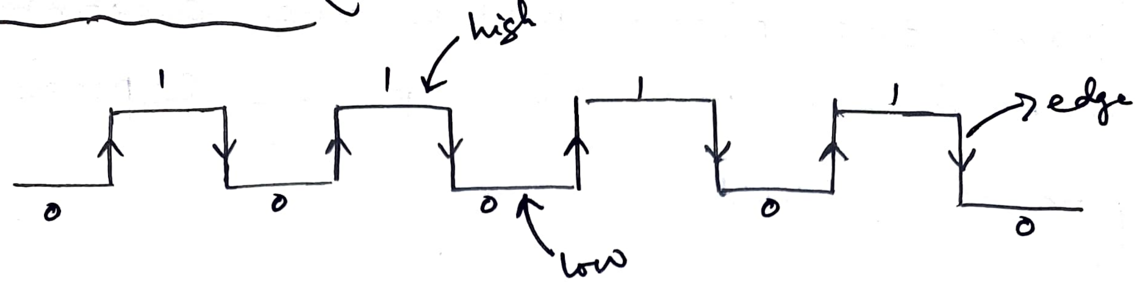
COUNTER:

clock:



triggering
- level
  - High level (1)
  - Low level (0)
- edge
  - +ve edge ⇒ rising (0 → 1)
  - -ve edge ⇒ falling (1 → 0)

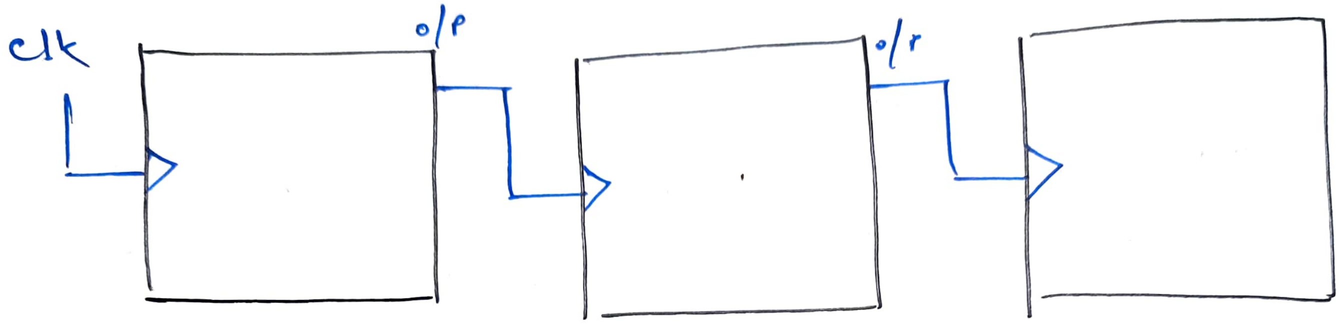
Types of Counter:

1. Asynchronous Counter / Ripple counter.
2. Synchronous counter

Again, Synchronous counter
- ~~counter~~ Up counter
- Down counter.
- Up-down counter.

Asynchronous counter: (Ripple counter)

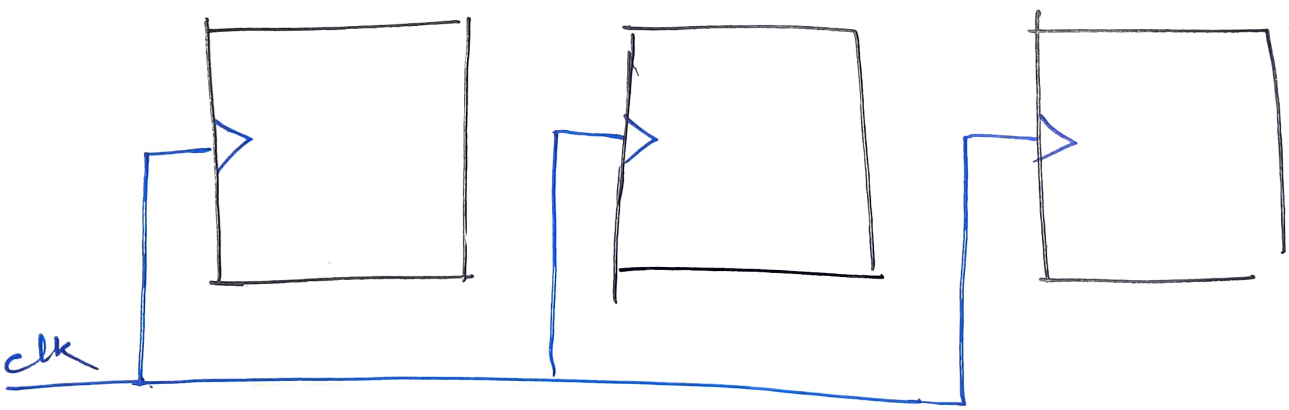
- have ~~one~~ clock pulse and another FF's ~~depends on prev~~ clock pulse depends on prev. output.



- It is slow.

Synchronous Counter:

- have same clock pulse for all the FF.



- It is fast.

Up- counter :-

increased out starting from 0 to 2^{n-1}.

Down- counter :

decreased from 2^{n-1} to 0.

Up-down -counter :

combination of down and up counter.

NOTE :

No. of bits = n

No. of flip flop = n.

Max. count = 0 to 2^{n-1}

Modulus = mod = 2^n

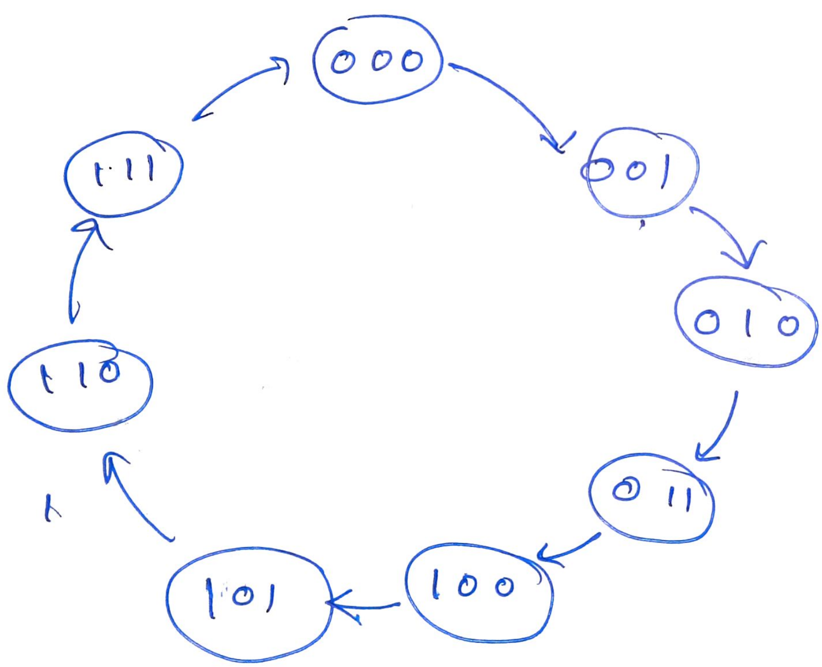
Asynchronous Counter:

* 3-bit Asynchronous counter:

Q. Design a 3-bit Ripple counter with -ve edge triggered.

Ans No. of bits = $n = 3$
No. of FFs = $n = 3$
Max. count = 0 to $2^3 - 1 = 0$ to 7.
Mod = $2^3 = 8$.

Step 1. State diagram.



