Registers and Counters

- Registers are used for temporary storage of data.
- Counters are mainly used in counting applications, where they either measure the time interval between two unknown time instants or measure the frequency of a given signal.

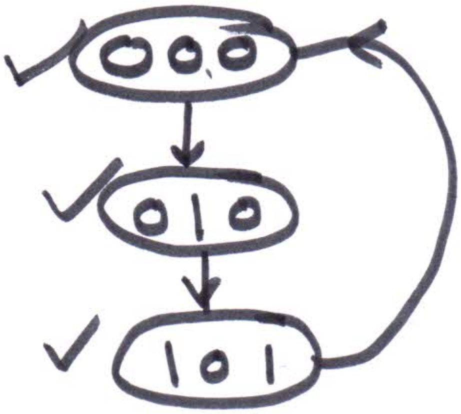
Counters

- Ripple Counter or Asynchronous Counter
- Synchronous Counter

- A ripple counter is a cascaded arrangement of flip-flops where the output of one flip-flop drives the clock input of the following flip-flop.

- In synchronous counter, the clock is applied the flip-flops simultaneously, and thus, all the flip-flop change their states at the same time.

- Modulus (MOD) of a counter is the number of different logic states it goes through before it comes back to the initial state to repeat the count sequence.



MOD = 3

$0 \rightarrow 2 \rightarrow 5 \rightarrow 0 \rightarrow 2 \rightarrow 5$

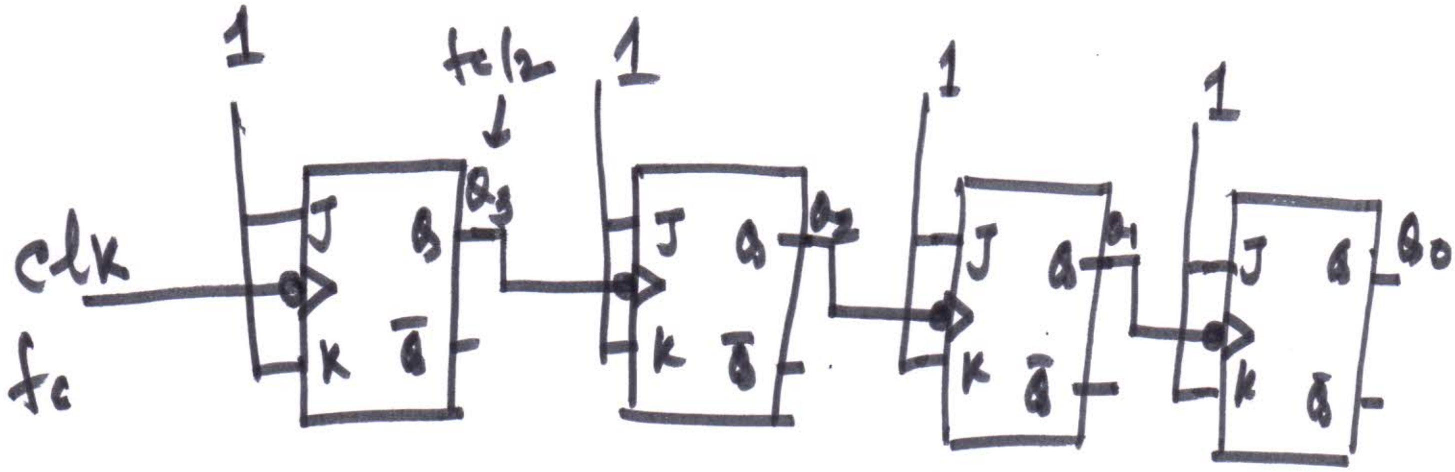
MOD- 2^N binary ripple counter:

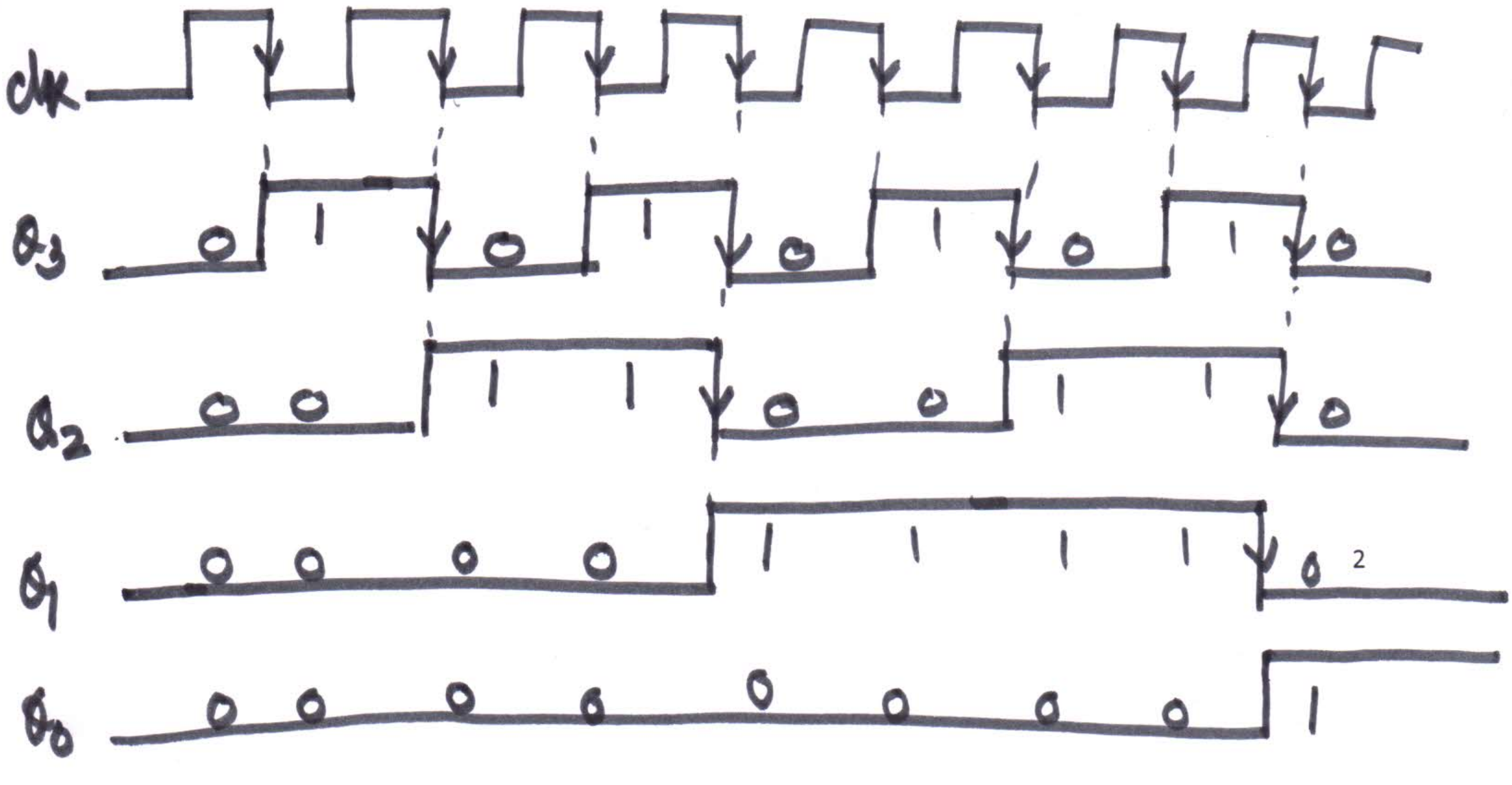
$N = 4$

$Q_0 \; Q_1 \; Q_2 \; Q_3$

0000
↓
0001
↓
0010
↓
⋮
↓
1111

$MOD = 2^4 = 16$





MOD- 5 binary ripple counter:

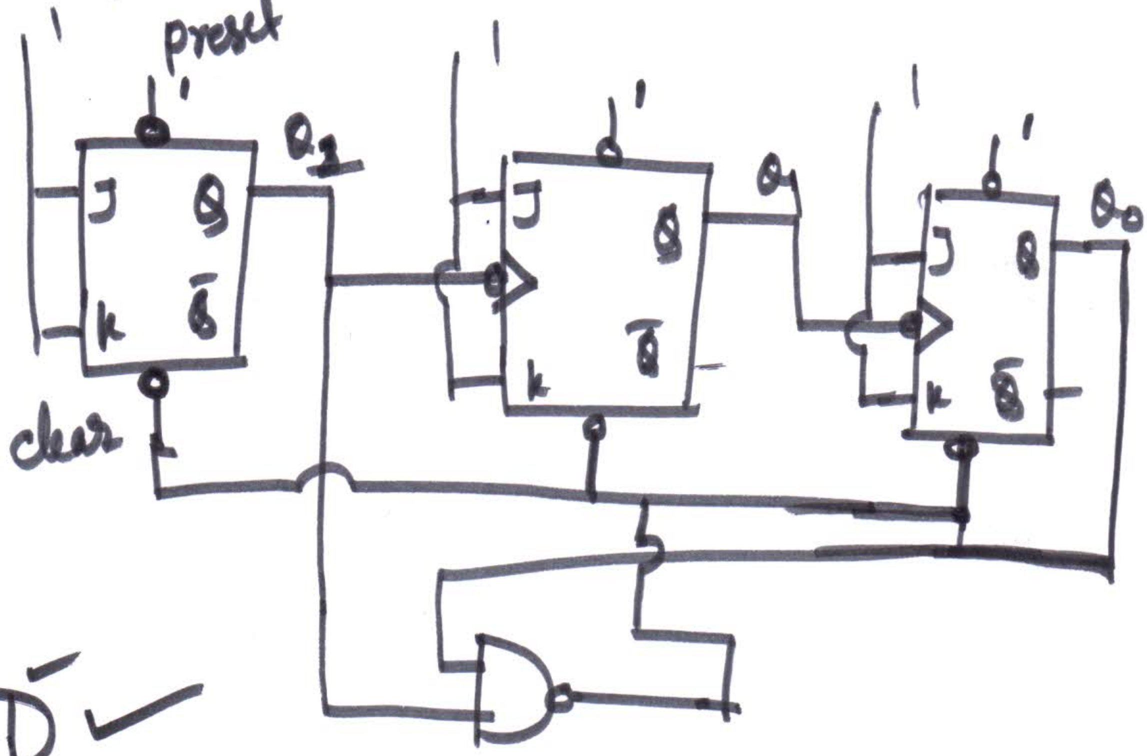
$2^{N-1}+1 \leq MOD \leq 2^N$

$N=3$

Q_0	Q_1	Q_2
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0

~~1 0 1~~ 0 0 0

Preset	Clear	Q	Q^+
0	1	x	1
1	0	x	0

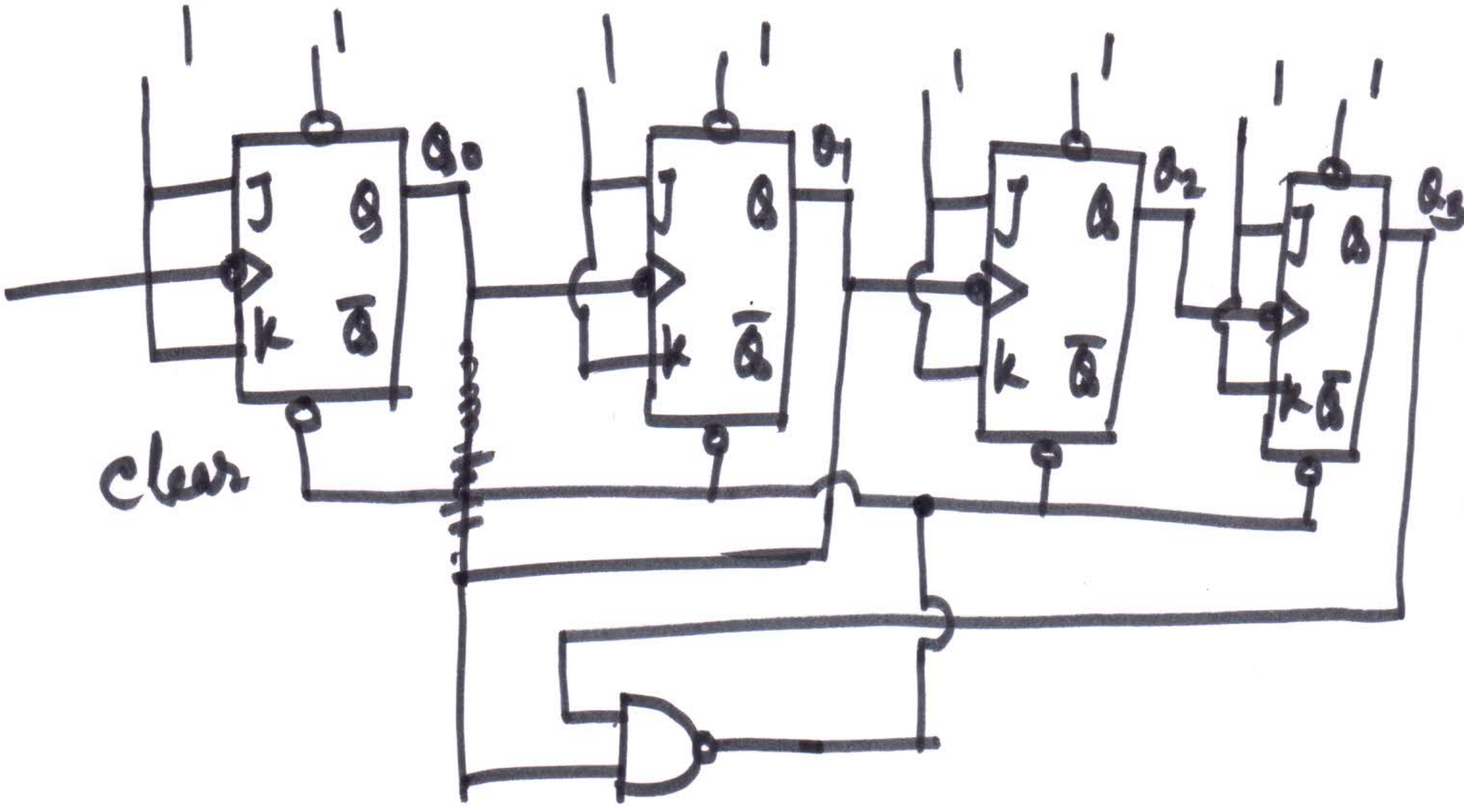


101 ✓

x111 ✓

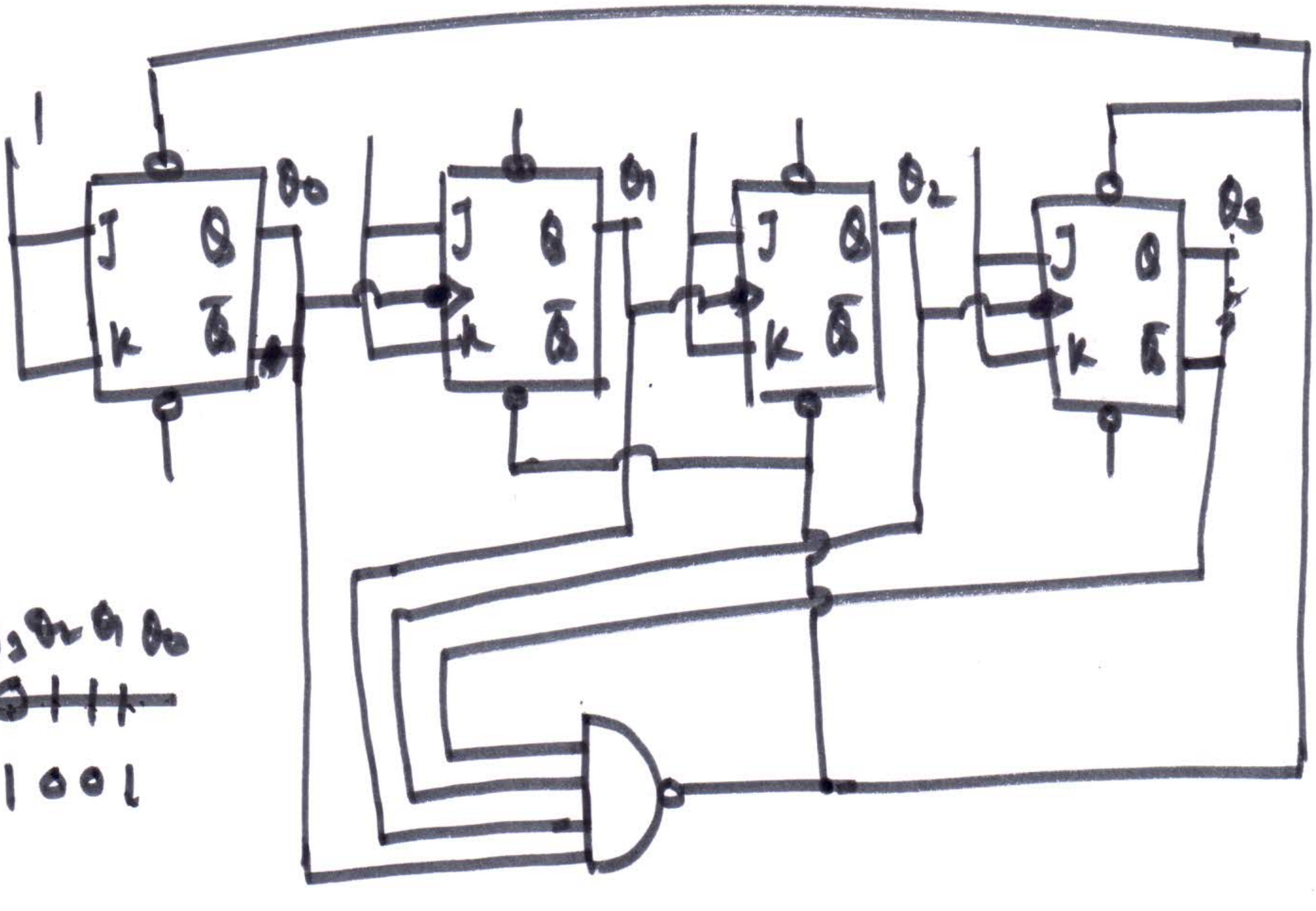
BCD Decade Ripple Counter:

Q_3 (MSB)	Q_2	Q_1	Q_0 (LSB)
0	0	0	0
0	0	0	1
⋮	⋮	⋮	⋮
1	0	0	1
~~1~~	~~0~~	~~1~~	~~0~~



ex

Q_3	Q_2	Q_1	Q_0
0	0	0	0
0	0	0	1
⋮			
0	1	1	0
1	0	0	1
1	0	1	0
⋮			
1	1	1	1



$Q_3\ Q_2\ Q_1\ Q_0$

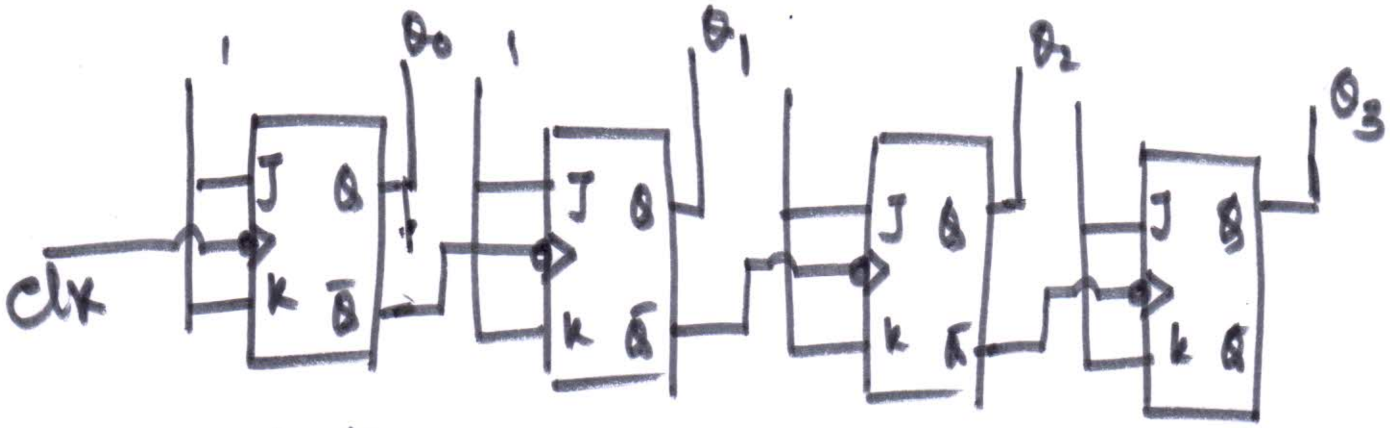
0 1 1 1

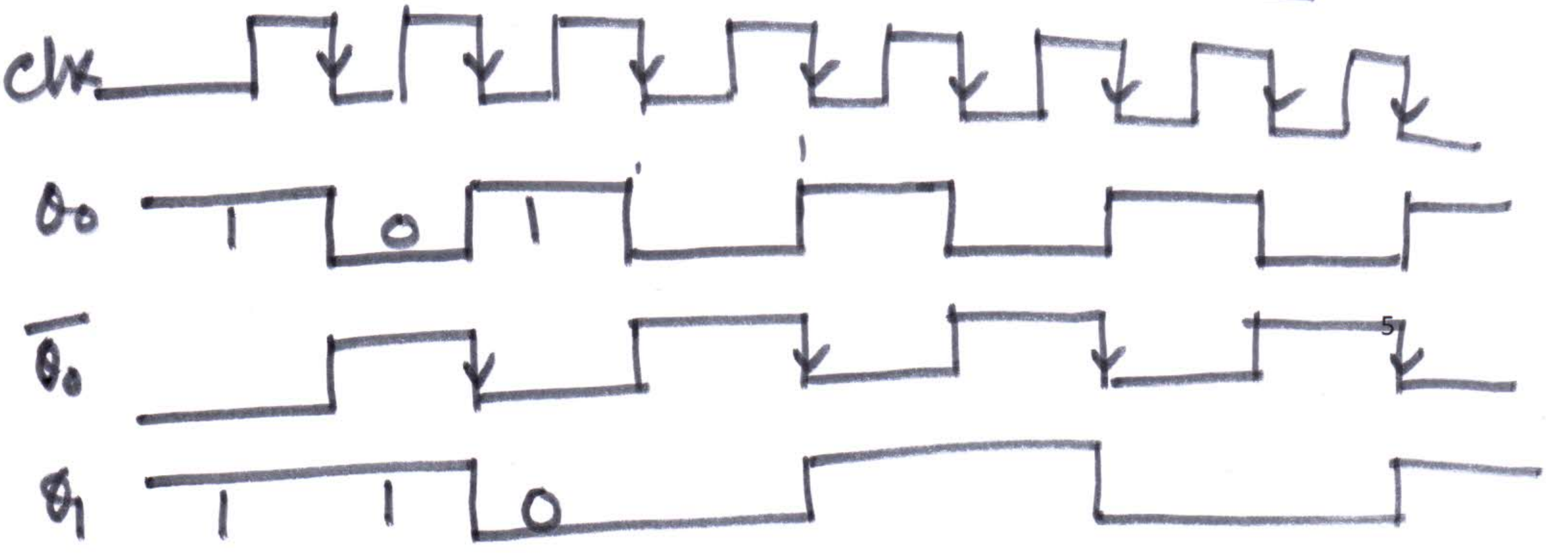
1 0 0 1

MOD- 2^N DOWN Ripple Counter:

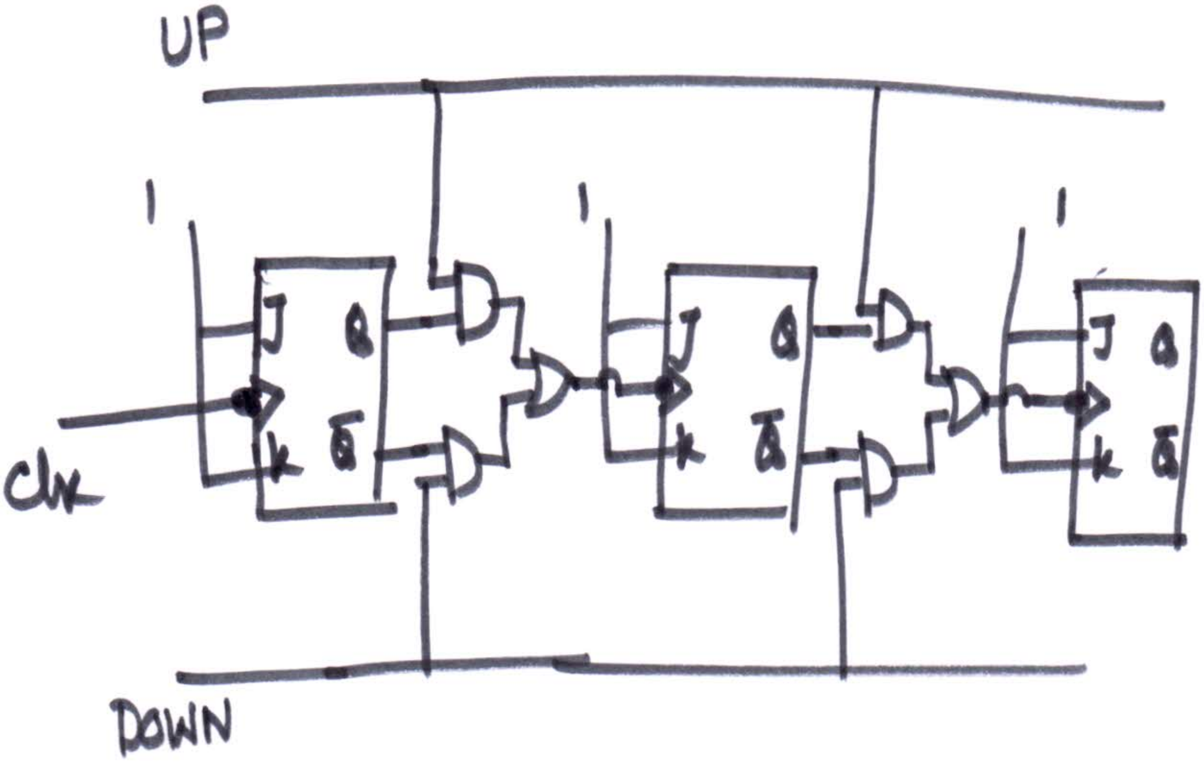
N=4

Q_3	Q_2	Q_1	Q_0
1	1	1	1
1	1	1	0
1	1	0	1
1	1	0	0
	⋮		
0	0	0	1
0	0	0	0





Asynchronous Up/Down Counter:

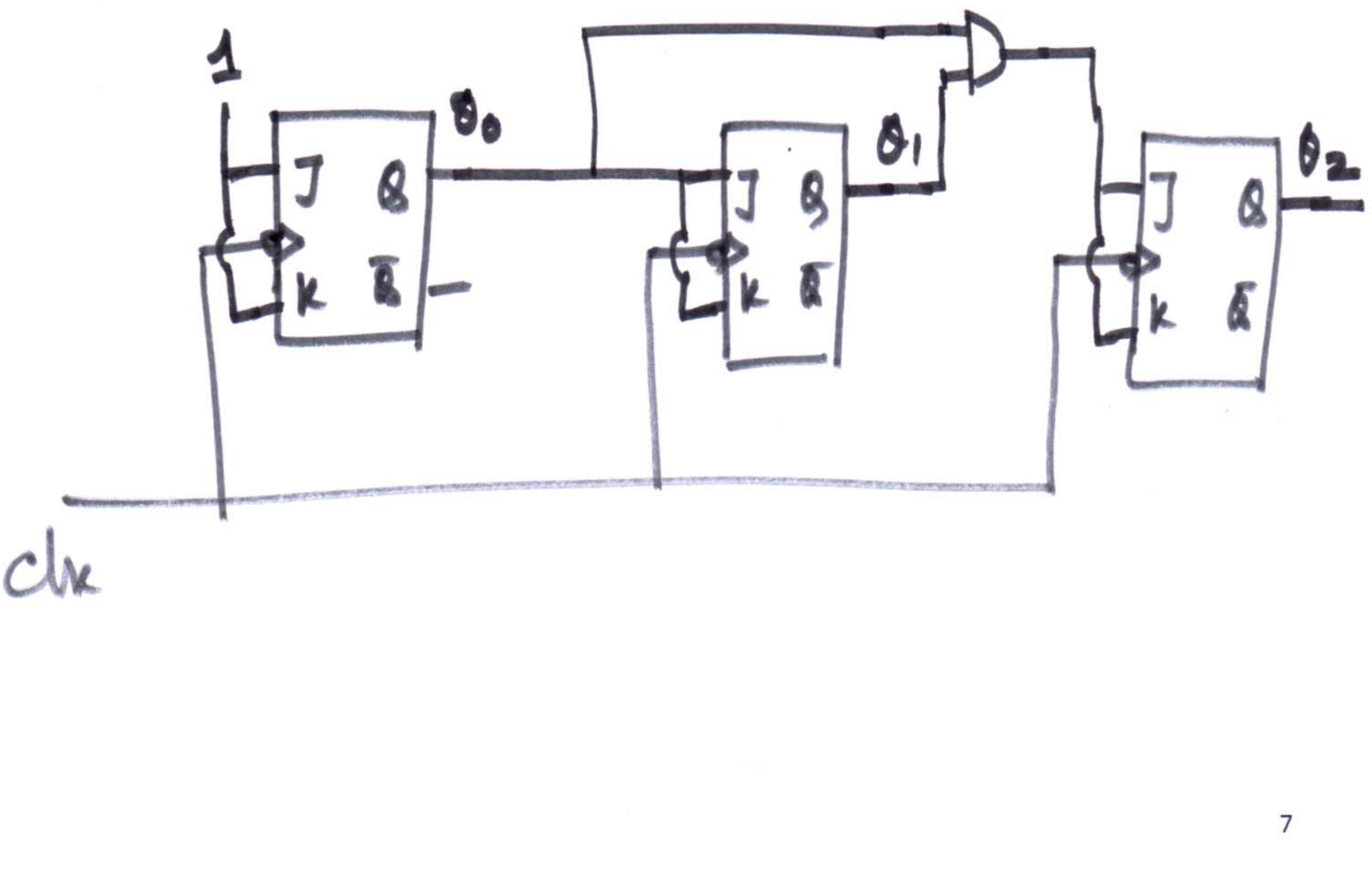


Synchronous Counters:

MOD-8 Synchronous Counter:

$2^N = 8 \Rightarrow N = 3$

Q_2	Q_1	Q_0
0	0	0
0	0	1
0	1	0
0	1	1
1	0	0
1	0	1
1	1	0
1	1	1



Present state			Next state			I/P					
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

Present State Q	Next State Q^+	J	K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0

0 0 1 1 1 1 0 0

0 1 1 0 0 1 1 0

J_0

Q_2Q_1 \ Q_0	0	1
00	1	X
01	1	X
11	1	X
10	1	X

$J_1 = 1$

K_0

Q_2Q_1 \ Q_0	0	1
00	X	1
01	X	1
11	X	1
10	X	1

$K_0 = 1$

J_1

Q_2Q_1 \ Q_0	0	1
00		1
01	X	X
11	X	X
10		1

$J_1 = Q_0$

K_1

Q_2Q_1 \ Q_0	0	1
00	X	X
01		1
11		1
10	X	X

$K_1 = Q_0$

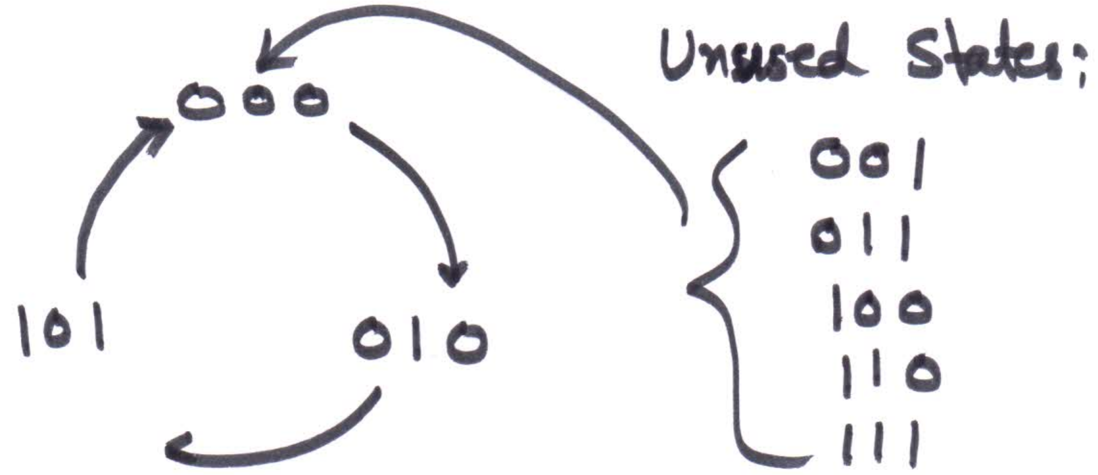
J_2

$J_2 = Q_1Q_0$

$K_2 = Q_1Q_0$

Counter with an arbitrary sequence:

ex

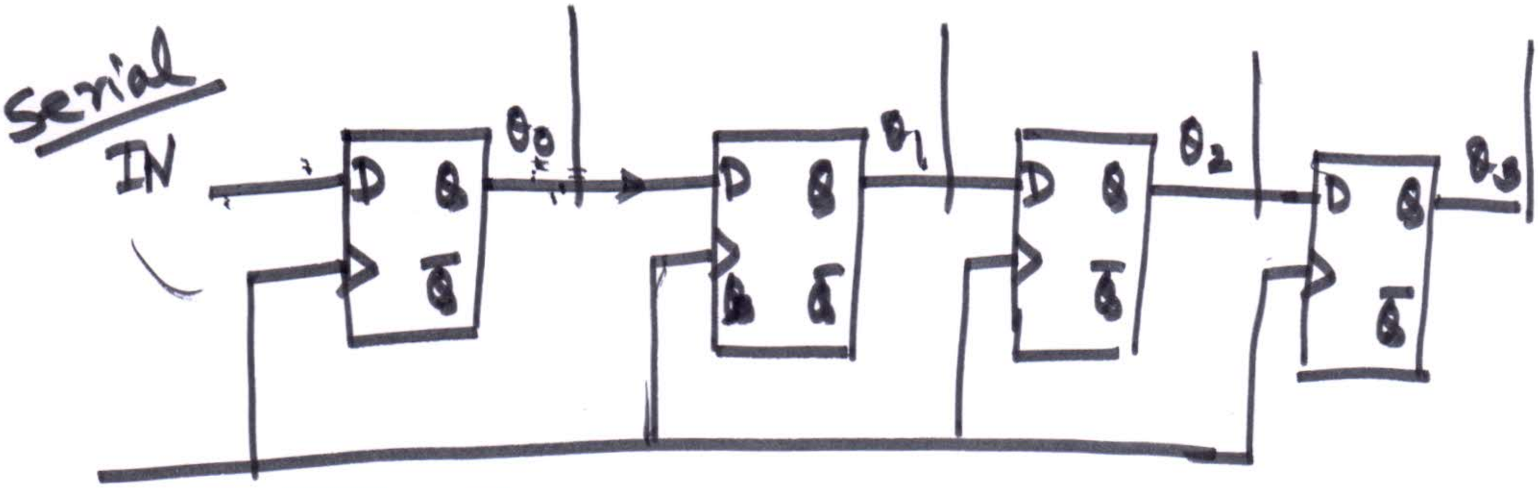


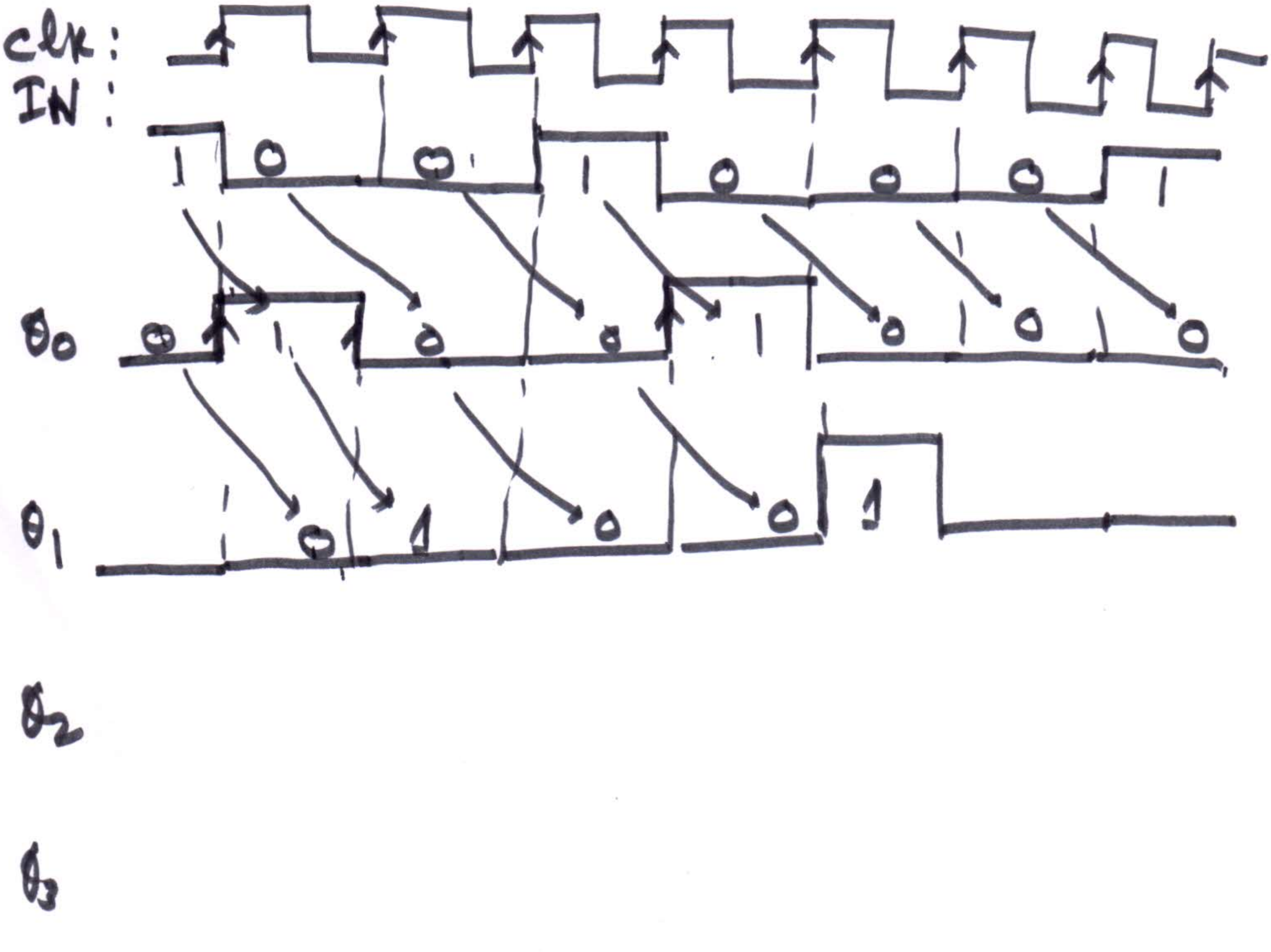
Present States			Next States			I/p					
Q_2	Q_1	Q_0	Q_2^+	Q_1^+	Q_0^+	J_2	K_2	J_1	K_1	J_0	K_0
0	0	0	0	1	0						
0	0	1	0	0	0						
0	1	0	1	0	1						
0	1	1	0	0	0						
1	0	0	0	0	0						
1	0	1	0	0	0						
1	1	0	0	0	0						
1	1	1	0	0	0						

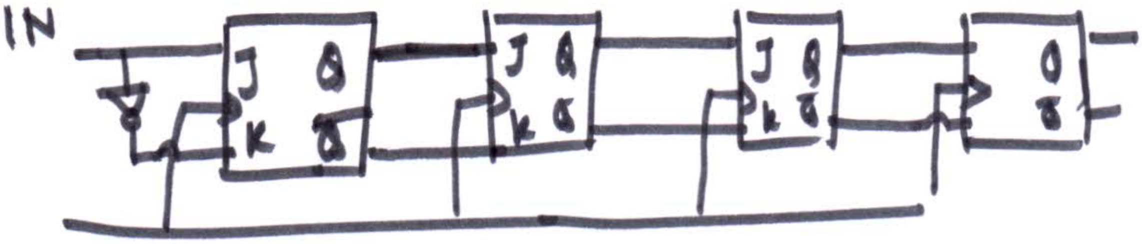
If unused states are ignored.

