Counters

Reference
Chapter 7
Registers and Register Transfers
Moris Mano 4th Edition

Counter

- A register that goes through a prescribed sequence of distinct states upon the application of a sequence of input pulses
- Input pulses may be
  - Clock pulses
  - Originate from some other source
  - May occur at regular or irregular interval of time

Binary Counter

- Counter that follows the binary number sequence is called binary counter
- An n-bit binary counter consists of n flip-flops and can count in binary from 0 through 2^n-1

Types of Counters

1. Asynchronous Counters

   In which C input of some of the flip-flops are triggered not by common pulse but rather by the transitions that occur on other flip-flop outputs

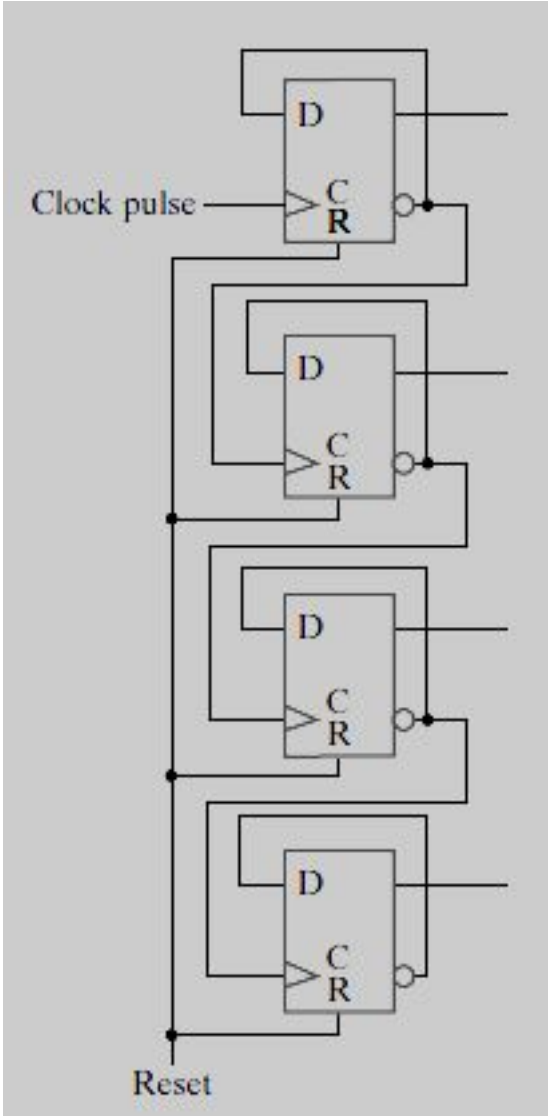
   e.g. Ripple counters

2. Synchronous Counters

   In which the C inputs of all flip-flops receive common pulse

Asynchronous Counters

4-bit Ripple Counter



Upward Counting Sequence			
Q_3	Q_2	Q_1	Q_0
0	0	0	0
0	0	0	1
0	0	1	0
0	0	1	1
0	1	0	0
0	1	0	1
0	1	1	0
0	1	1	1
1	0	0	0
1	0	0	1
1	0	1	0
1	0	1	1
1	1	0	0
1	1	0	1
1	1	1	0
1	1	1	1

What will be the state of counter on positive edge after 1111?

4-bit Ripple Counter

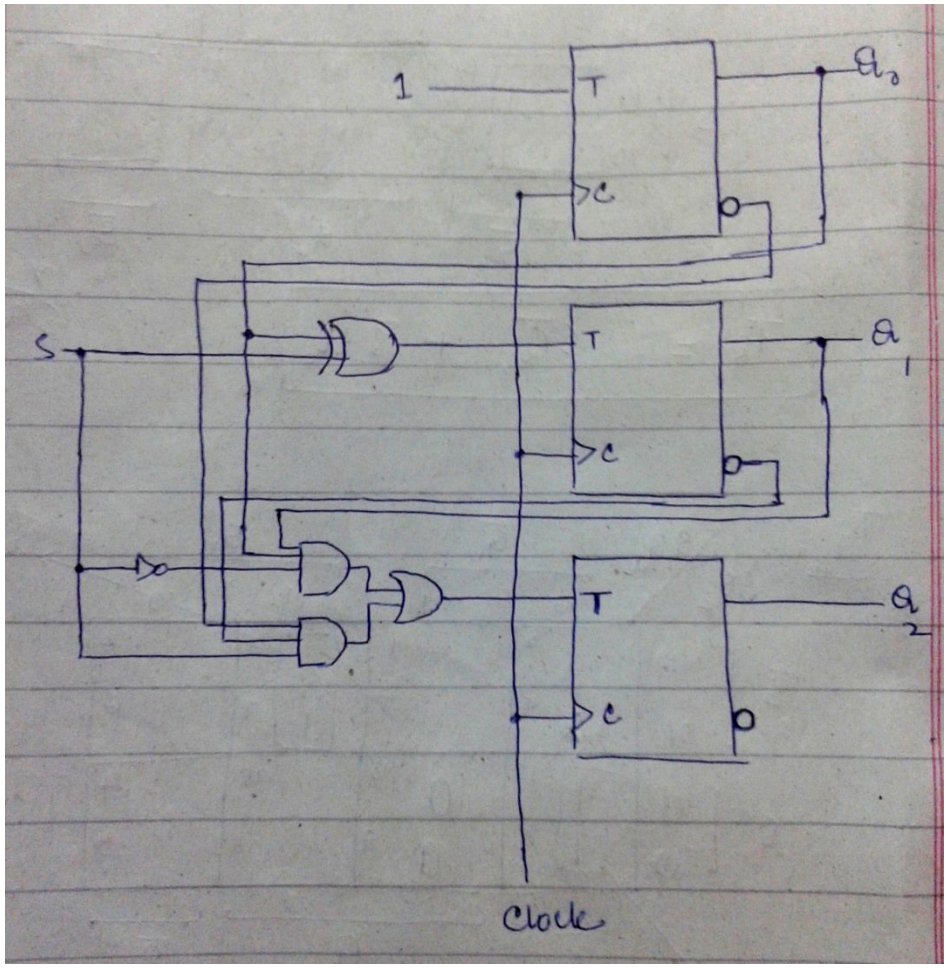
- Design a 4-bit ripple counter for downward counting

Can you design an asynchronous Up-Down Counter with Selection Input?

Downward Counting Sequence			
Q_3	Q_2	Q_1	Q_0
1	1	1	1
1	1	1	0
1	1	0	1
1	1	0	0
1	0	1	1
1	0	1	0
1	0	0	1
1	0	0	0
0	1	1	1
0	1	1	0
0	1	0	1
0	1	0	0
0	0	1	1
0	0	1	0
0	0	0	1
0	0	0	0