Step 2. State table:

Present state			Next state			Input FFs					
Q_2	Q_1	Q_0	Q_2	Q_1	Q_0	J_2	K_2	J_1	K_1	J_0	K_0
0	0	0	0	0	1	0	X	0	X	1	X
0	0	1	0	1	0	0	X	1	X	X	1
0	1	0	0	1	1	0	X	X	0	1	X
0	1	1	1	0	0	1	X	X	1	X	1
1	0	0	1	0	1	X	0	0	X	1	X
1	0	1	1	1	0	X	0	1	X	X	1
1	1	0	1	1	1	X	0	X	0	1	X
1	1	1	0	0	0	X	1	X	1	X	1

Step 3. Find FF inputs using K-map.

$J_2 = \sum m(3) + d(4,5,6,7)$

Q_2 \ Q_1Q_0	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1Q_0$	Q_1Q_0	$Q_1\bar{Q}_0$
$\bar{Q}_2$	0:	1:	3: 1	2:
Q_2	4: X	5: X	7: X	6: X

$J_2 = Q_1 Q_0$

$K_2 = \sum m(7) + d(0,1,2,3)$

$Q_2 \backslash Q_1Q_0$	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}Q_0$	Q_1Q_0	$Q\bar{Q}_0$
$\bar{Q}_2$	0: X	1: X	2: X	3: X
Q_2	4:	5:	7: 1	6:

$K_2 = Q_1Q_0$

$J_1 = \sum m(1,5) + d(2,3,6,7)$

$Q_2 \backslash QQ_0$	$\bar{Q}\bar{Q}_0$	$\bar{Q}_1Q_0$	QQ_0	$Q\bar{Q}_0$
$\bar{Q}_2$	0:	1: 1	3: X	2: X
Q_2	4:	5: 1	7: X	6: X

$J_1 = Q_0$

$K_1 = \sum m(3,7) + d(0,1,4,5)$

$Q_2 \backslash Q_1Q_0$	$\bar{Q}\bar{Q}_0$	$\bar{Q}Q_0$	QQ_0	$Q\bar{Q}_0$
$\bar{Q}_2$	0: X	1: X	3: 1	2:
Q_2	4: X	5: X	7: 1	6:

$K_1 = Q_0$

$$J_0 = \sum m(0,2,4,6) + d(1,3,5,7)$$

$Q_2 \backslash Q_1Q_0$	$\bar{Q_1}\bar{Q_0}$	$\bar{Q_1}Q_0$	Q_1Q_0	$Q_1\bar{Q_0}$
$\bar{Q_2}$	1 (0)	X (1)	X (3)	1 (2)
Q_2	1 (4)	X (5)	X (7)	1 (6)

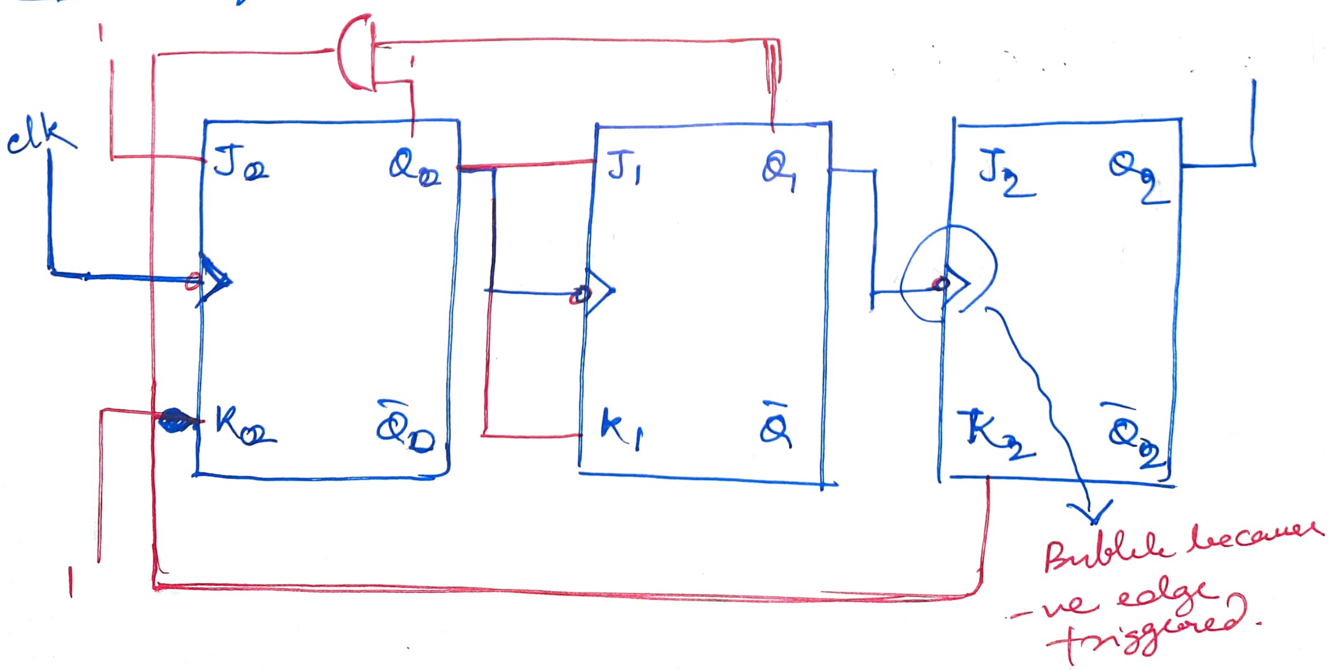
$$J_0 = 1.$$

$$K_0 = \sum m(1,3,5,7) + d(0,2,4,6)$$

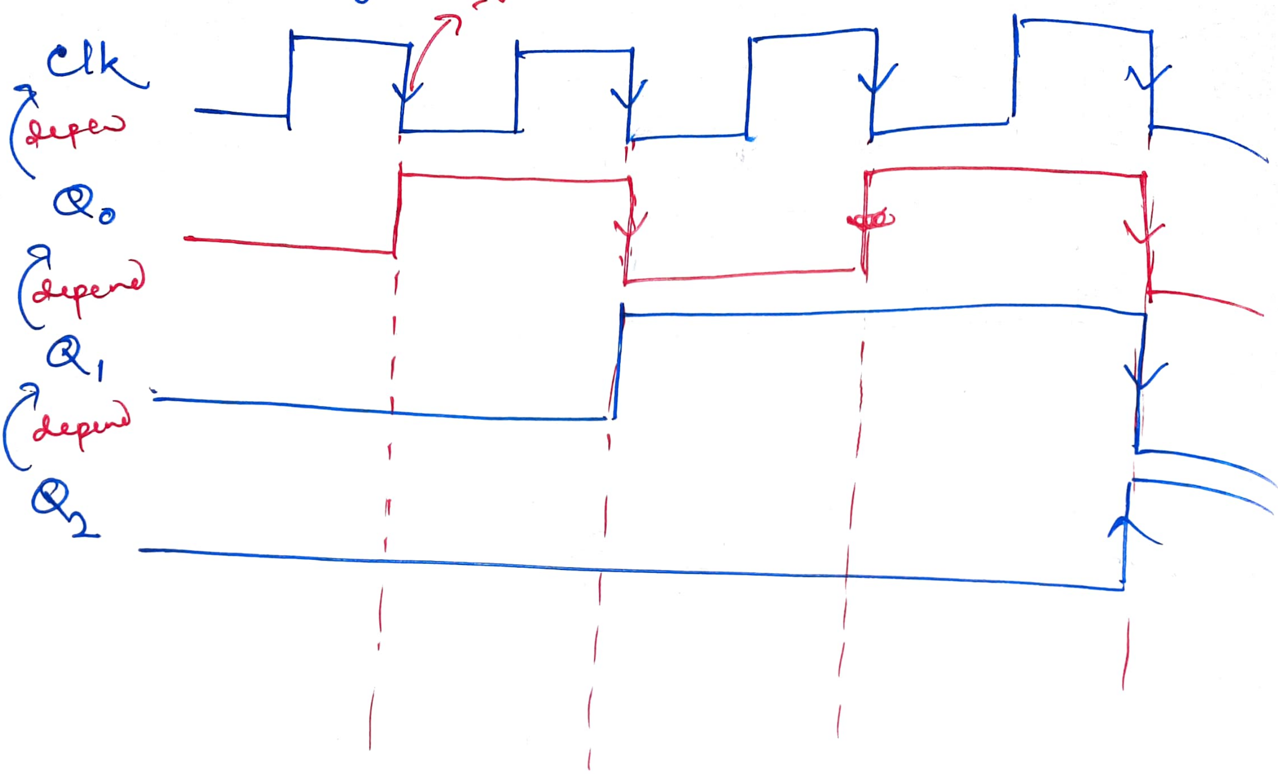
$Q_2 \backslash Q_1Q_0$	$\bar{Q_1}\bar{Q_0}$	$\bar{Q_1}Q_0$	Q_1Q_0	$Q_1\bar{Q_0}$
$\bar{Q_2}$	X (0)	1 (1)	1 (3)	X (2)
Q_2	X (4)	1 (5)	1 (7)	X (6)

