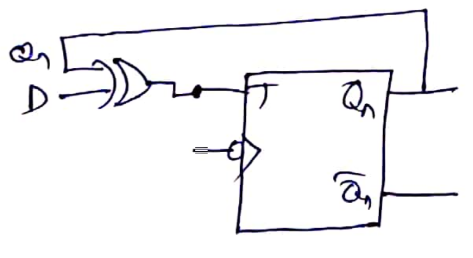
Tutorial 13 (solution)

1. available FF = T
   Required ff = D

1. Identify available and required F/F
2. Make characteristic table for required F/F
3. Make excitation table for available F/F
4. Write boolean expression for available F/F
5. Draw the circuit

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

$$T = D \oplus Q_n$$



2 available = JK

Required = T

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

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

for J

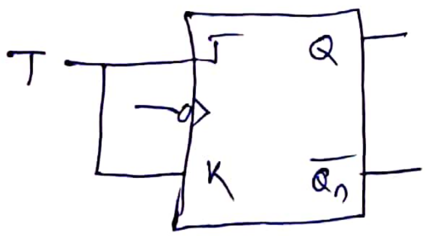
Q_n \ T	0	1
0	0	1
1	X	X

$J = T$

for K

Q_n \ T	0	1
0	X	X
1	0	1

$K = T$



(3) A mod-6 counter has six states 000, 001, 010, 011, 100, 101. When the sixth clock pulse is applied, the counter should immediately reset to 000. (Though it will temporarily goes to 110 state) This will happen as we are providing feedback.

It is a divide by 6 counter, in the sense that it divides the input clock frequency by 6.

It requires 3 FFs as smallest value satisfying the condition $N \leq 2^n$ is $n = 3$.

Three FFs can have eight possible states, out of which only six are utilized and the remaining two states 110 and 111, are invalid.

If initially the counter is in 000 state, then after 1st clock pulse it goes to 001, after the second clock pulse it goes to 010, and so on. After the sixth clock pulse it goes to 000.

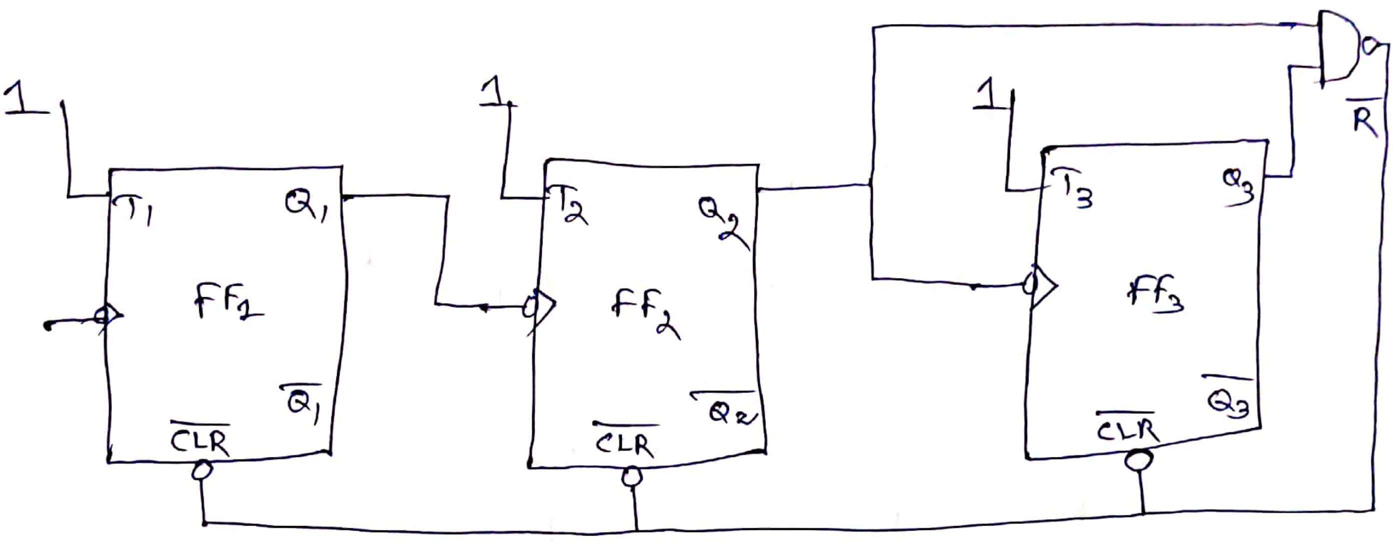
After pulses	Q_3	Q_2	Q_1	R
	0	0	0	0
0	0	0	1	0
1	0	1	0	0
2	0	1	1	0
3	1	0	0	0
4	1	0	1	0
5	1	1	0	1
6	0	0	0	0
7	0	0	1	0