Synchronous Counters

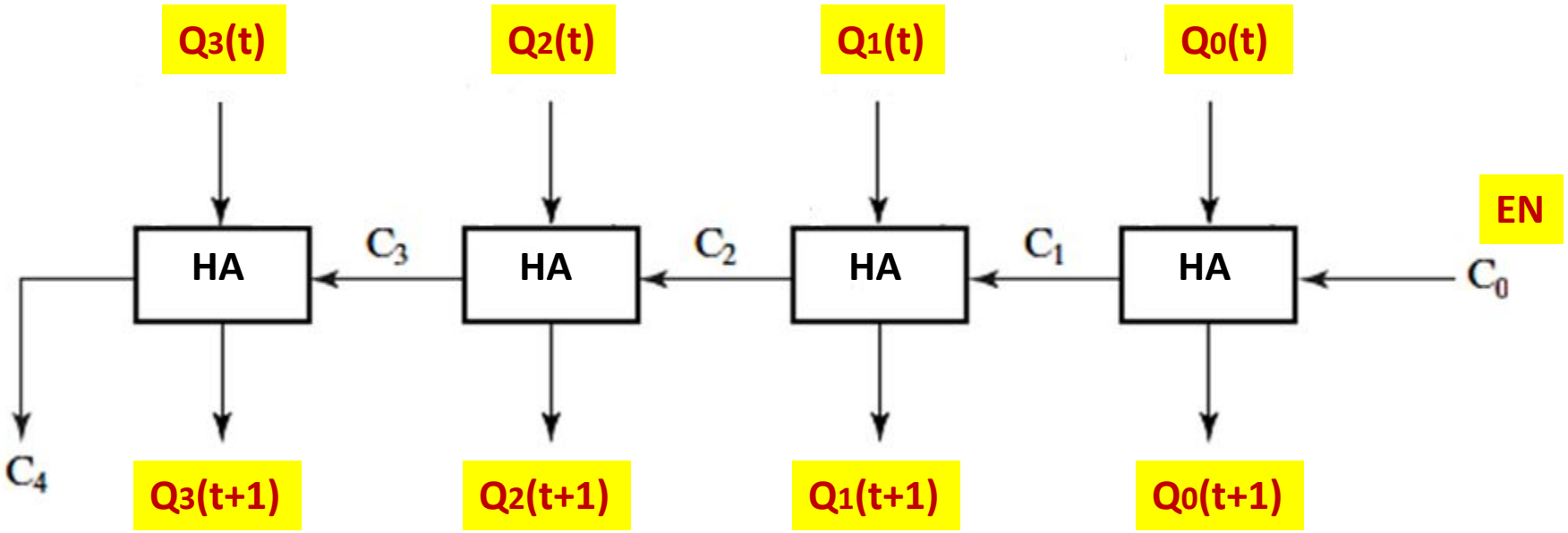
Synchronous 3-bit Up-Down Counter



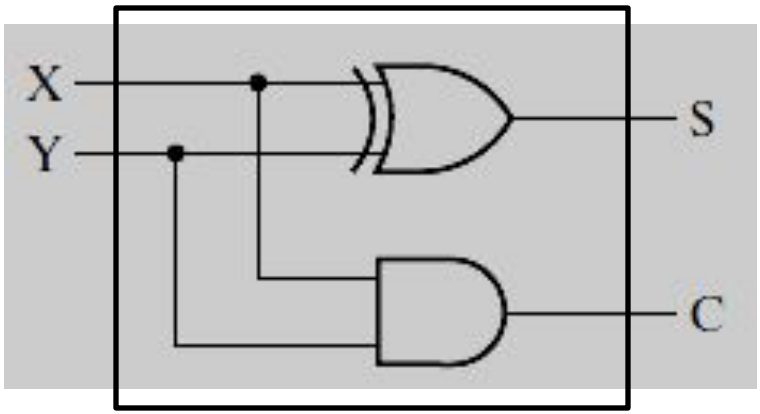
For S=0
Count Upward

For S=1
Count Downward

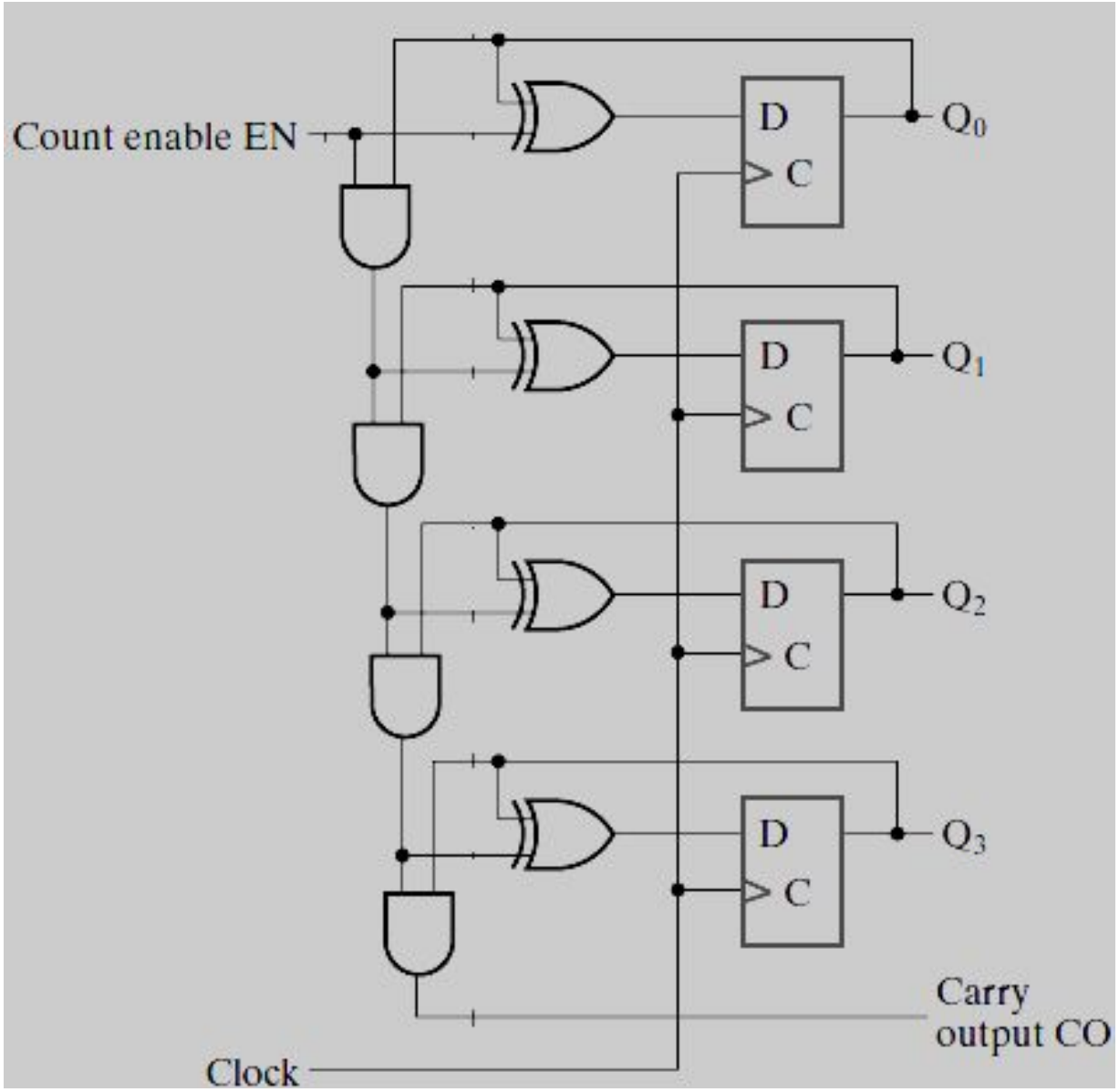
Serial Counter



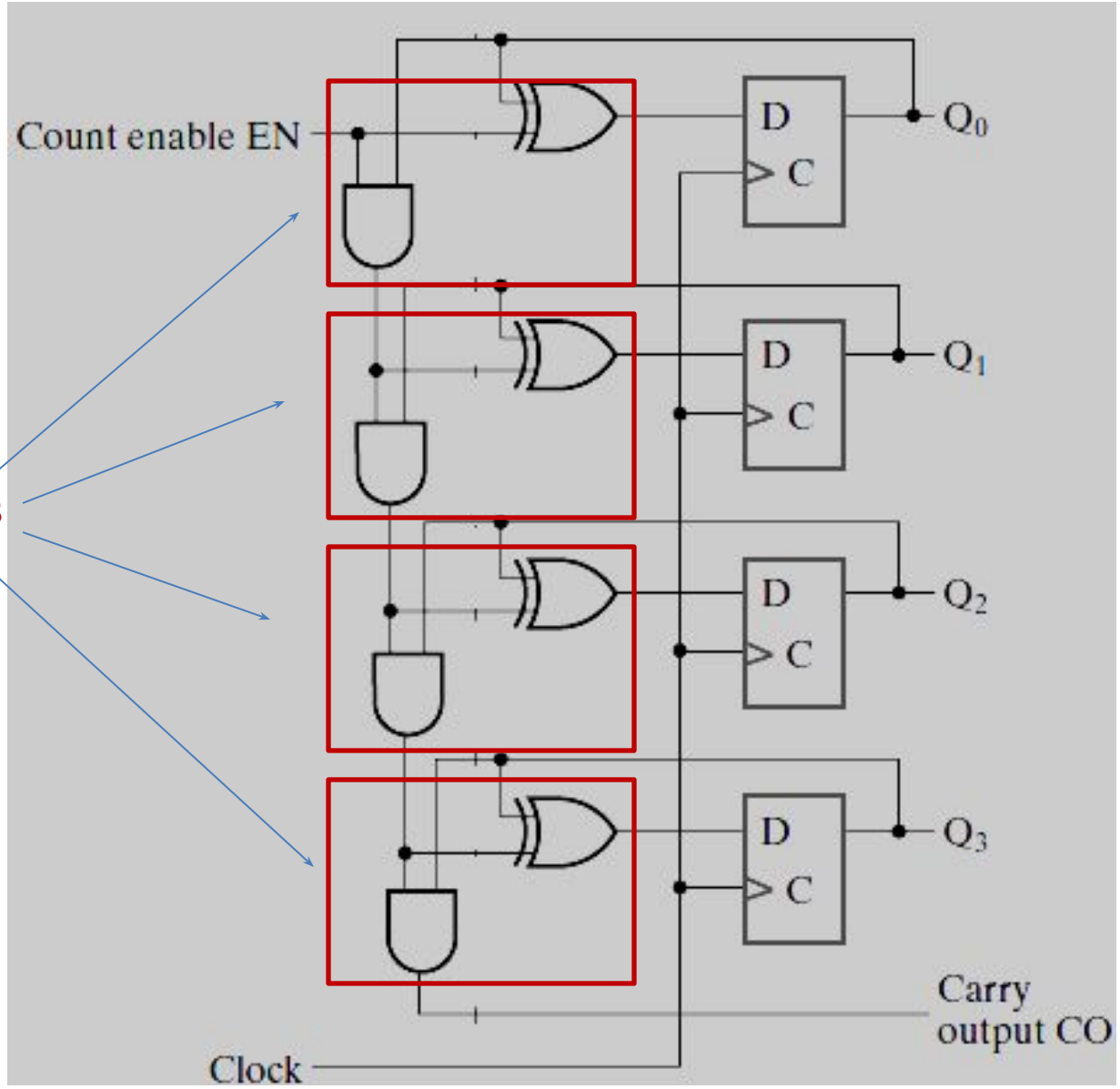
Half Adder



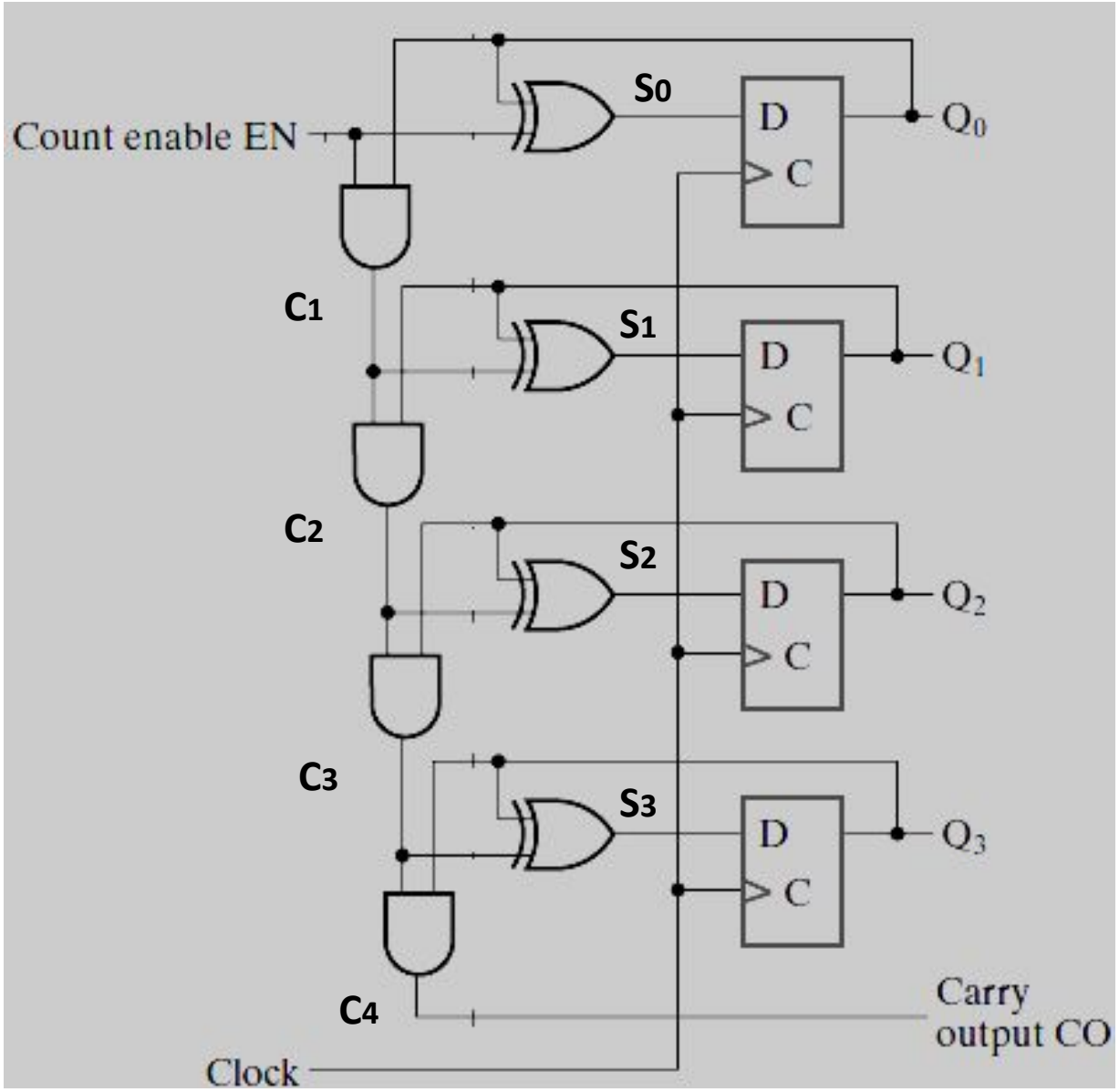
Serial Counter



Serial Counter