$$K_0 = 1$$

Step 4: Design the counter.



Time diagram:



Note: Instead of JK-FF, we can do with other FFs also.

Q12. Design mod 5 counter using T-FF with -ve edge triggering.

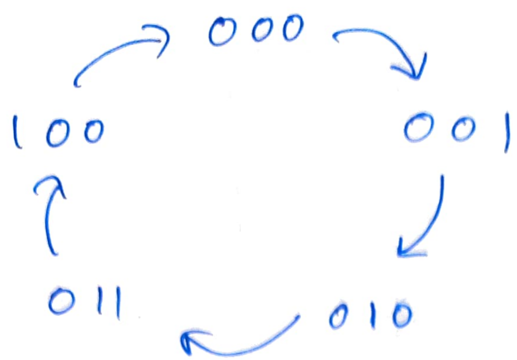
Ans. $Mod = 5 < (2^3 = 8)$.

$\therefore$ No. of bits = 3

No. of FF = 3

Max count = 5 (0 to 4)

step1. State diagram:



step2.

present state			Next state			FF I/Ps		
Q_2	Q_1	Q_0	Q_2	Q_1	Q_0	T_2	T_1	T_0
0	0	0	0	0	1	0	0	1
0	0	1	0	1	0	0	1	1
0	1	0	0	1	1	0	0	1
0	1	1	1	0	0	1	1	1
1	0	0	0	0	0	1	0	0

step3.

$$T_2 = \Sigma m(3,4) + d(5,6,7).$$

Q_2 \ Q_1Q_0	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1Q_0$	Q_1Q_0	$Q_1\bar{Q}_0$
$\bar{Q}_2$	(0)	(1)	(3) 1	(2)
Q_2	(4) 1	(5) X	(7) X	(6) X

$$T_2 = Q_2 + Q_1Q_0$$

$T_1 = \sum m(1,3) + d(5,6,7)$

$Q_2 \backslash Q_1Q_0$	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1Q_0$	Q_1Q_0	$Q_1\bar{Q}_0$
$\bar{Q}_2$	(0)	1 (1)	1 (3)	(2)
Q_2	(4)	X (5)	X (7)	X (6)