Present States Q_2 q_1 q_0	Next States Q_2^+ Q_1^+ Q_0^+	J_2 K_2	J_1 K_1	J_0 K_0
0 0 0	0 1 0			
0 0 1	x x x	x x	x x	x x
0 1 0	1 0 1			
0 1 1	x x x	x x	x x	x x
1 0 0	x x x	x x	x x	x x
1 0 1	0 0 0			
1 1 0	x x x	x x	x x	x x
1 1 1	x x x	x x	x x	x x

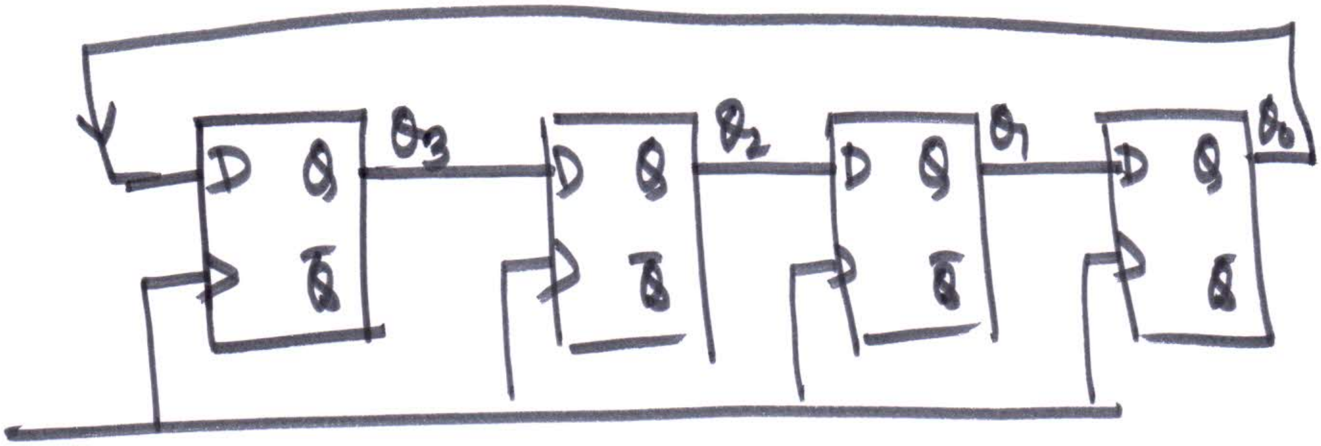
Shift Register:







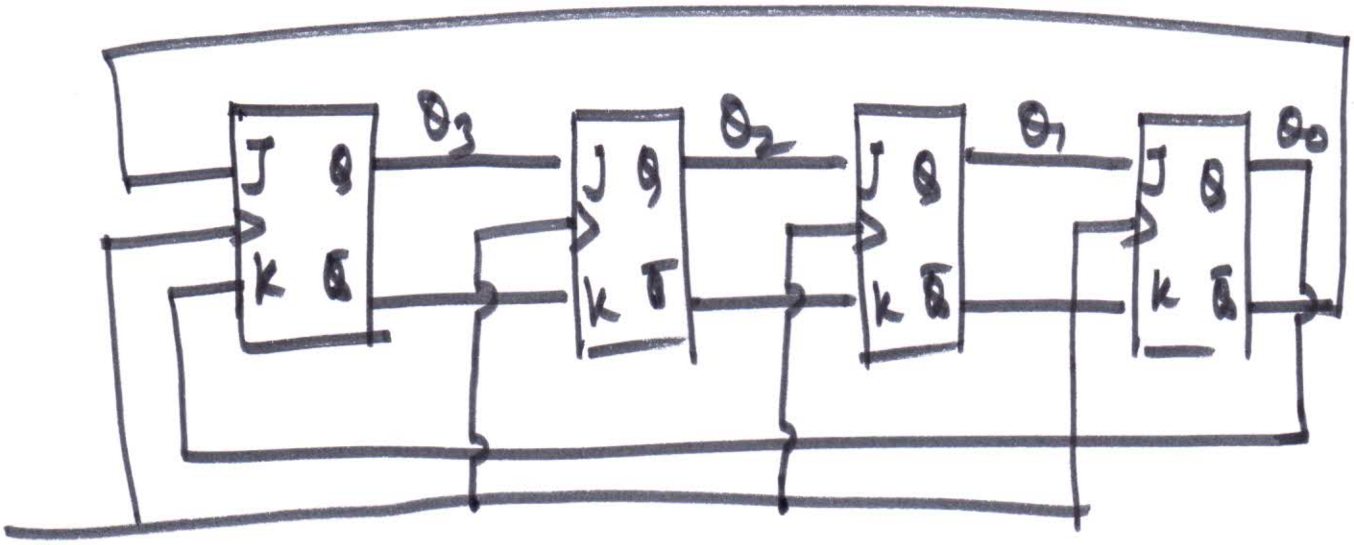
Ring Counter:



Q_3	Q_2	Q_1	Q_0	
1	0	0	0	✓
0	1	0	0	✓
0	0	1	0	✓
0	0	0	1	✓
1	0	0	0	

<u>MOD – 4</u>

Johnson Counter:



Q_3	Q_2	Q_1	Q_0
0	0	0	0
1	0	0	0
1	1	0	0
1	1	1	0
1	1	1	1
0	1	1	1
0	0	1	1
0	0	0	1
0	0	0	0

MOD-8.

for N-FF → MOD-2N