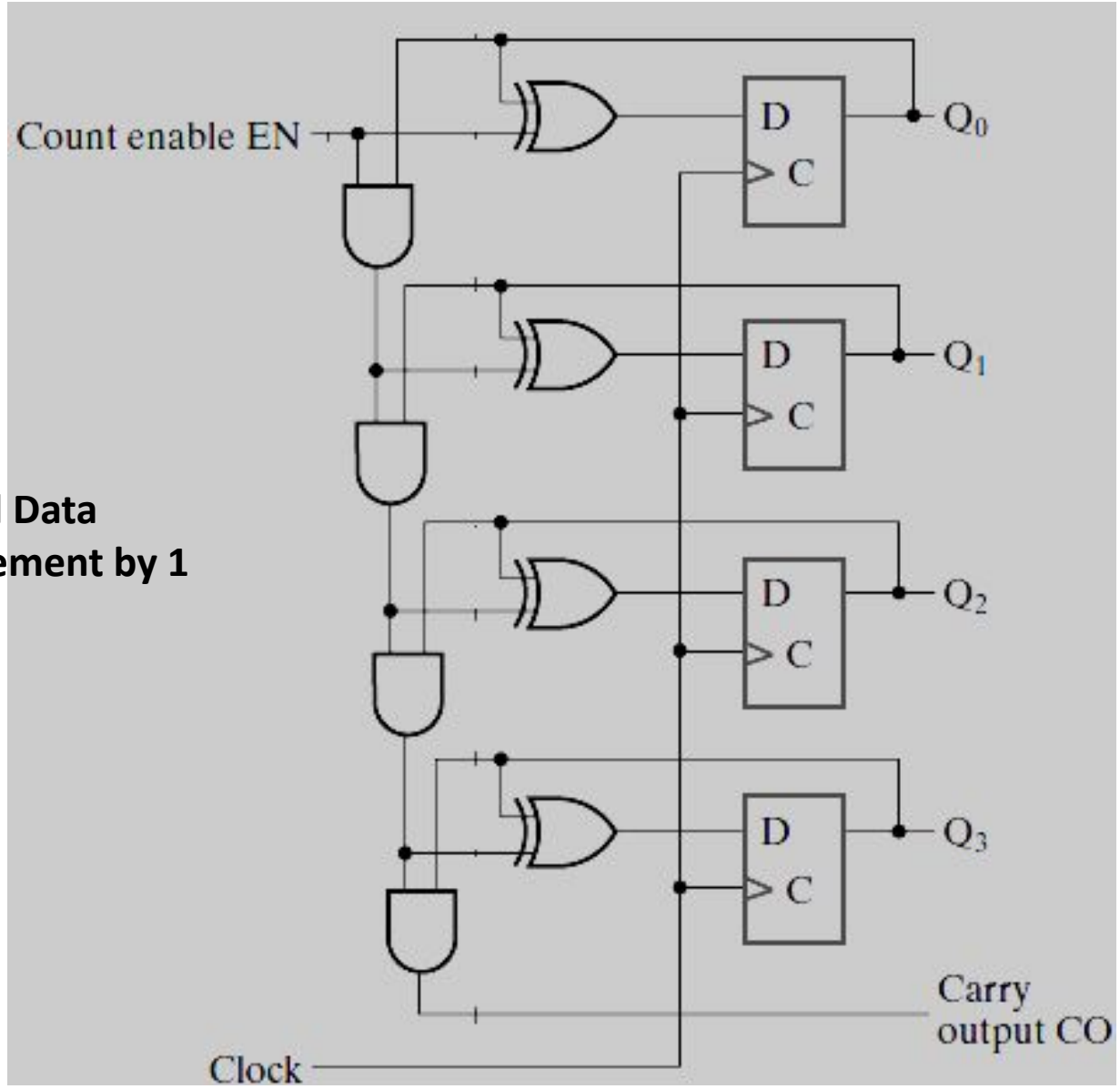


Serial Counter

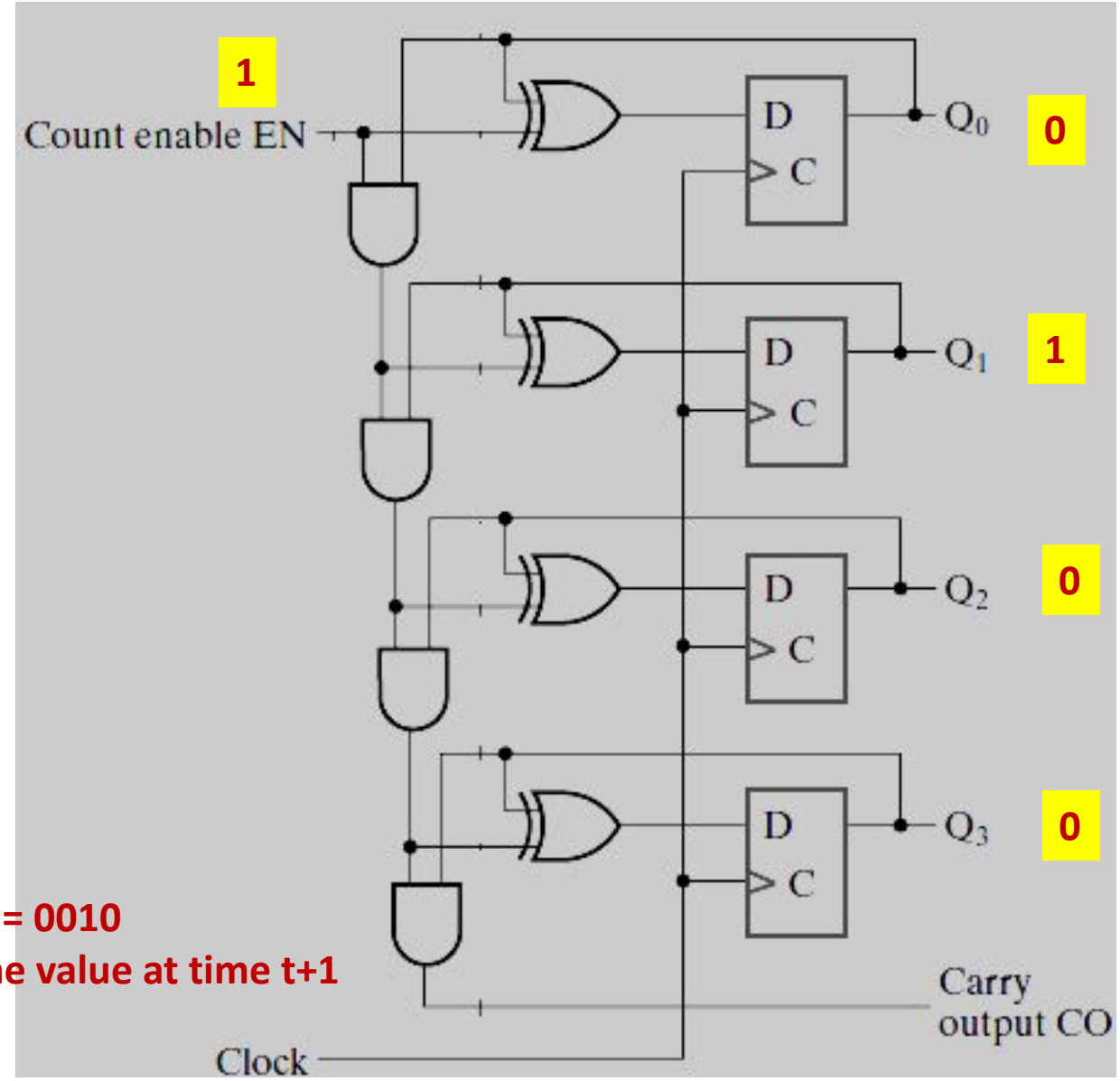


Serial Counter

If EN = 0, Hold Data
If EN = 1, Increment by 1



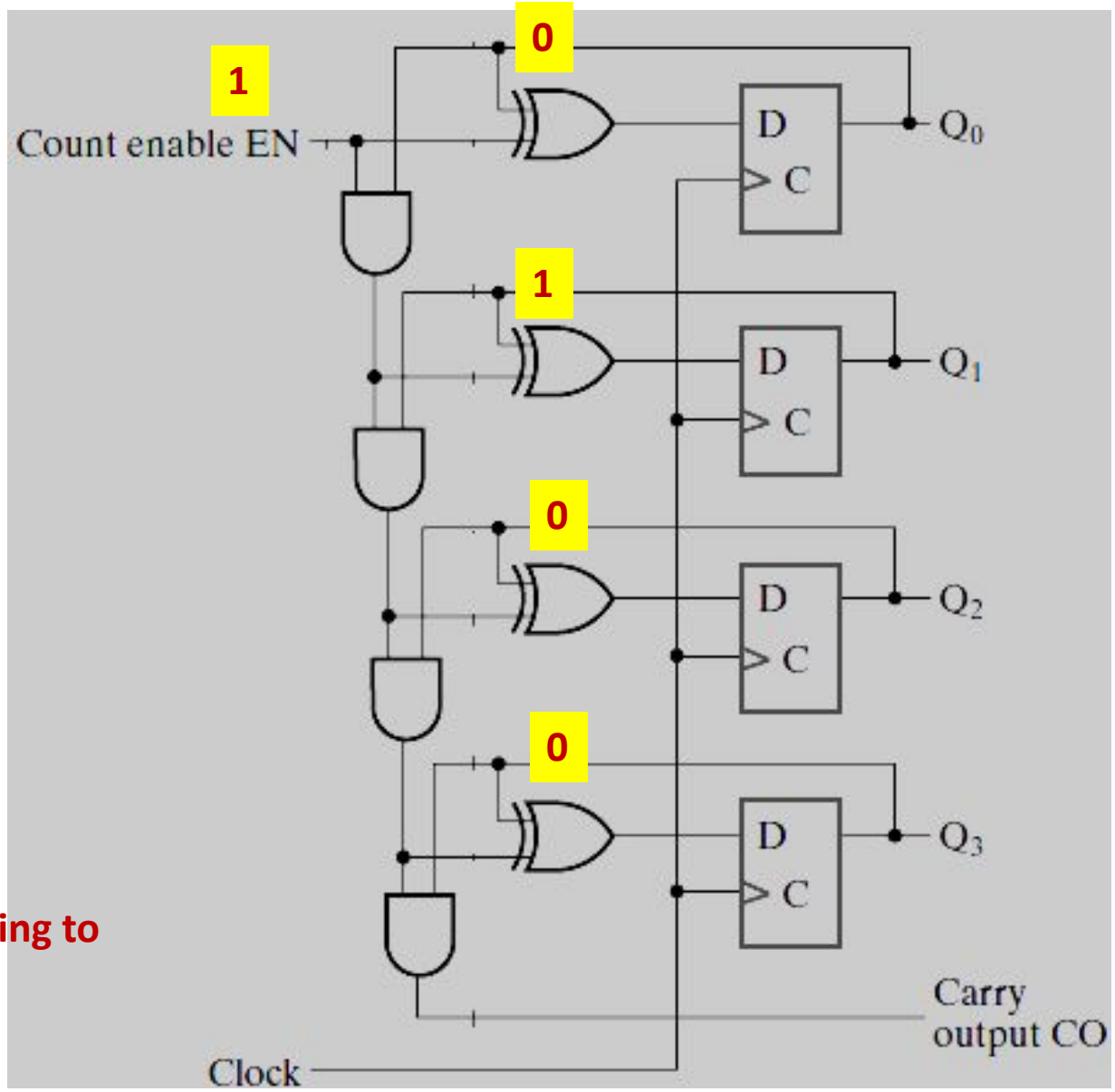
How Serial Counter Works?



Value at time t = 0010

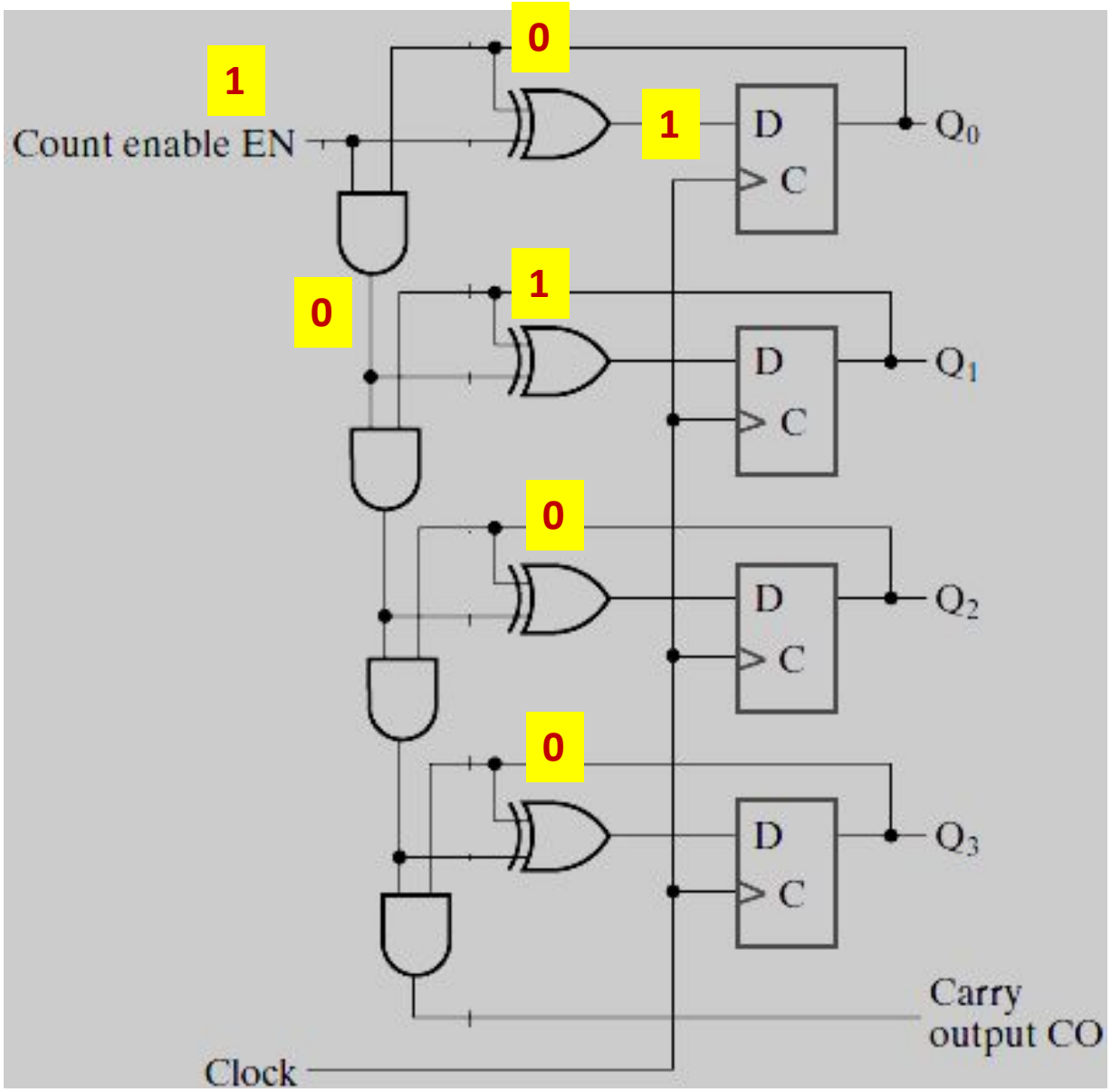
What will be the value at time t+1

How Serial Counter Works?