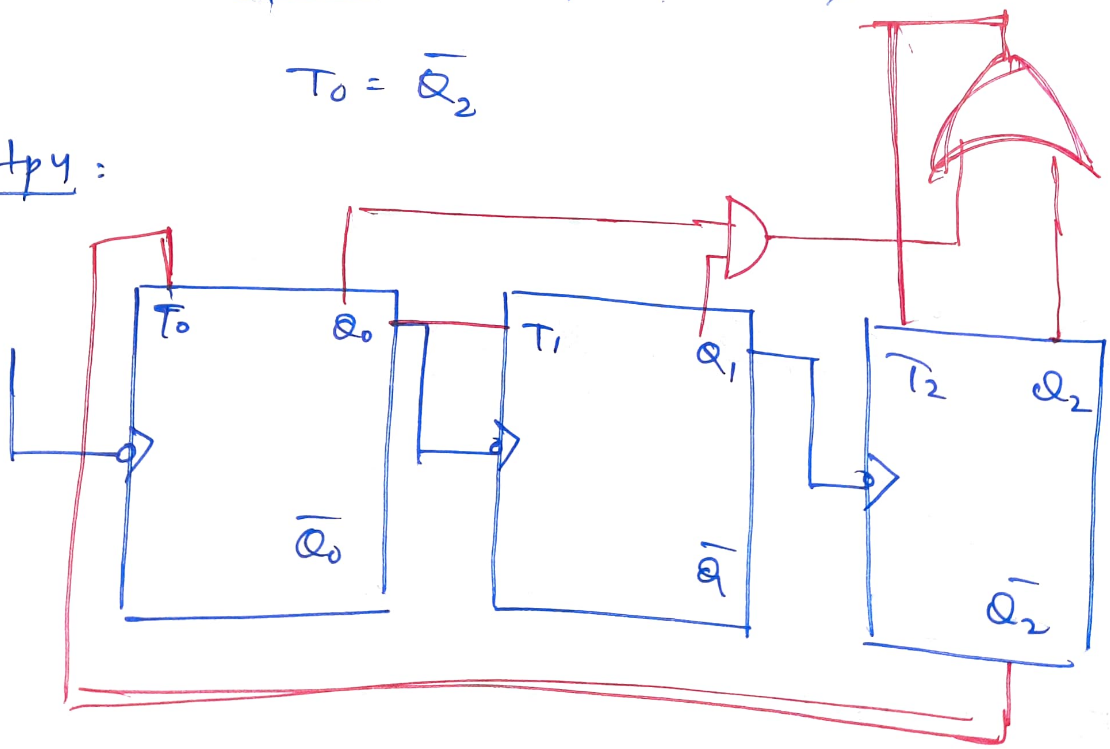
$T_1 = Q_0$

$T_0 = \sum m(0,1,2,3) + d(5,6,7)$

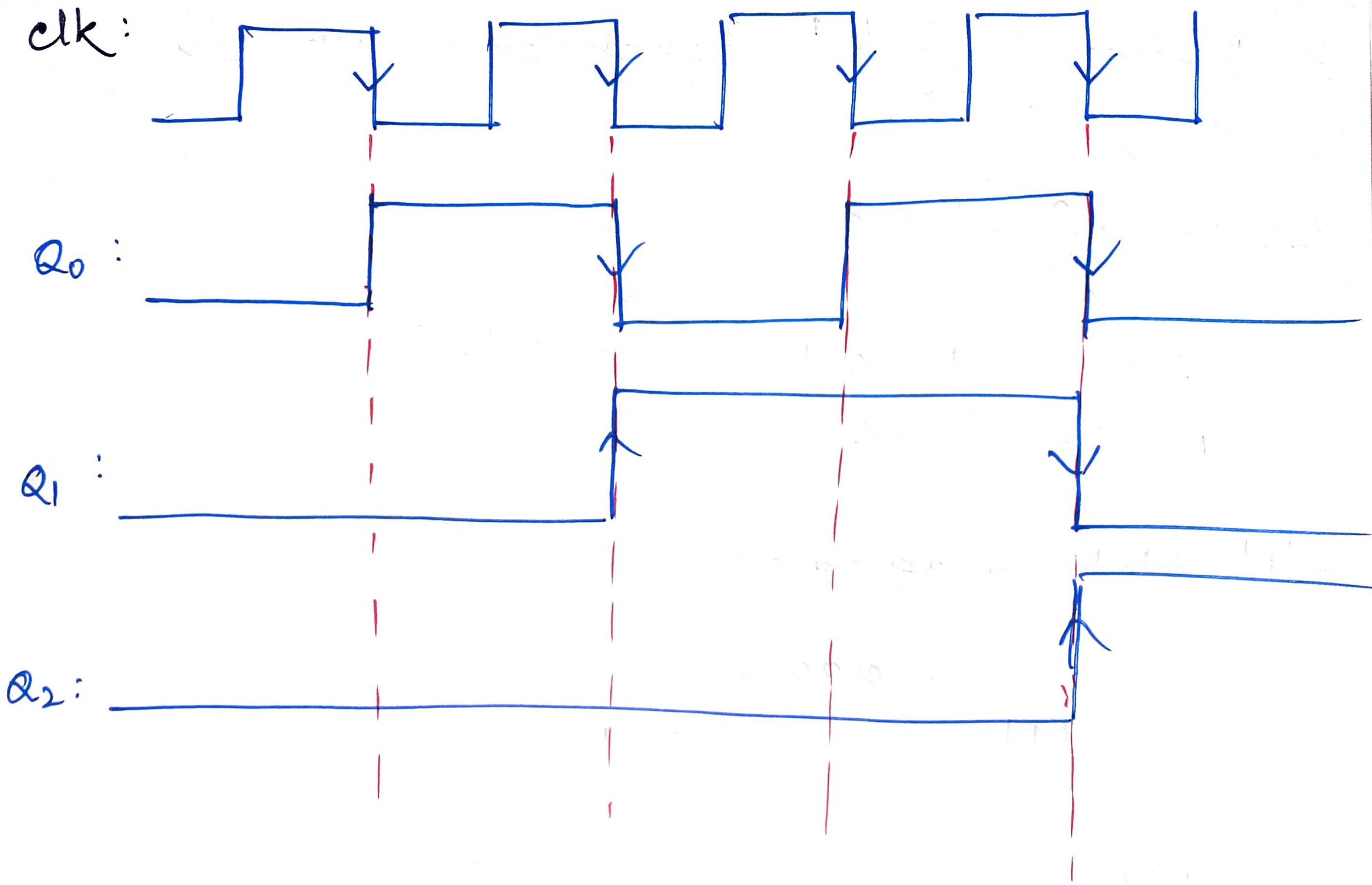
$Q_2 \backslash Q_1Q_0$	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1Q_0$	Q_1Q_0	$Q_1\bar{Q}_0$
$\bar{Q}_2$	1 (0)	1 (1)	1 (3)	1 (2)
Q_2	(4)	X (5)	X (7)	X (6)

$T_0 = \bar{Q}_2$

stp4 :



Time diagram:

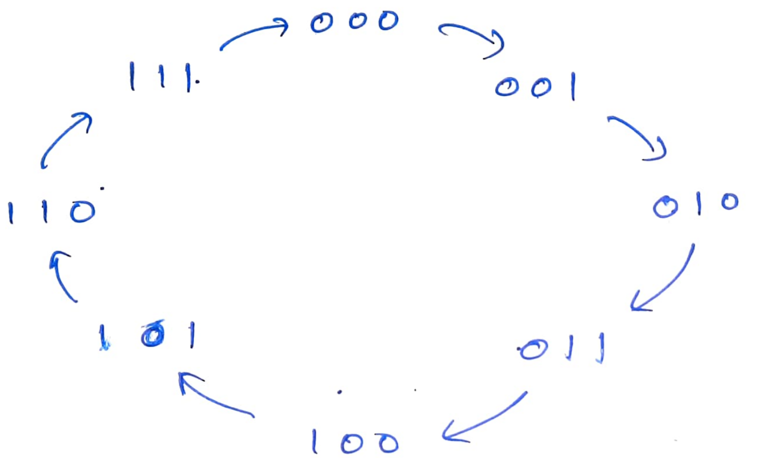


Synchronous Counter:

Q. Design a 3-bit synchronous up counter using T-FF.

Ans: No. of bits = 3
No. of FFs = 3
Max. count = 0 to 2^{3-1} = 0 to 7.
Mod = $2^3 = 8$.

Step 1. State diagram:



Step 2.

present state			Next state			I/Ps of FF		
Q_2	Q_1	Q_0	Q_2	Q_1	Q_0	T_2	T_1	T_0
0	0	0	0	0	1	0	0	1
0	0	1	0	1	0	0	1	1
0	1	0	0	1	1	0	0	1
0	1	1	1	0	0	1	1	1
1	0	0	1	0	1	0	0	1
1	0	1	1	1	0	0	1	1
1	1	0	1	1	1	0	0	1
1	1	1	0	0	0	1	1	1

stp3. $T_2 = \sum m(3, 7)$

Q_2 \ Q_1Q_0	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1Q_0$	Q_1Q_0	$Q_1\bar{Q}_0$
$\bar{Q}_2$	0	1	3: 1	2
Q_2	4	5	7: 1	6

$T_2 = Q_1Q_0$

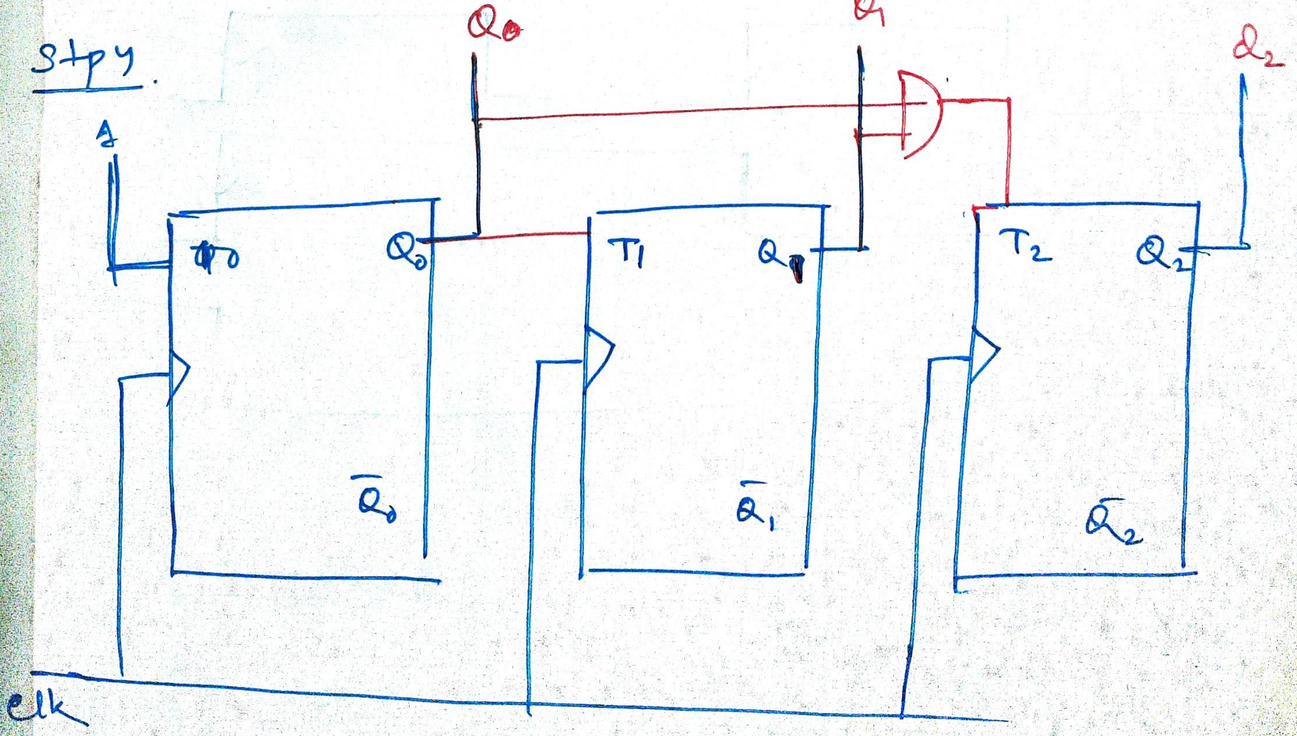
$T_1 = \sum m(1, 3, 5, 7)$

Q_2 \ Q_1Q_0	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1Q_0$	Q_1Q_0	$Q_1\bar{Q}_0$
$\bar{Q}_2$	0	1: 1	3: 1	2
Q_2	4	5: 1	7: 1	6