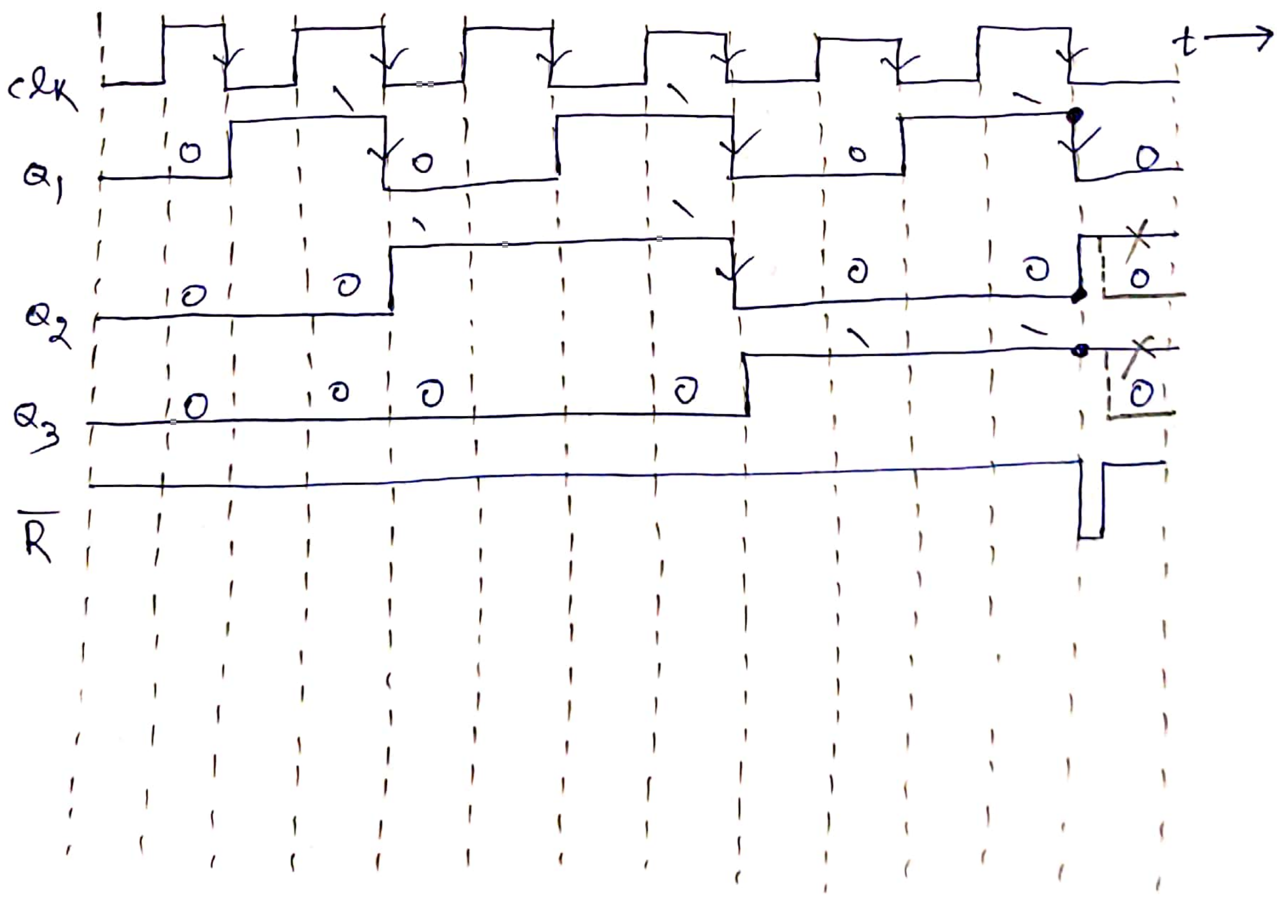
From the TT, $R = Q_3 Q_2$.