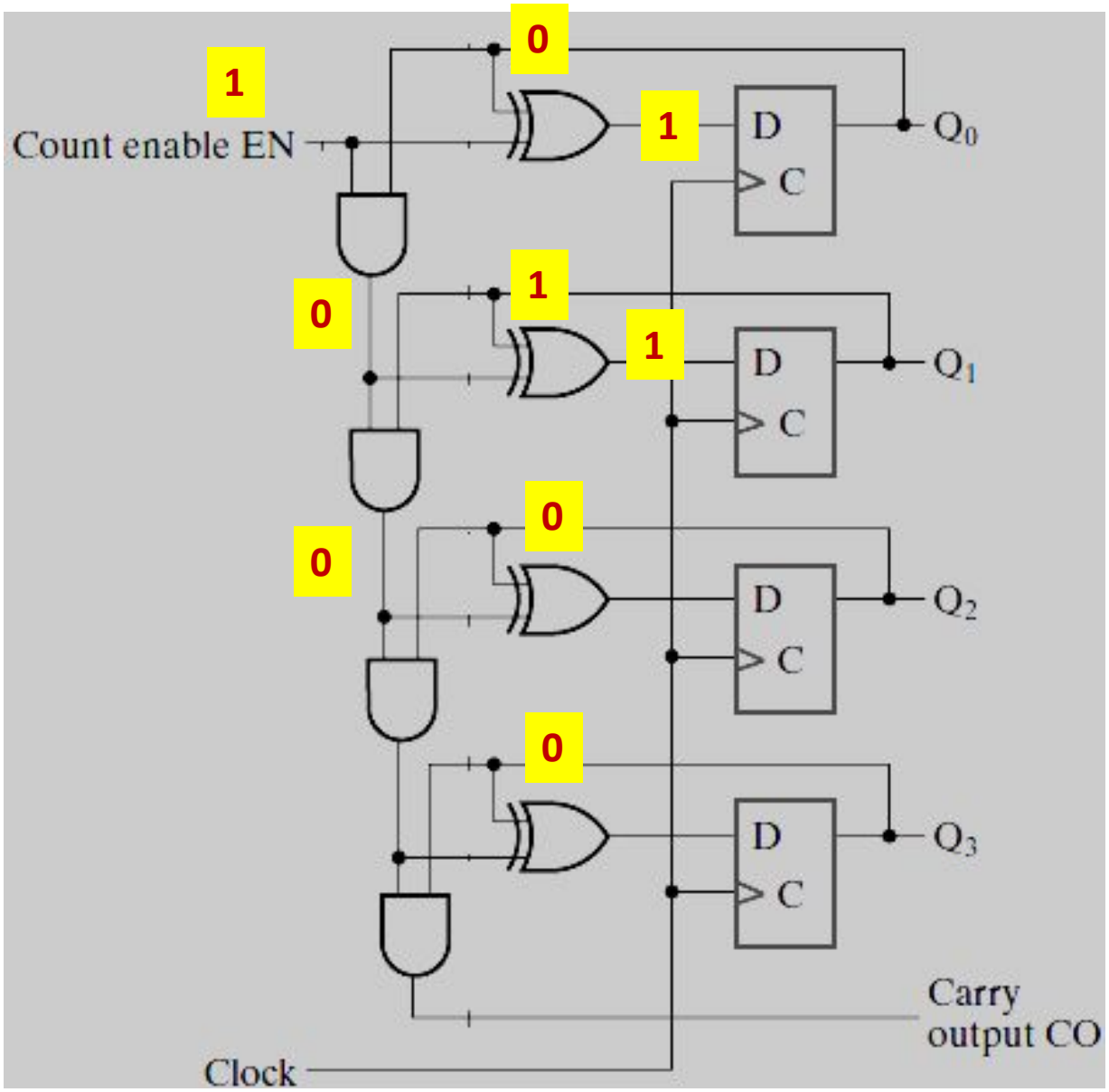


Qi outputs coming to XORs and ANDs

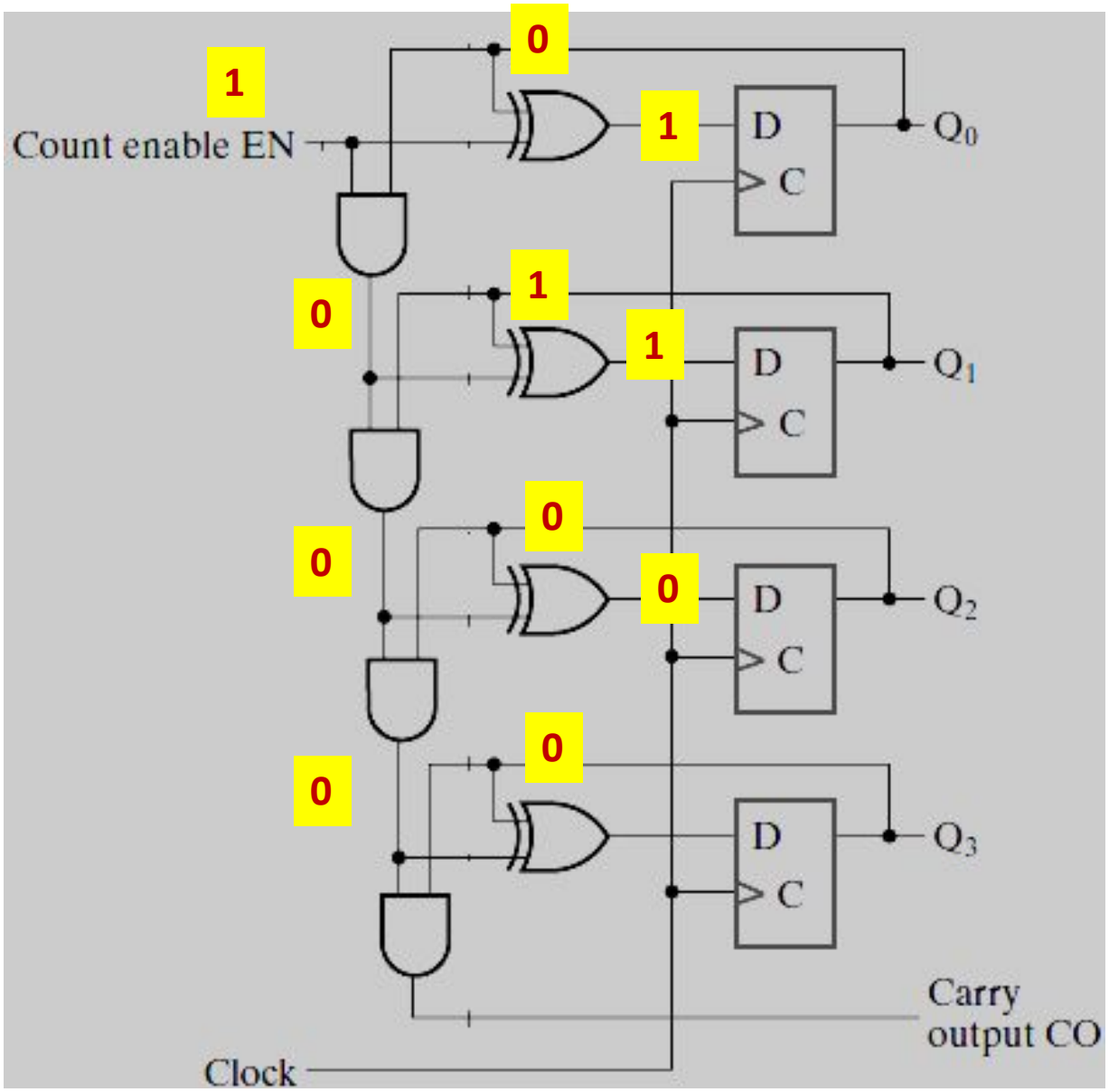
How Serial Counter Works?



How Serial Counter Works?



How Serial Counter Works?