$T_1 = Q_0$

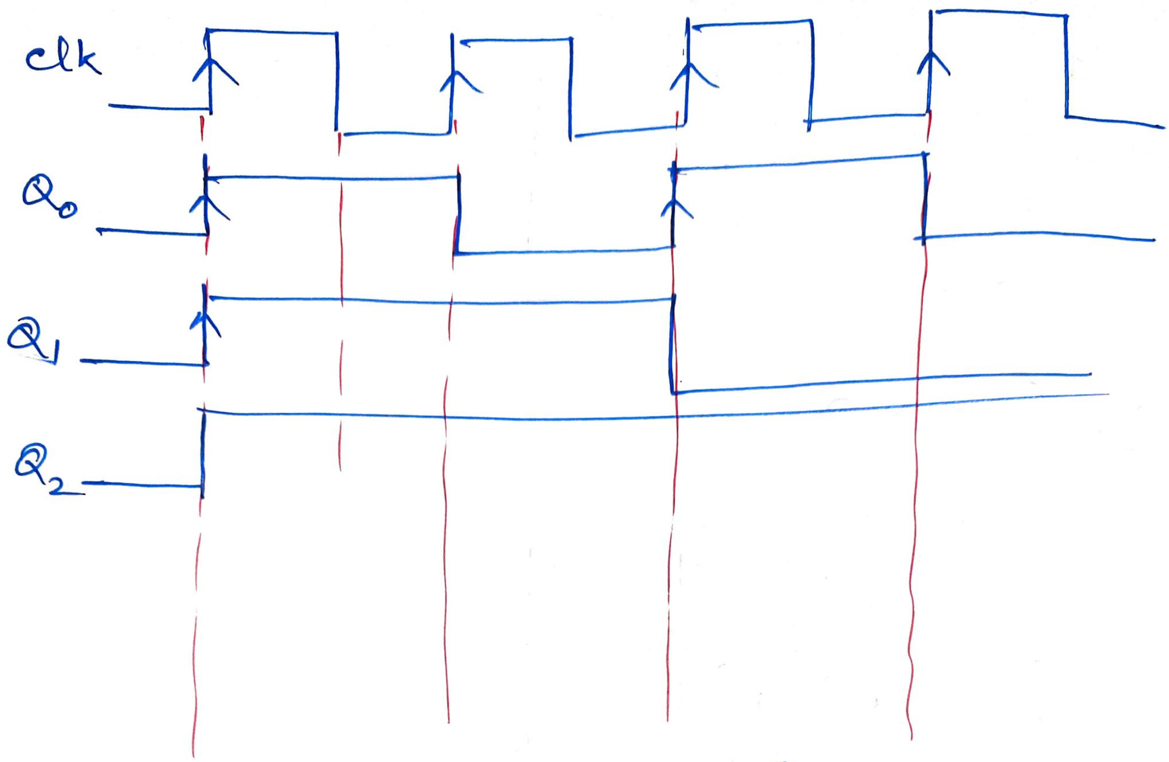
$T_0 = \sum m(0, 1, 2, 3, 4, 5, 6, 7) = 1$

stp4.

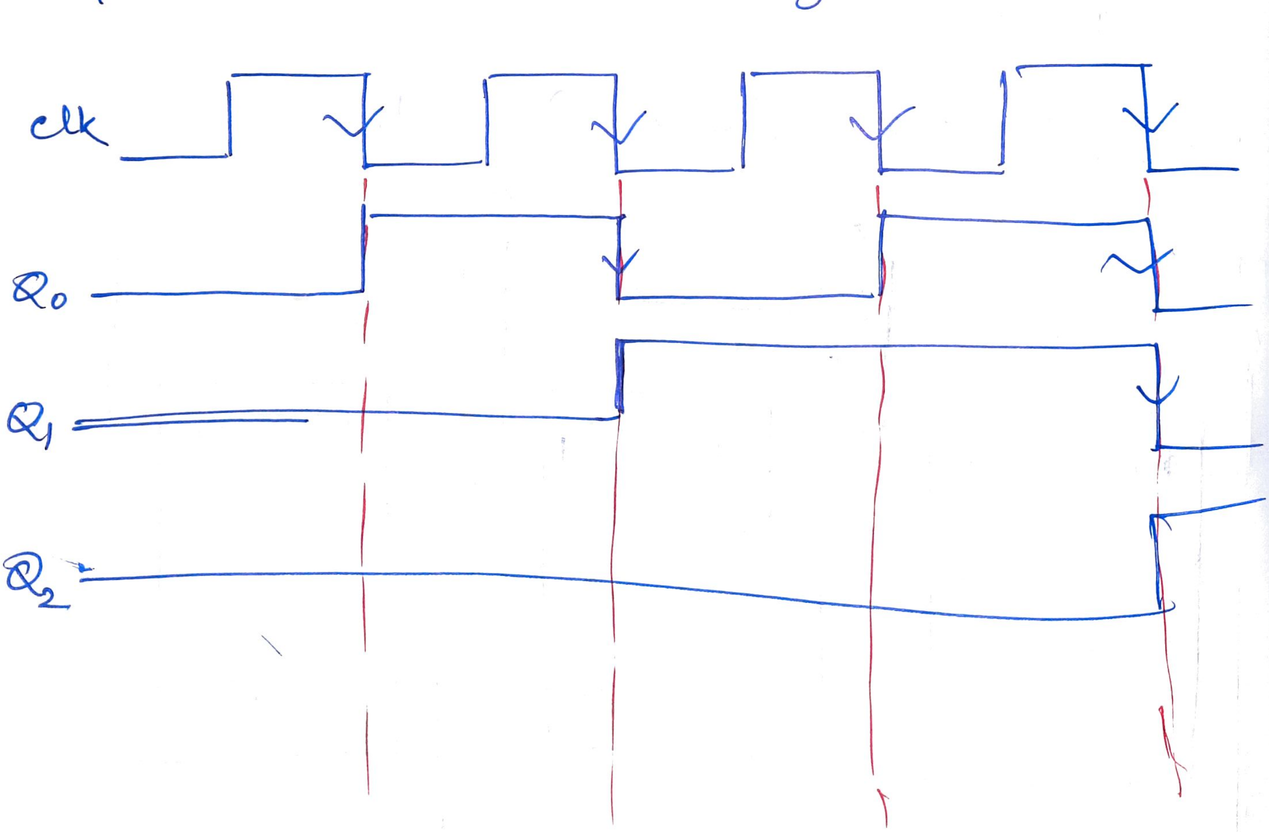


Time diagram:

* If we will take +ve edge



* If we will take -ve edge:



Q. Design a Mod 6 synchronous counter using T-FF with state diagram and time sequence.

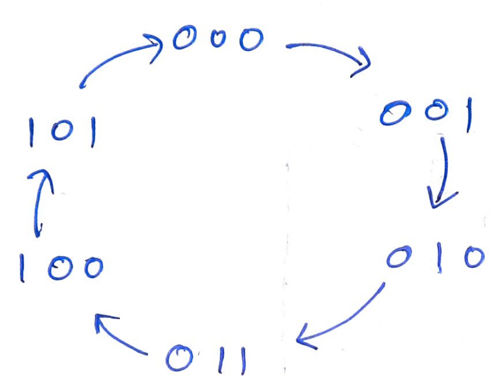
Ans Mod = 6 < ($2^3 = 8$).

