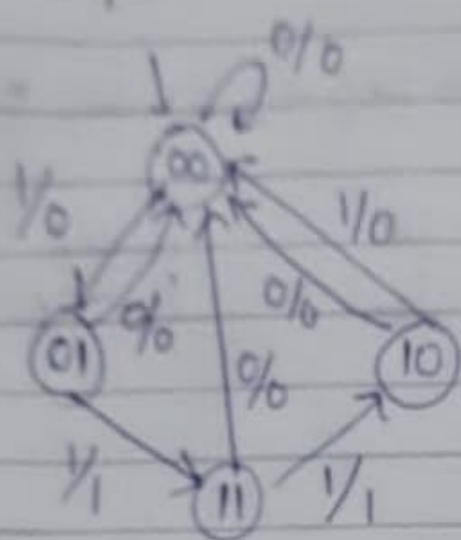
enter/exit/ in initial state output=0 or 1



Not Moore ext-  
because o/p also  
depends on ext i/p



Mealy



in/out

PS		i/p	NS						o/p
$\delta_A$	$\delta_B$		$\delta_A^+$	$\delta_B^+$	$J_A$	$K_A$	$J_B$	$K_B$	
0	0	0	0	0	0	$\phi$	0	$\phi$	0
0	0	1	0	1	0	$\phi$	1	$\phi$	0
0	1	0	0	0	0	$\phi$	$\phi$	1	0
0	1	1	1	1	1	$\phi$	$\phi$	0	1
1	1	0	0	0	$\phi$	1	$\phi$	1	0
1	1	1	1	0	$\phi$	0	$\phi$	1	1
1	0	0	0	0	$\phi$	1	0	$\phi$	0
1	0	1	0	0	$\phi$	1	0	$\phi$	0