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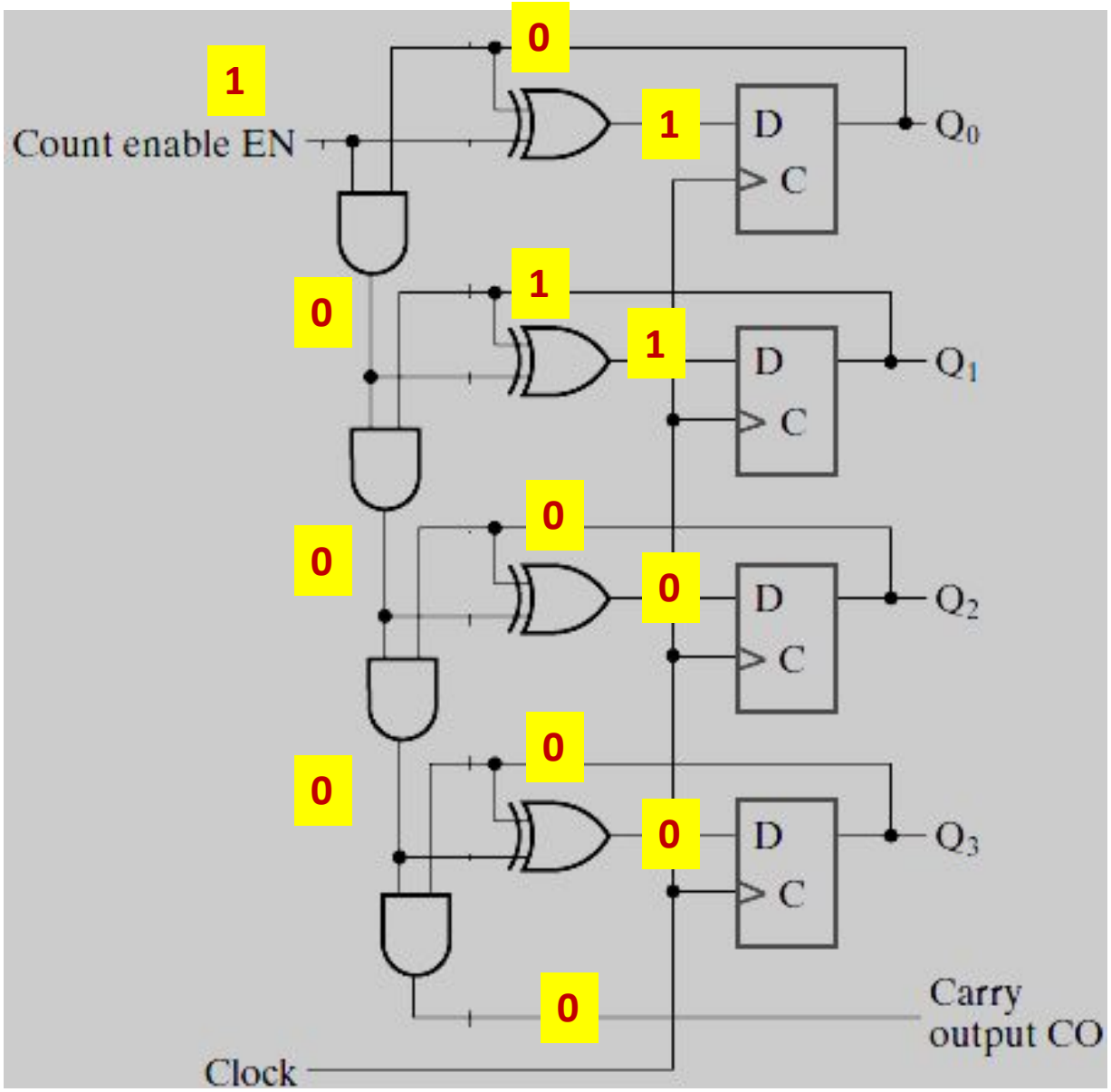
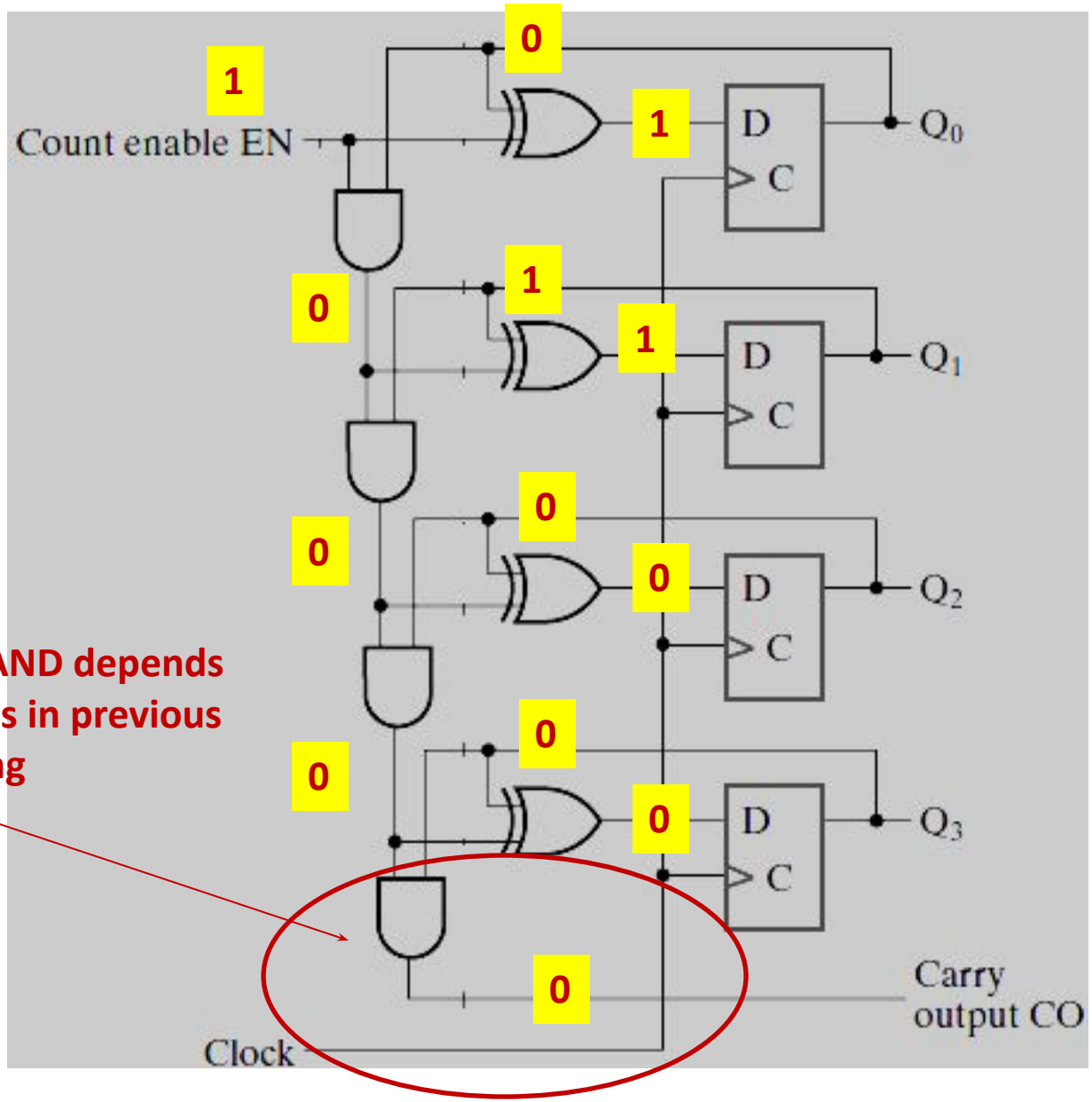
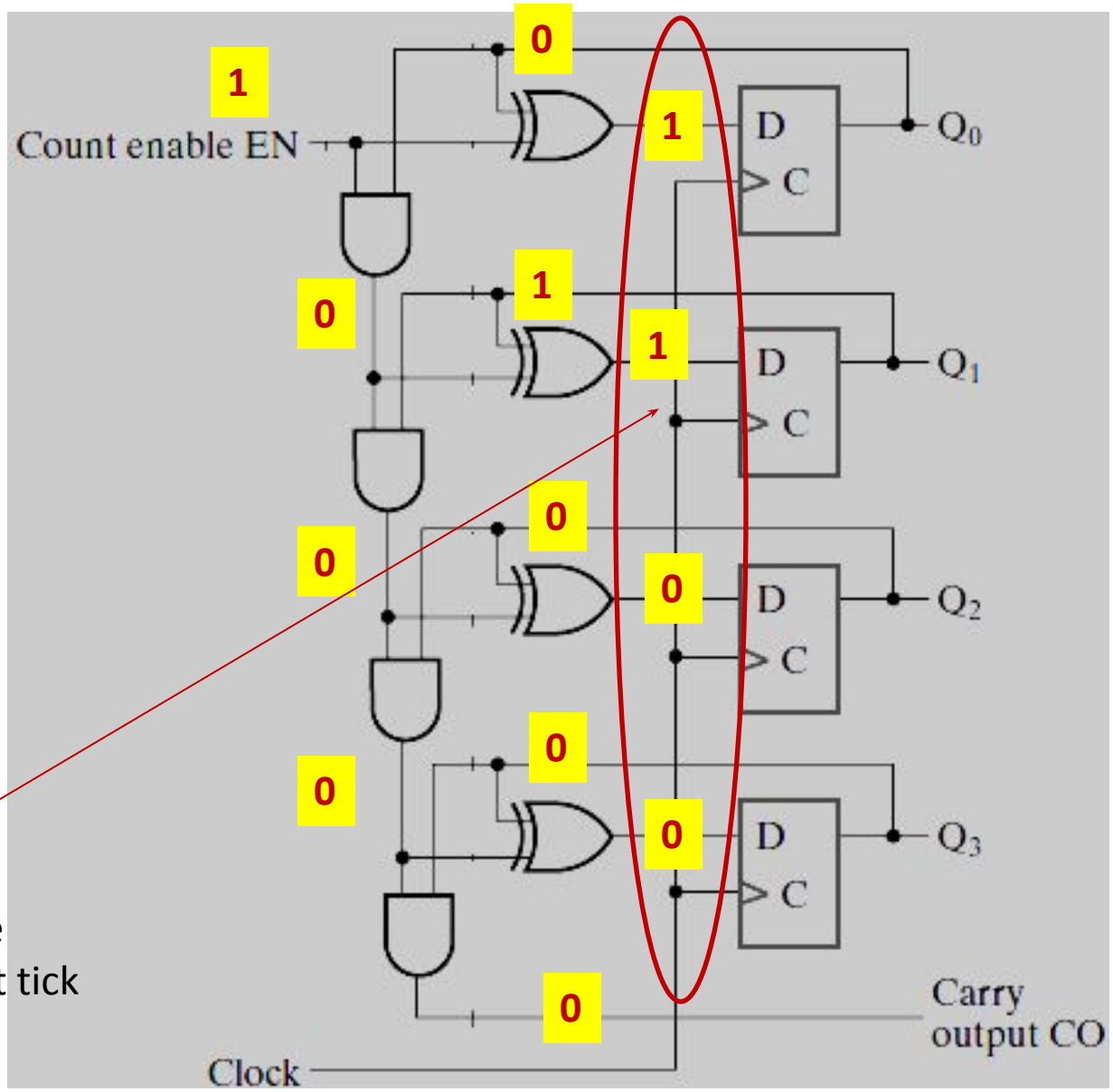


How Serial Counter Works?



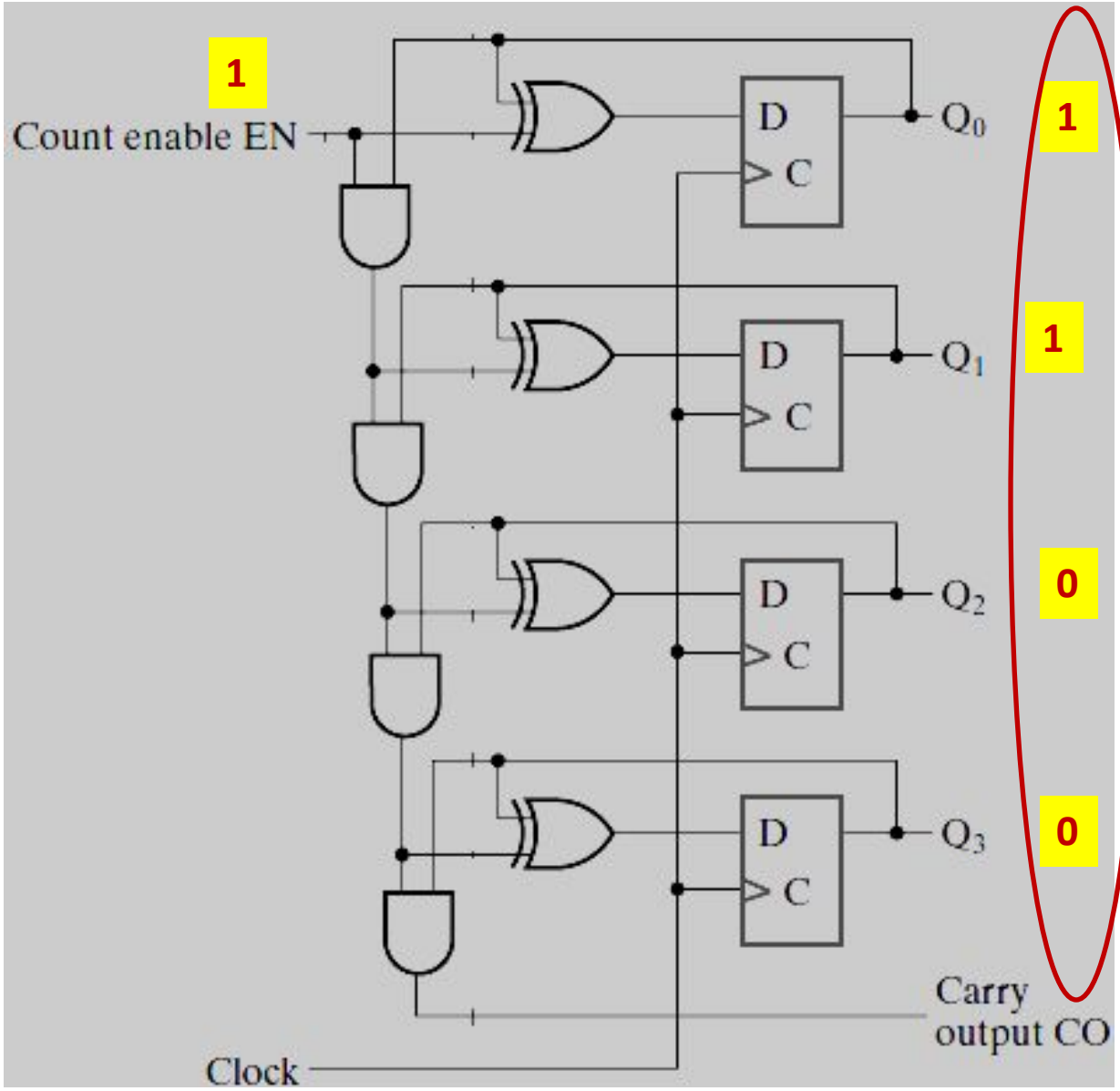
Value of this AND depends On three ANDs in previous Levels of gating

How Serial Counter Works?