($\because$ $R = 0$ for 000 to 101

$R = 1$ for 110

$R = X$ for 111)





4 The number of FFs n is to be selected such that the number of states $N \leq 2^n$. With n FFs, the largest count possible is $2^n - 1$.

Therefore,

$$2^n - 1 = 16,383$$

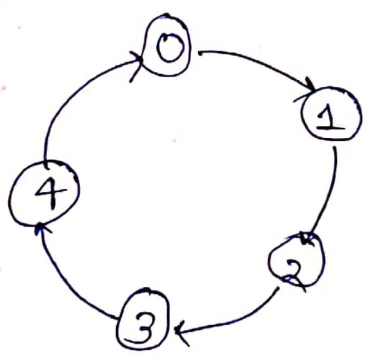
or $n = \log_2 16,384 = 14$

So, the number of FFs required is 14.

Frequency at the output of last stage is

$$f_{14} = \frac{f_c}{2^{14}} = \frac{8192\ MHz}{16,384} = 500 Hz$$

5 State Diagram :



(Mod-5 Counter)

Present state			Next State			Excitation Inputs					
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	0	0	0	X	1	0	X	0	X
1	0	1	X	X	X	X	X	X	X	X	X
1	1	0	X	X	X	X	X	X	X	X	X
1	1	1	X	X	X	X	X	X	X	X	X