No. of bits = 3

No. of FFs = 3

Max count = 6 i.e. 0 to 5.

Stp1. State diagram.



Stp2 :

Present state			Next State			I/Ps to FFs		
Q_2	Q_1	Q_0	Q_2	Q_1	Q_0	T_2	T_1	T_0
0	0	0	0	0	1	0	0	1
0	0	1	0	1	0	0	1	1
0	1	0	0	1	1	0	0	1
0	1	1	1	0	0	1	1	1
1	0	0	1	0	1	0	0	1
1	0	1	0	0	0	1	0	1

step3:

$T_2 = \sum m(3,5) + d(6,7)$

$Q_2 \backslash Q_1Q_0$	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1 Q_0$	$Q_1 Q_0$	$Q_1\bar{Q}_0$
$\bar{Q}_2$	^{0}	^{1}	^{3} 1	^{2}
Q_2	^{4}	^{5} 1	^{7} X	^{6} X

$T_2 = Q_2 Q_0 + Q_1 Q_0$

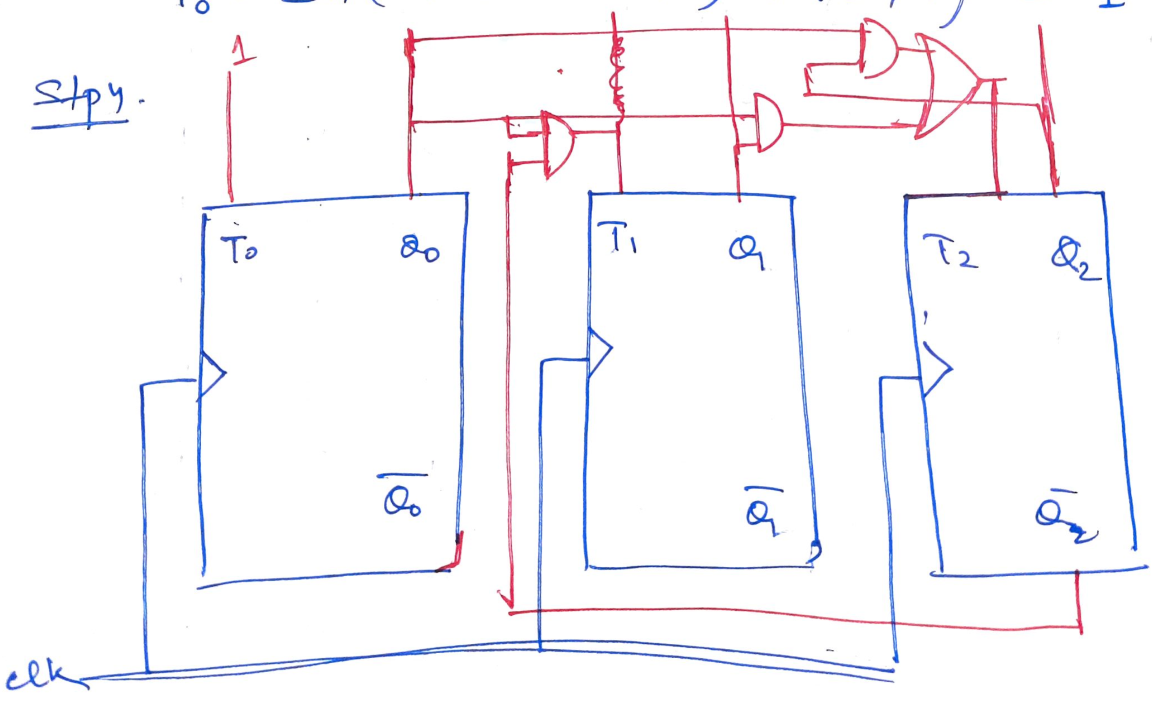
$T_1 = \sum m(1,3) + d(6,7)$

$Q_2 \backslash Q_1Q_0$	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1 Q_0$	$Q_1 Q_0$	$Q_1\bar{Q}_0$
$\bar{Q}_2$	^{0}	^{1} 1	^{3} 1	^{2}
Q_2	^{4}	^{5}	^{7} X	^{6} X

$T_1 = \bar{Q}_2 Q_0$

$T_0 = \sum m(0,1,2,3,4,5) + d(6,7) = 1$

Step 4.



Q. Design 3-bit synchronous down counter using D-FF.

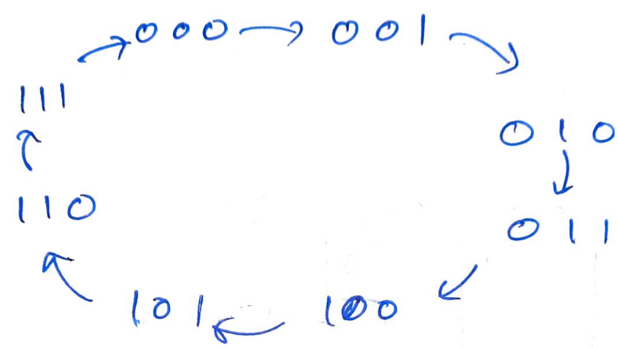
Ans. No. of bits = 3

No. of FF = 3

Max count = $0 + 2^3 - 1 = 0$ to 7.

Mod = $2^3 = 8$.

Step 1. State diagram:



Step 2.

Present state			Next state			Input to FFs.		
Q_2	Q_1	Q_0	Q_2	Q_1	Q_0	D_2	D_1	D_0
0	0	0	0	0	1	0	0	0
0	0	1	0	1	0	0	0	1
0	1	0	0	1	1	0	1	0
0	1	1	1	0	0	0	1	1
1	0	0	1	0	1	1	0	0
1	0	1	1	1	0	1	0	1
1	1	0	1	1	1	1	1	0
1	1	1	0	0	0	1	1	1

step 3. $D_2 = \Sigma(4,5,6,7)$

$Q_2 \backslash Q_1Q_0$	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1Q_0$	Q_1Q_0	$Q_1\bar{Q}_0$
$\bar{Q}_2$	0	1	3	2
Q_2	4 1	5 1	7 1	6 1

$D_2 = Q_2$

$D_1 = \Sigma m(2,3,6,7)$

$Q_2 \backslash Q_1Q_0$	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1Q_0$	Q_1Q_0	$Q_1\bar{Q}_0$
$\bar{Q}_2$	0	1	3 1	2 1
Q_2	4	5	7 1	6 1