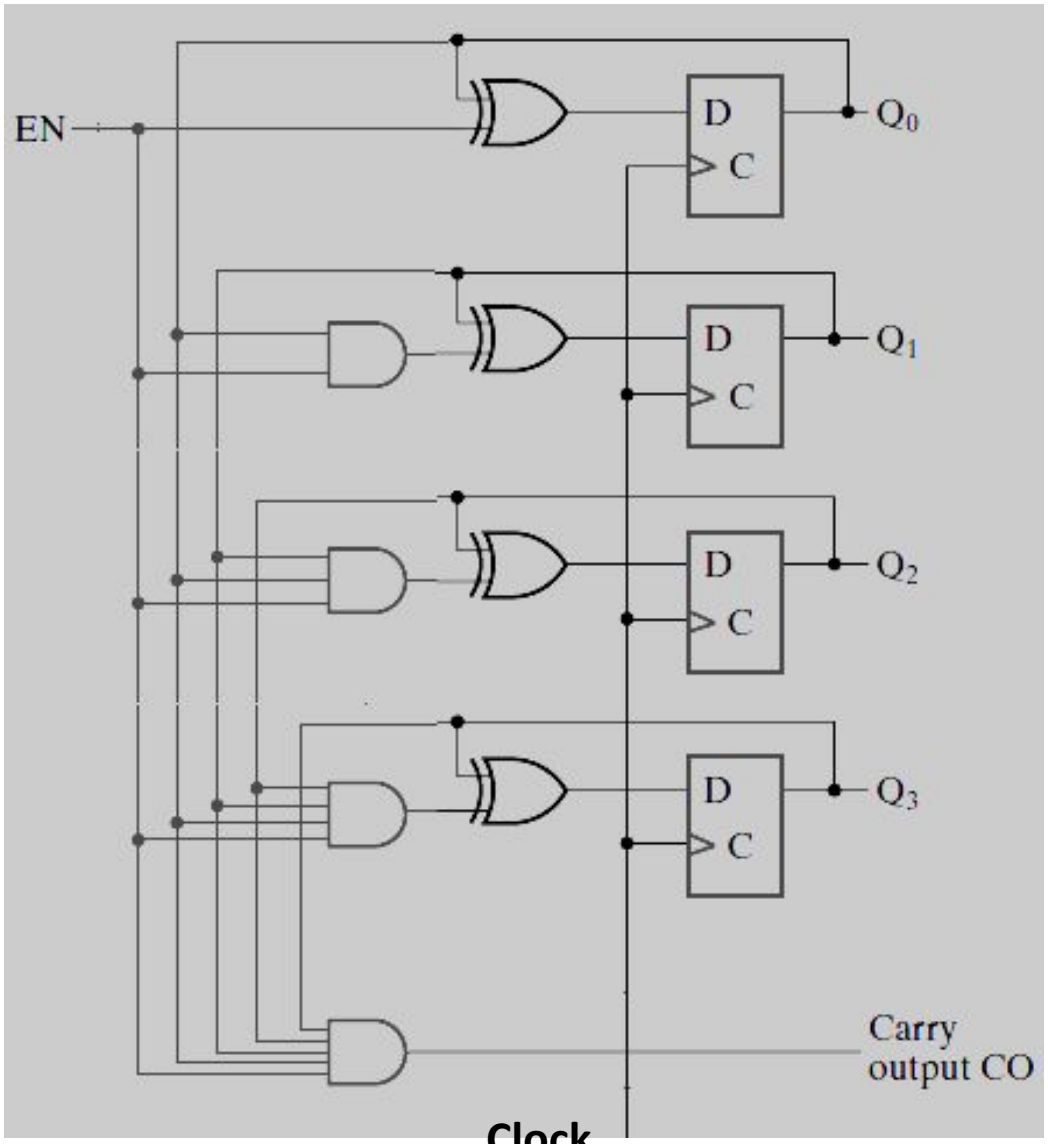


This data will be available at next tick

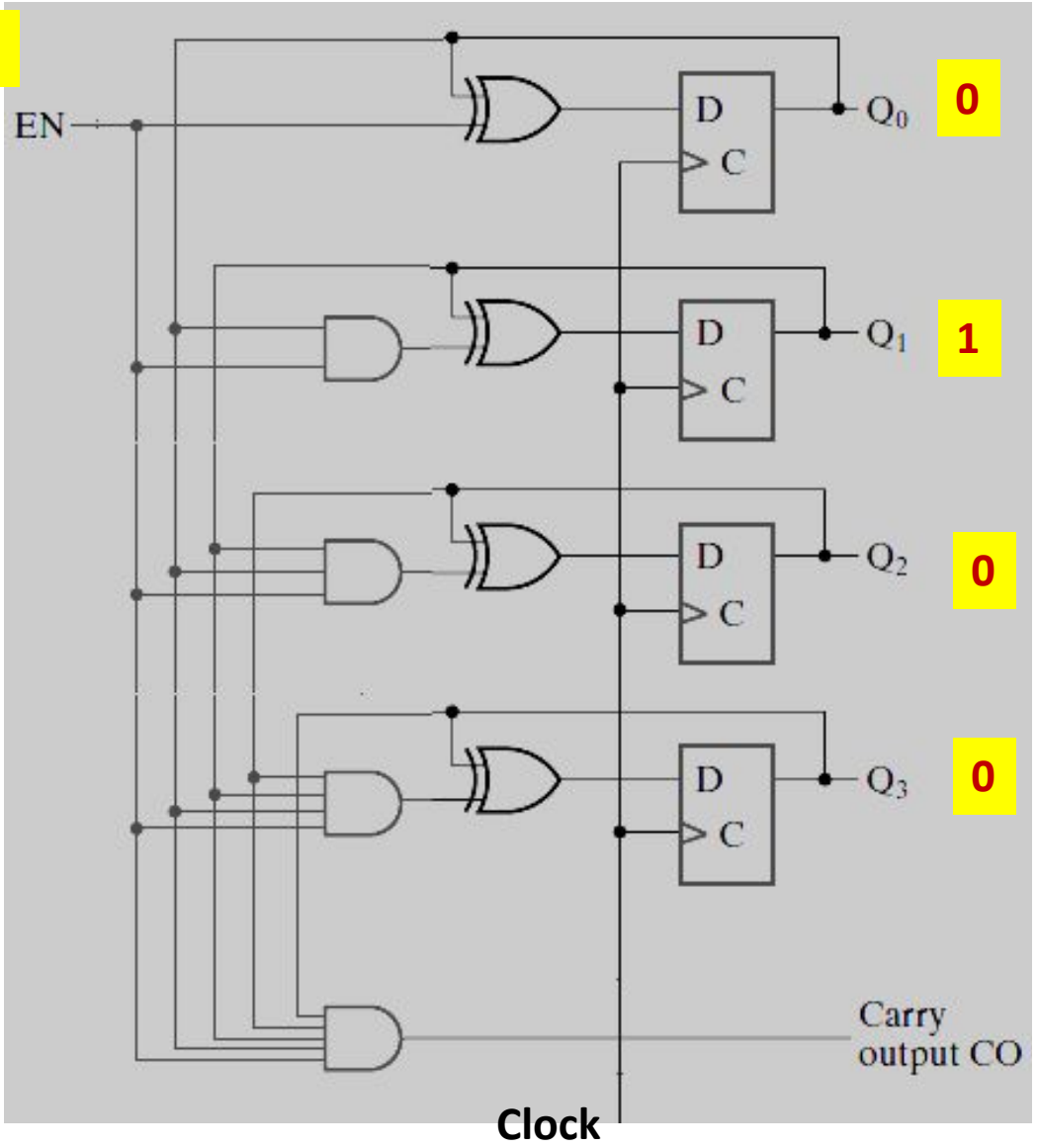
How Serial Counter Works?



Parallel Counter



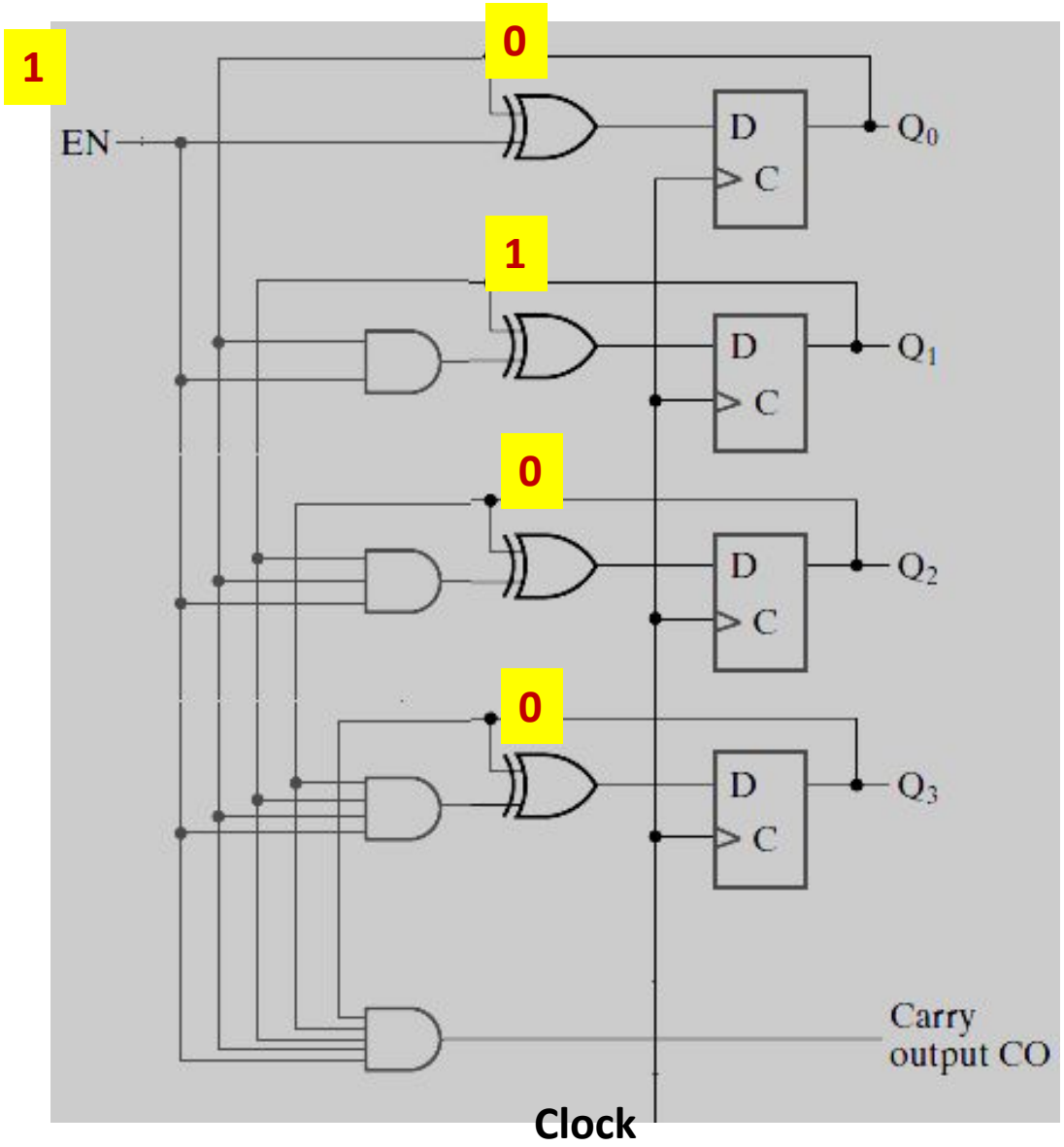
How Parallel Counter works?