K-map Simplification

$q_2 \backslash q_1q_0$	00	01	11	10
0			1	
1	X	X	X	X

$J_2 = q_0 q_1$

$q_2 \backslash q_1q_0$	00	01	11	10
0	X	X	X	X
1	1	X	X	X

$K_2 = 1$

$q_2 \backslash q_1q_0$	00	01	11	10
0		1	X	X
1		X	X	X

$J_1 = q_0$

$q_2 \backslash q_1q_0$	00	01	11	10
0	X	X	1	
1	X	X	X	X

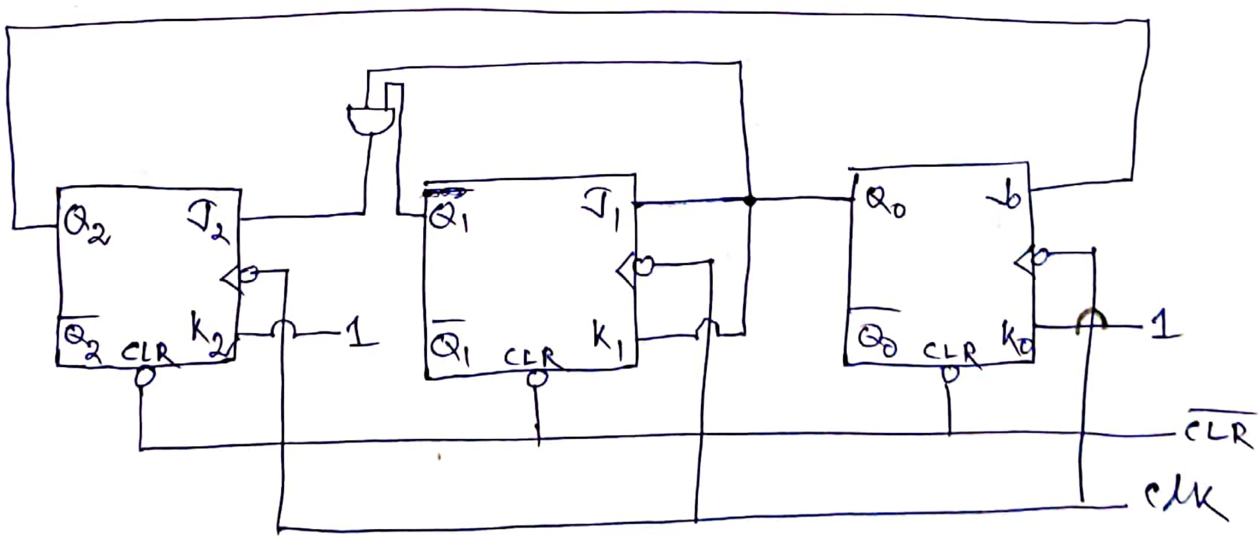
$K_1 = q_0$

$q_2 \backslash q_1q_0$	00	01	11	10
0	1	X	X	1
1		X	X	X

$J_0 = \overline{q_2}$

$q_2 \backslash q_1q_0$	00	01	11	10
0	X	1	1	X
1	X	X	X	X

$K_0 = 1$



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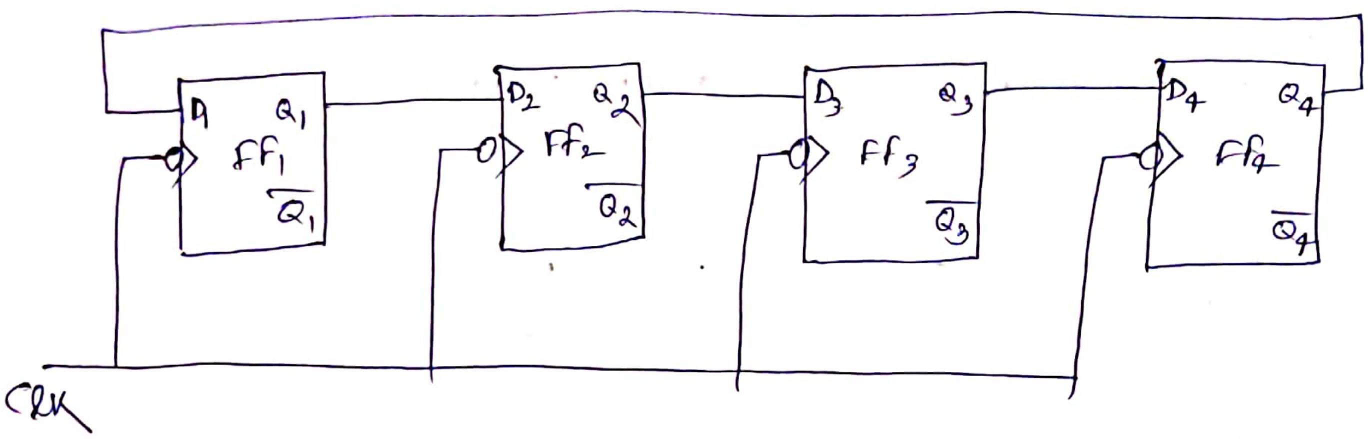