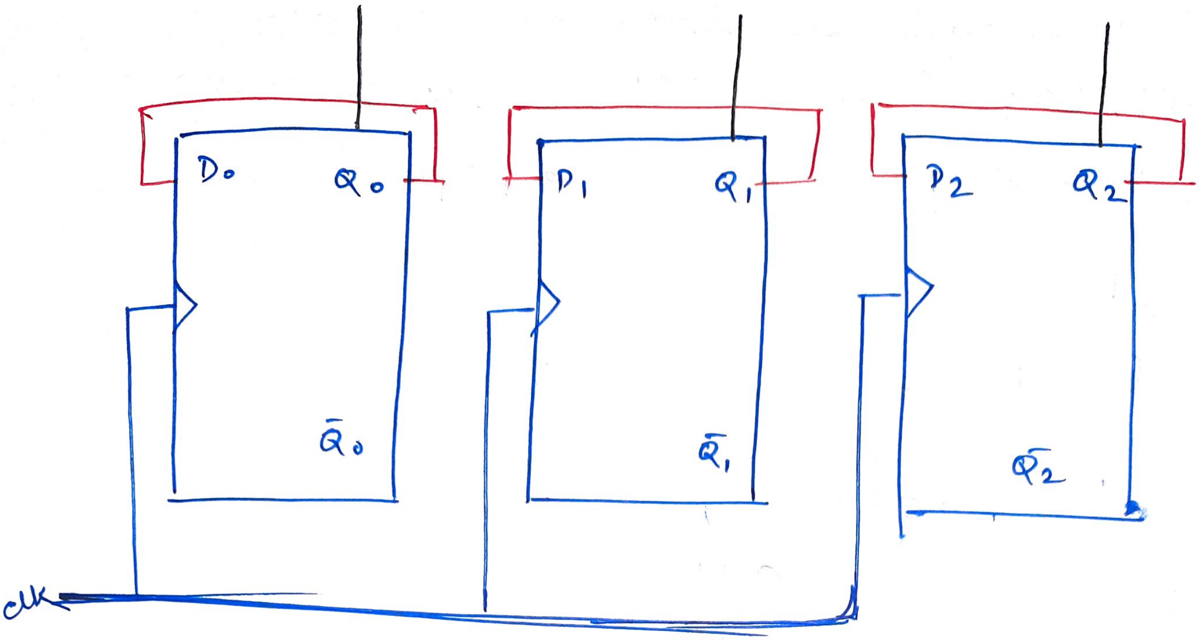
$D_1 = Q_1$

$D_0 = \Sigma m(1,3,5,7)$.

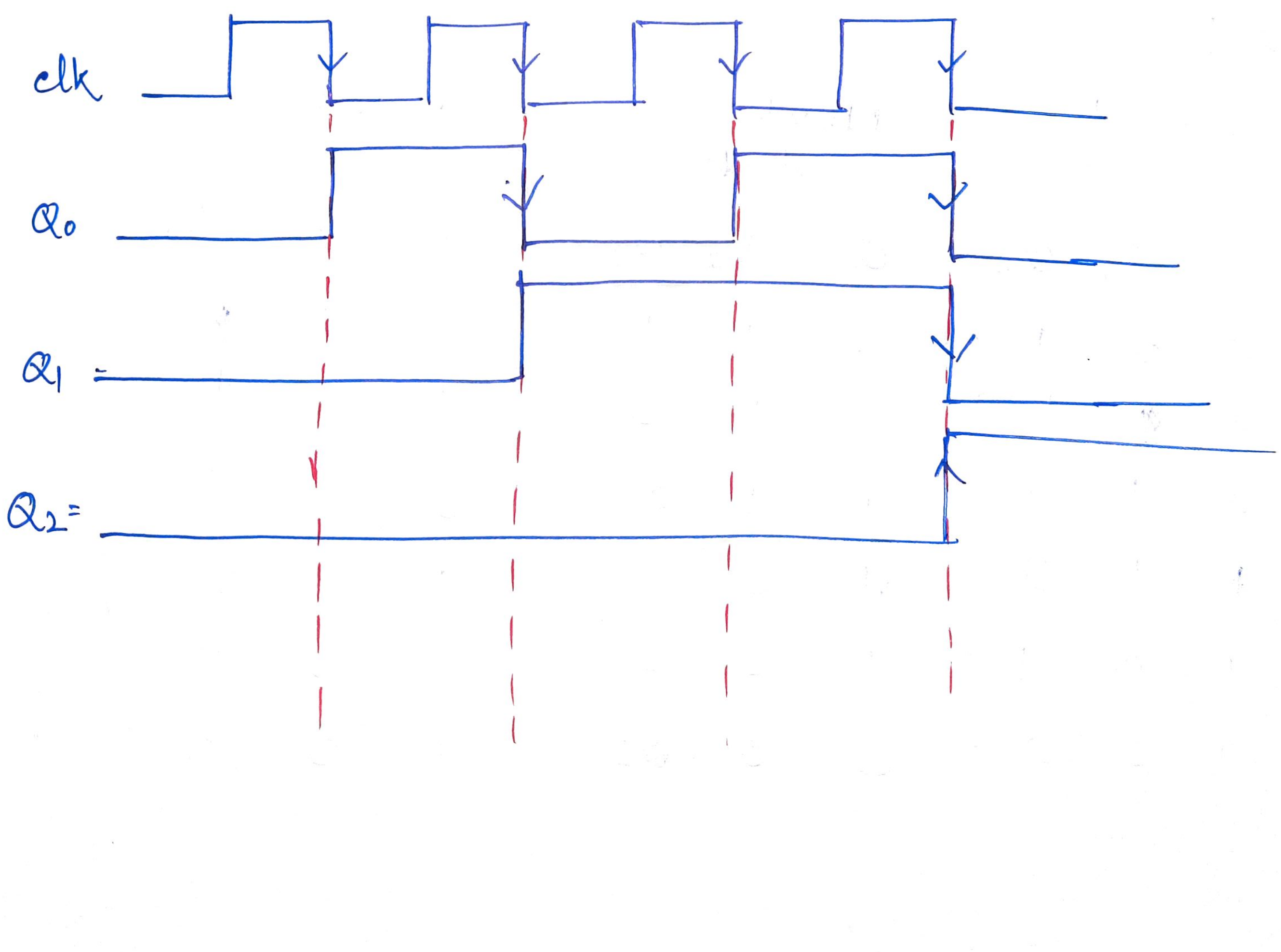
$Q_2 \backslash Q_1Q_0$	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1Q_0$	Q_1Q_0	$Q_1\bar{Q}_0$
$\bar{Q}_2$	0	1 1	3 1	2
Q_2	4	5 1	7 1	6

$D_0 = Q_0$

stp4.



Time diagram:

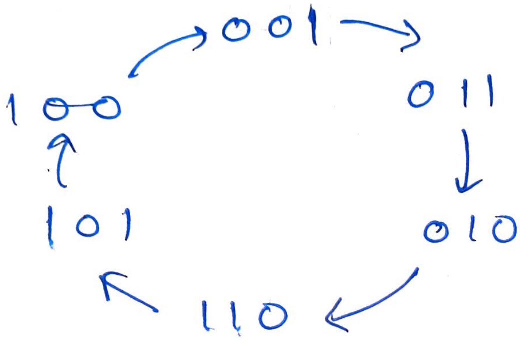


Q. Design 3-bit synchronous counter which counts the sequence : ~~000~~, 001, 011, 010, 110, 101, 100, (repeat) 001, ---- using D-FF with state diagram and time sequence.

Ans. No. of bits = 3

No. of FFs = 3.

step1.



step2:

Present state				Next state			I/Ps to FF		
Q_2	Q_1	Q_0		Q_2	Q_1	Q_0	D_2	D_1	D_0
0	0	1	1	0	1	1	0	0	1
0	1	1	3	0	1	0	0	1	1
0	1	0	2	1	1	0	0	1	0
1	1	0	6	1	0	1	1	1	0
1	0	1	5	1	0	0	1	0	1
1	0	0	4	0	0	1	1	0	0

Step 3:

$D_2 = \sum m(4,5,6) + d(7)$

Q_2 \ Q_1Q_0	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1Q_0$	Q_1Q_0	$Q_1\bar{Q}_0$
$\bar{Q}_2$	0:	1:	3:	2:
Q_2	4: 1	5: 1	7: X	6: 1

$D_2 = Q_2$.