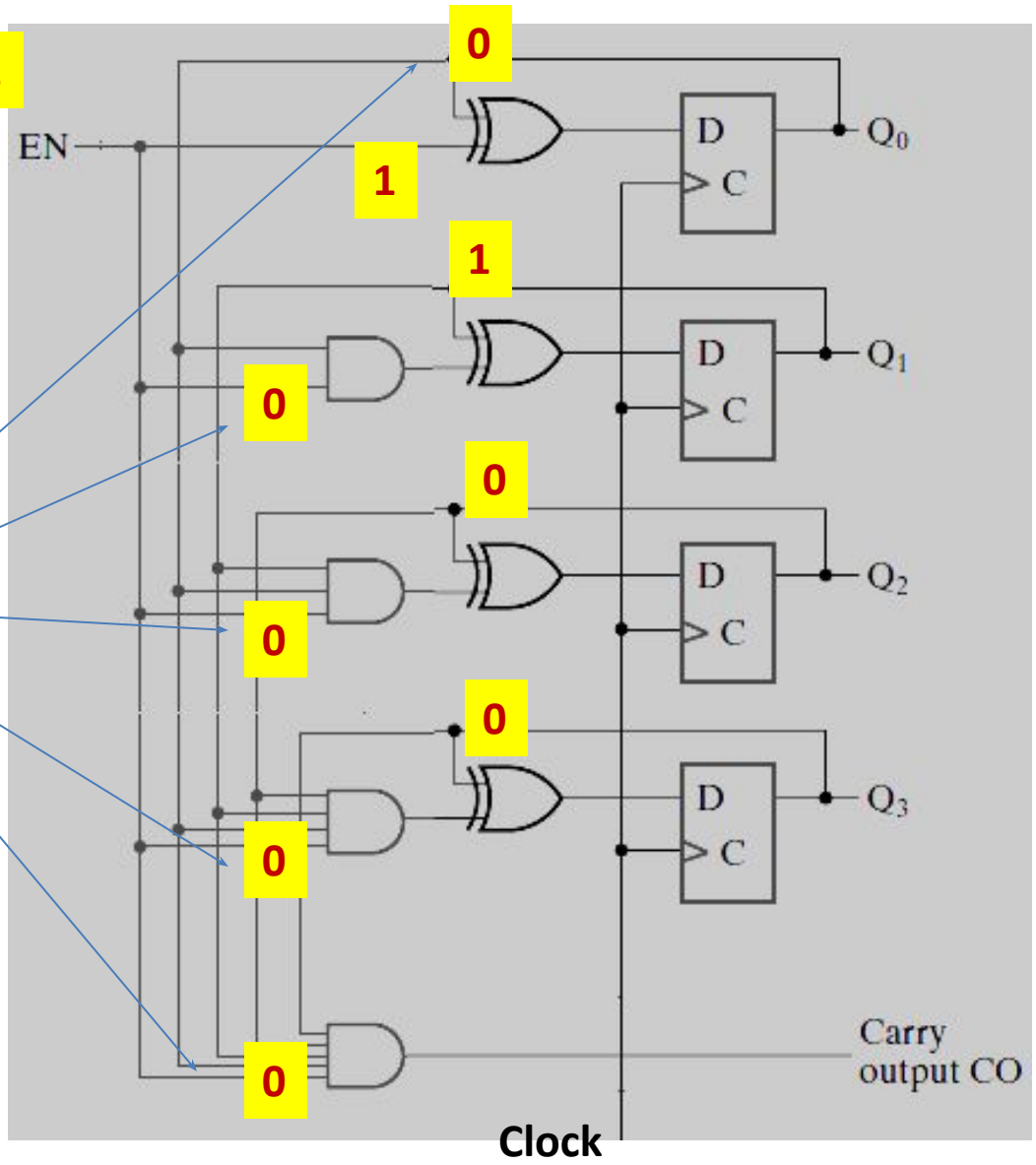
Value at time t = 0010

What will be the value at time t+1

How Parallel Counter works?



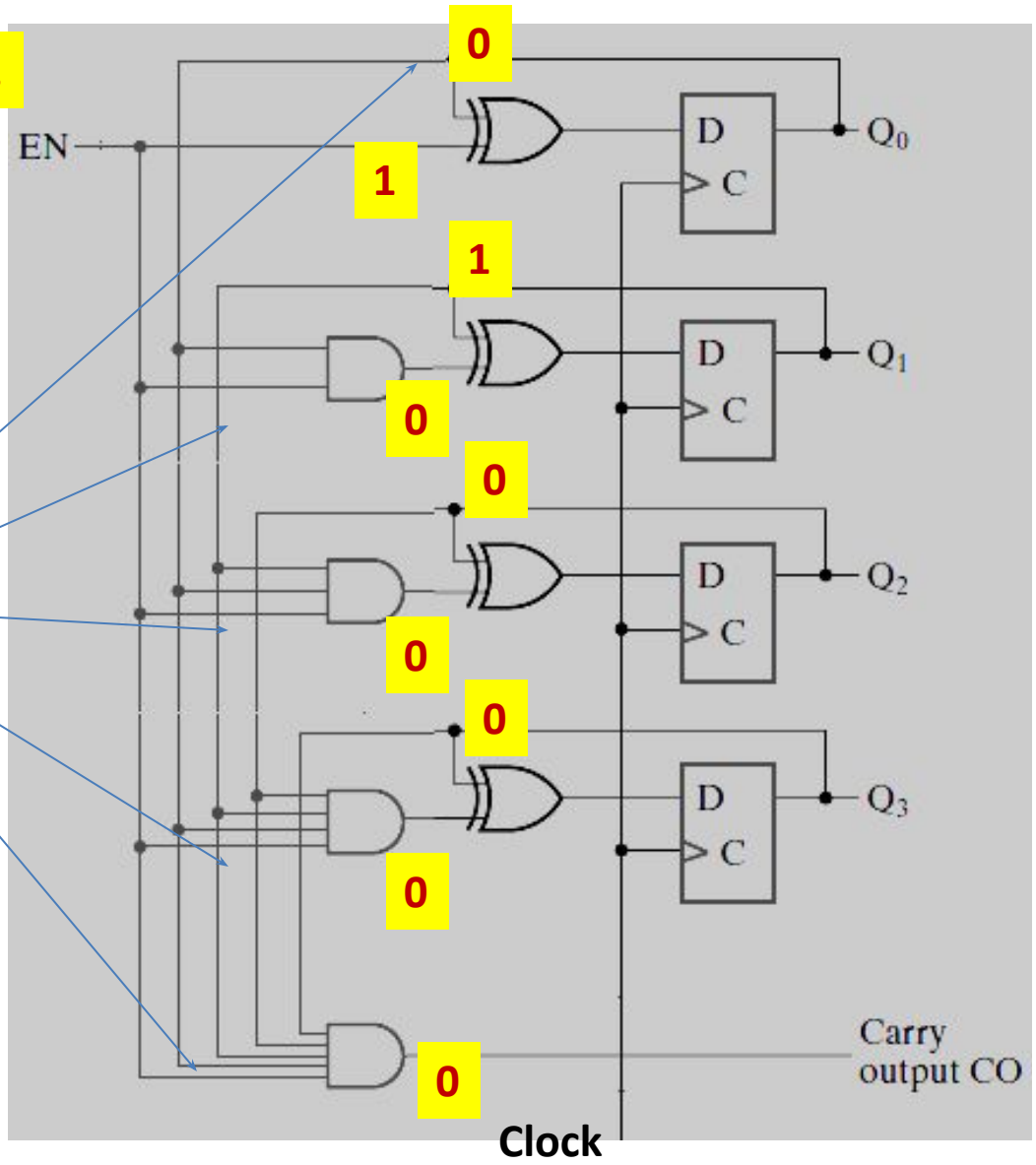
How Parallel Counter works?



This signal 0 is coming from Q_0

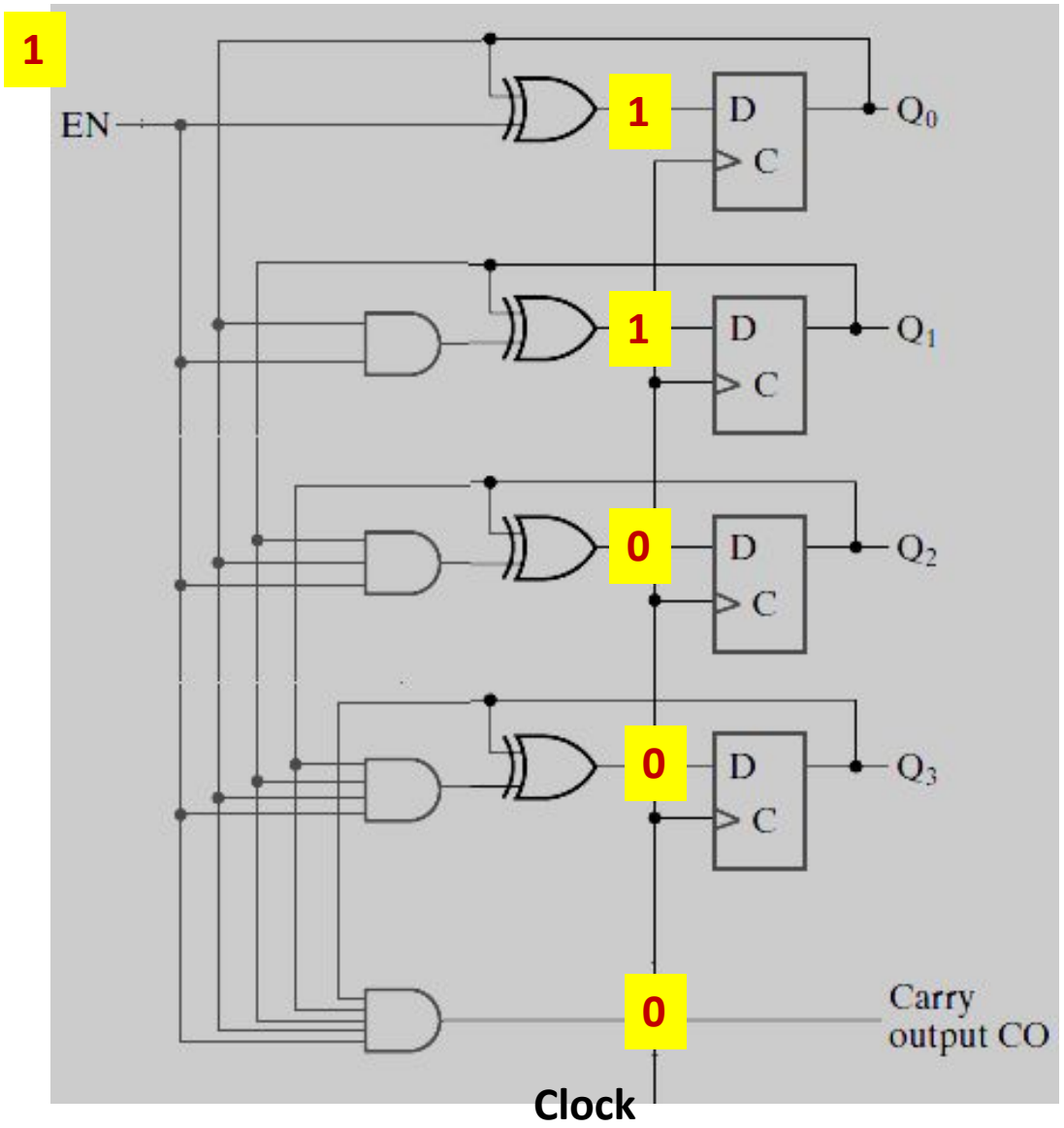
How Parallel Counter works?

All the ANDs which got 0
Gave output 0



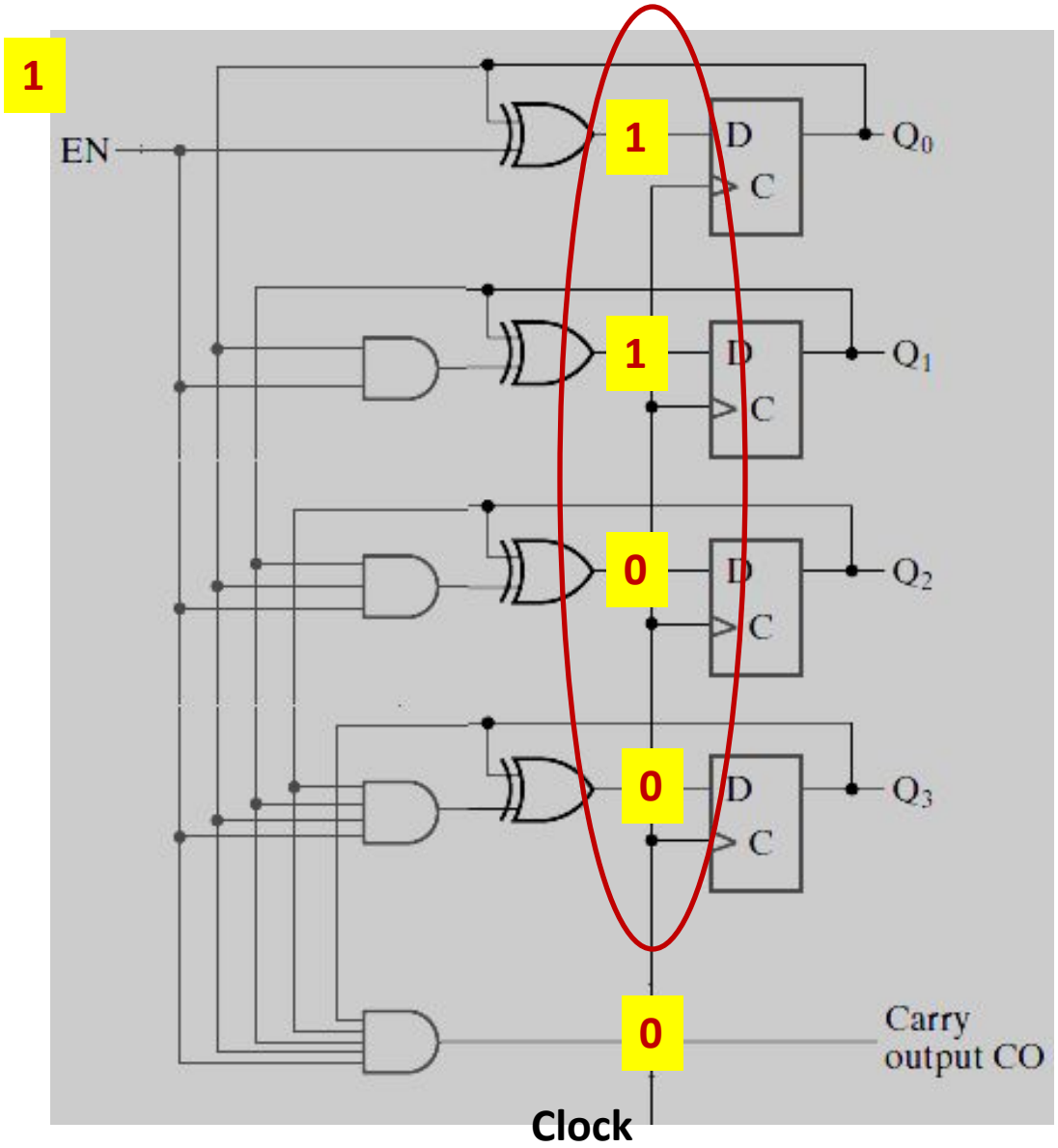
How Parallel Counter works?