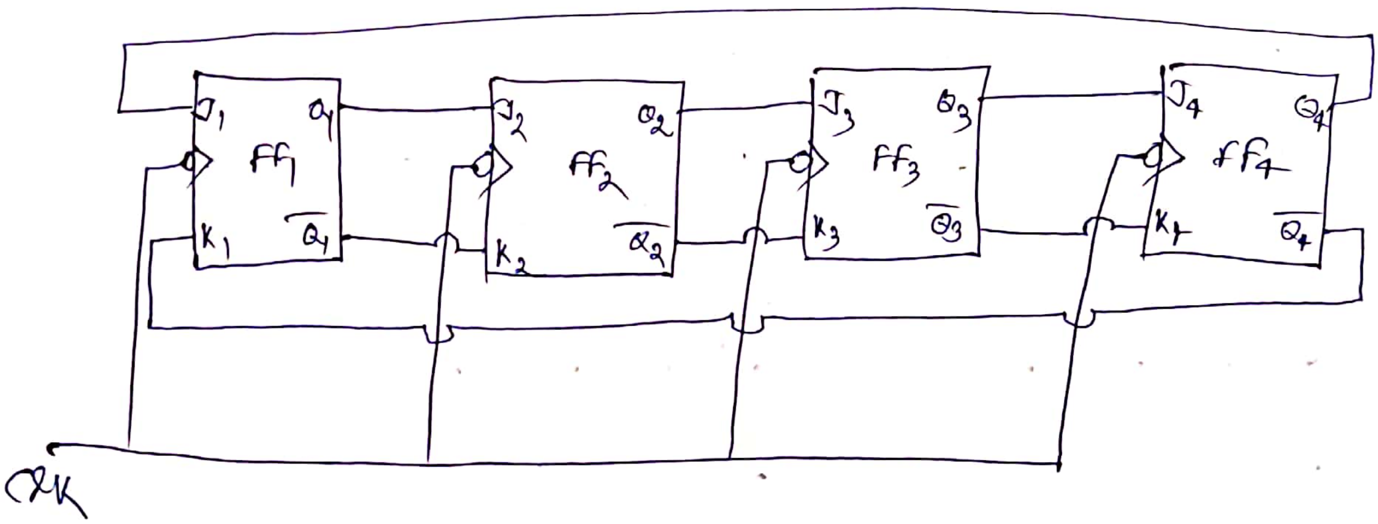
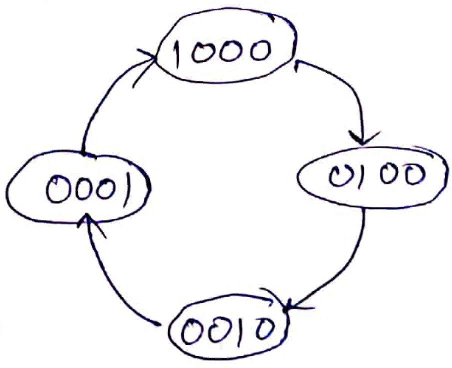
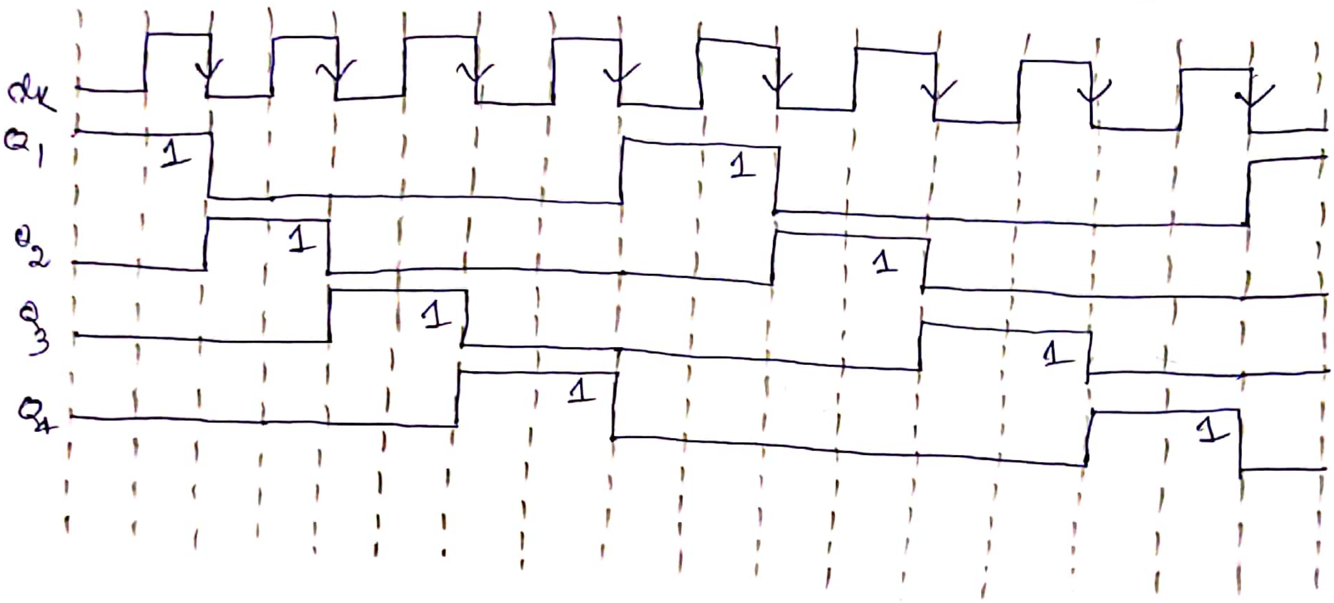




After clock pulse	Q_1	Q_2	Q_3	Q_4
0	1	0	0	0
1	0	1	0	0
2	0	0	1	0
3	0	0	0	1
4	1	0	0	0
5	0	1	0	0





The FFs are arranged as in a normal shift register, i.e. the Q output of each stage is connected to the D input of the next stage, but the Q output of the last FF is connected back to the D input of the first FF such that the array of FFs is arranged in a ring and therefore the name ring counter.