$D_1 = \sum m(2,3,6) + d(7)$

Q_2 \ Q_1Q_0	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1Q_0$	Q_1Q_0	$Q_1\bar{Q}_0$
$\bar{Q}_2$	0:	1:	3: 1	2: 1
Q_2	4:	5:	7: X	6: 1

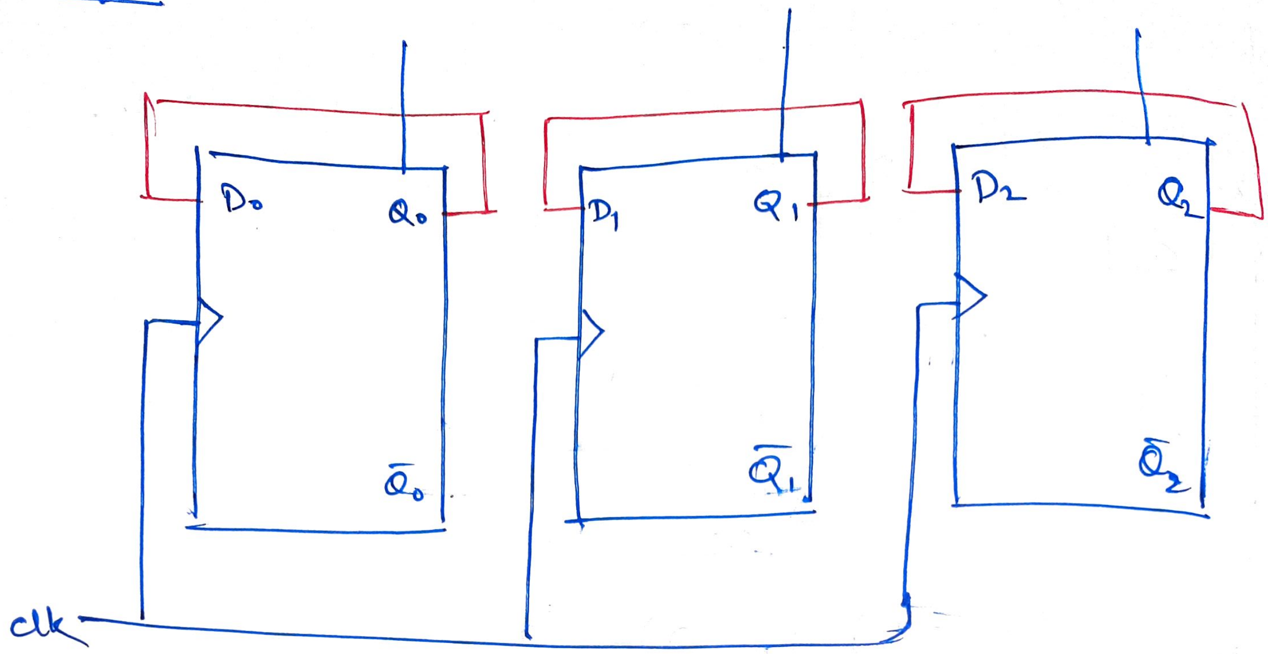
$D_1 = Q_1$

$D_0 = \sum m(1,3,5) + d(7)$

Q_2 \ Q_1Q_0	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1Q_0$	Q_1Q_0	$Q_1\bar{Q}_0$
$\bar{Q}_2$	0:	1: 1	3: 1	2:
Q_2	4:	5: 1	7: X	6:

$D_0 = Q_0$

stpy.



Decade Counter:

→ mod 10

Q. Design a synchronous decade counter.

~~No. of bits =~~

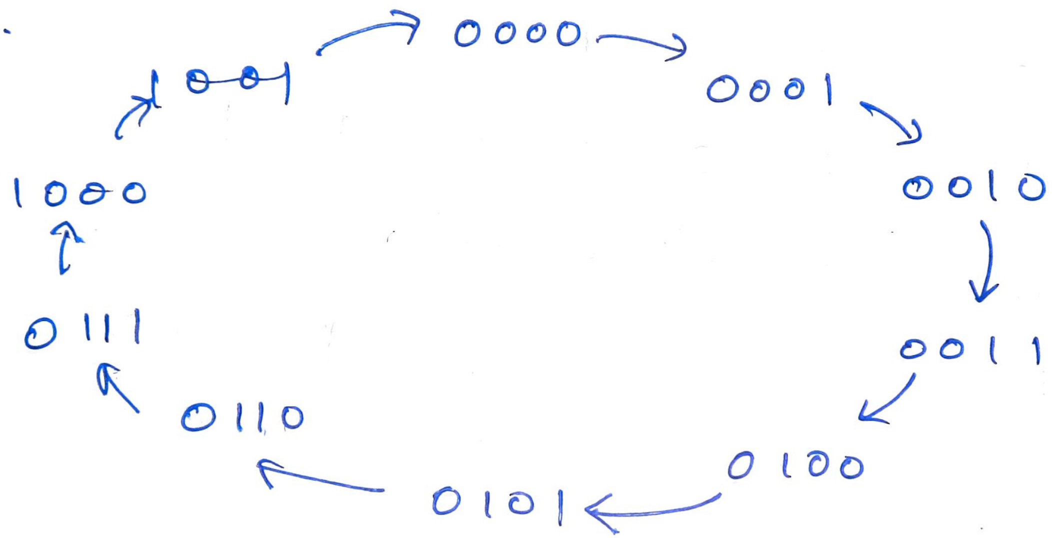
$Mod = 10 < (2^4 = 16)$

$\therefore$ No. of bits = 4

No. of FF's = 4

Max. count = 0 to 9.

step 1.



step 2.

I/Ps to FFs

stp2.

Present state				Next state				I/Ps to FFs			
Q_3	Q_2	Q_1	Q_0	Q_3	Q_2	Q_1	Q_0	T_3	T_2	T_1	T_0
0	0	0	0	0	0	0	1	0	0	0	1
0	0	0	1	0	0	1	0	0	0	1	1
0	0	1	0	0	0	1	1	0	0	0	1
0	0	1	1	0	1	0	0	0	1	1	1
0	1	0	0	0	1	0	1	0	0	0	1
0	1	0	1	0	1	1	0	0	0	1	1
0	1	1	0	0	1	1	1	0	0	0	1
0	1	1	1	1	0	0	0	1	1	1	1
1	0	0	0	1	0	0	1	0	0	0	1
1	0	0	1	0	0	0	0	1	0	0	1

stp3.

$T_3 = \sum m(7, 9) + d(10, 11, 12, 13, 14, 15)$

Q_3Q_2 \ Q_1Q_0	$\bar{Q}_1\bar{Q}_0$	$\bar{Q}_1 Q_0$	$Q_1 Q_0$	$Q_1\bar{Q}_0$
$\bar{Q}_3\bar{Q}_2$	0	1	3	2
$\bar{Q}_3 Q_2$	4	5	7: 1	6
$Q_3 Q_2$	12: X	13: X	15: X	14: X
$Q_3\bar{Q}_2$	8	9: 1	11: X	10: X

$T_3 = Q_3 Q_0 + Q_2 Q_1 Q_0$

$T_2 = \sum m(3, 7) + d(10, 11, 12, 13, 14, 15)$

^{0}	^{1}	1^{3}	^{2}
^{4}	^{5}	1^{7}	^{6}
X^{12}	X^{13}	X^{15}	X^{14}
^{8}	^{9}	X^{11}	X^{10}

$T_2 = Q_1 Q_0$

$T_1 = \sum m(1, 3, 5, 7) + d(10, 11, 12, 13, 14, 15)$

$Q_3Q_2 \backslash Q_1Q_0$	$\bar{Q}_1 \bar{Q}_0$	$\bar{Q}_1 Q_0$	$Q_1 Q_0$	$Q_1 \bar{Q}_0$
$\bar{Q}_3 \bar{Q}_2$	^{0}	1^{1}	1^{3}	^{2}
$\bar{Q}_3 Q_2$	^{4}	1^{5}	1^{7}	^{6}
$Q_3 Q_2$	X^{12}	X^{13}	X^{15}	X^{14}
$Q_3 \bar{Q}_2$	^{8}	^{9}	X^{11}	X^{10}

$t_1 = \bar{Q}_3 Q_0$

$T_0 = 1.$

Step 4.