X XOR 1 = X'
X XOR 0 = X



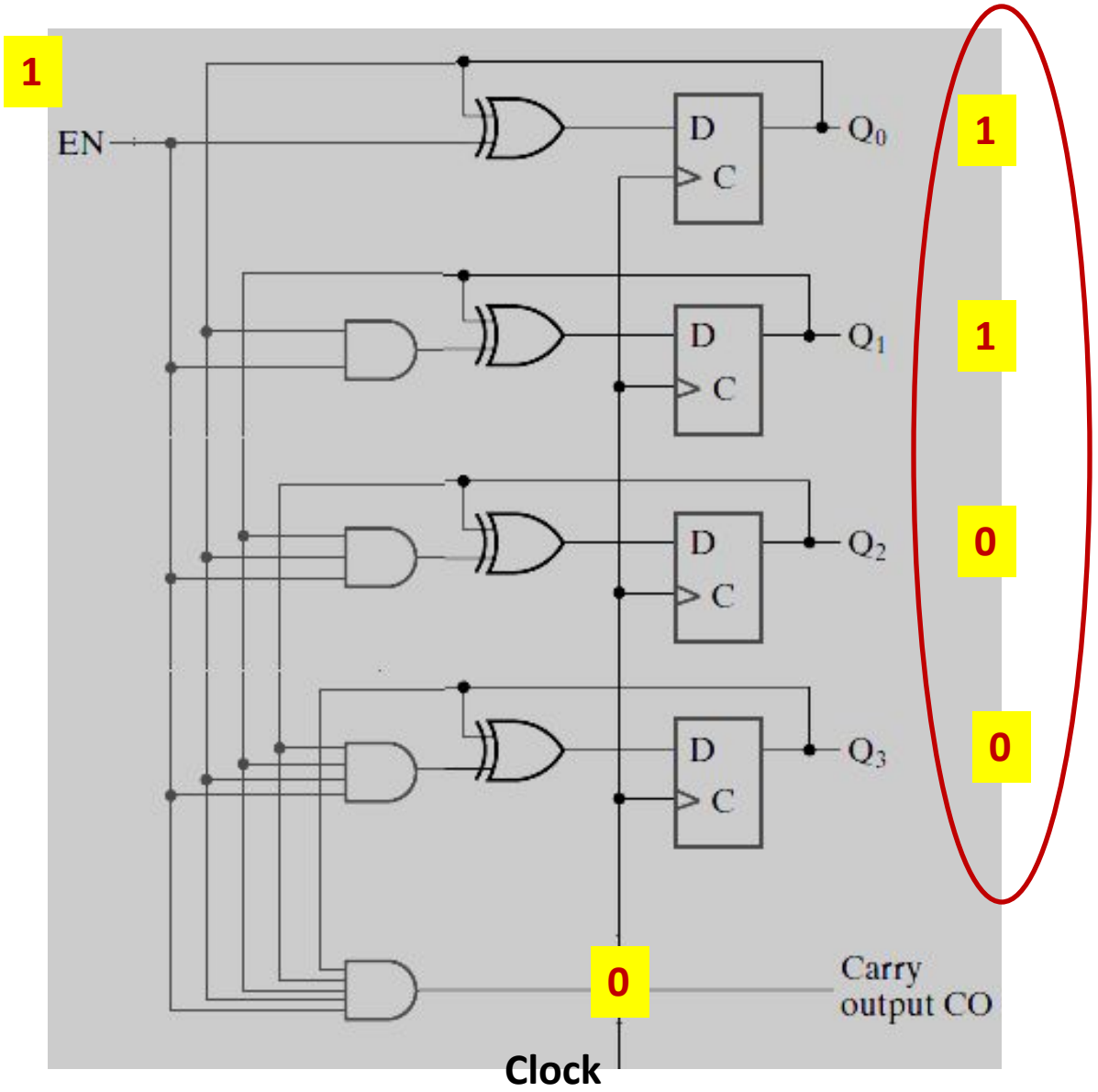
How Parallel Counter works?

This data will be available
On counter output at time t+1

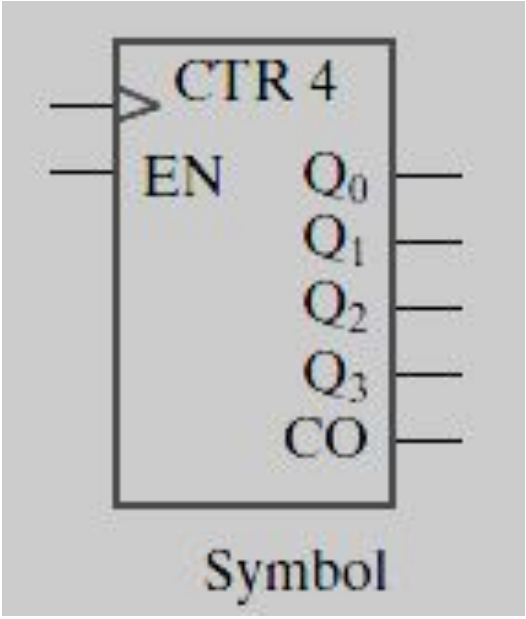


How Parallel Counter works?

Counter at time t+1

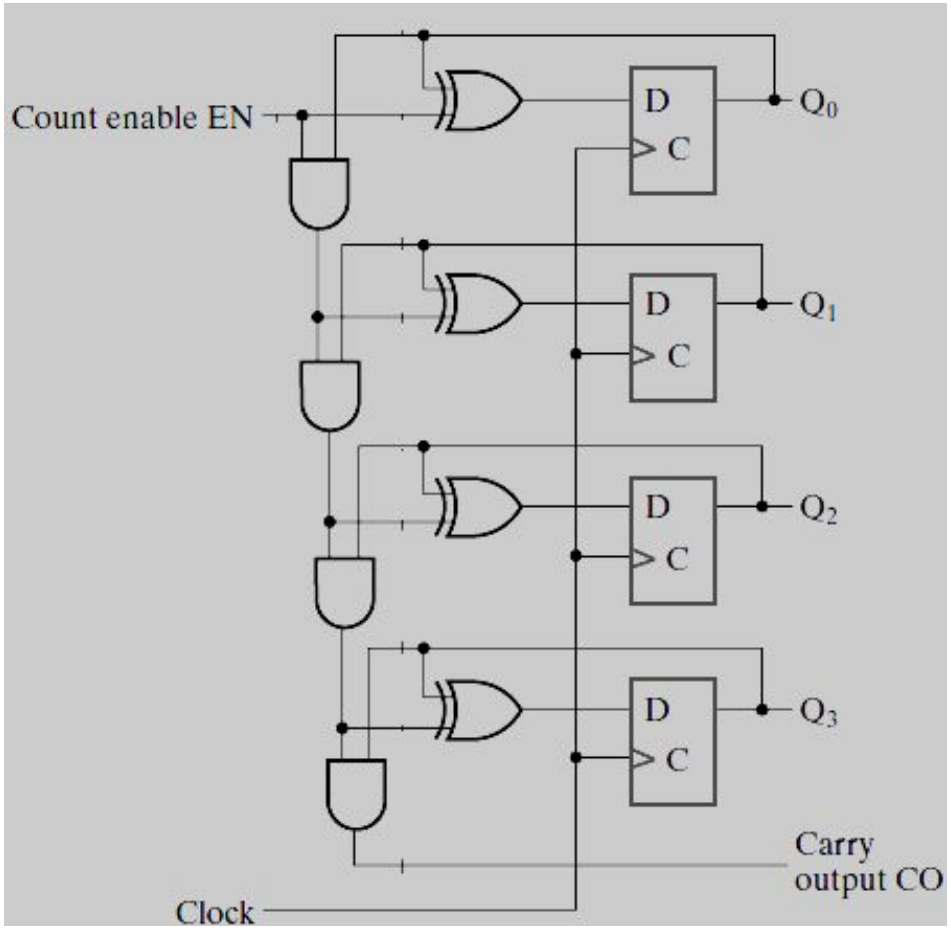


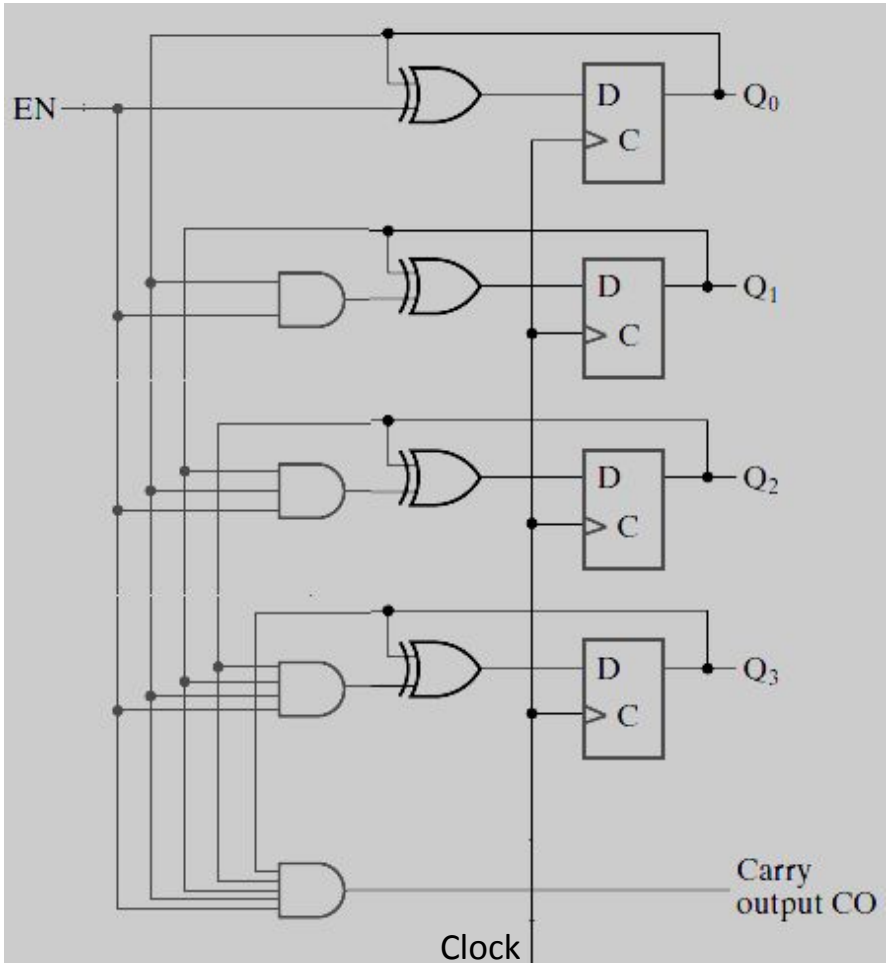
4-Bit Synchronous Binary Counter



Symbol

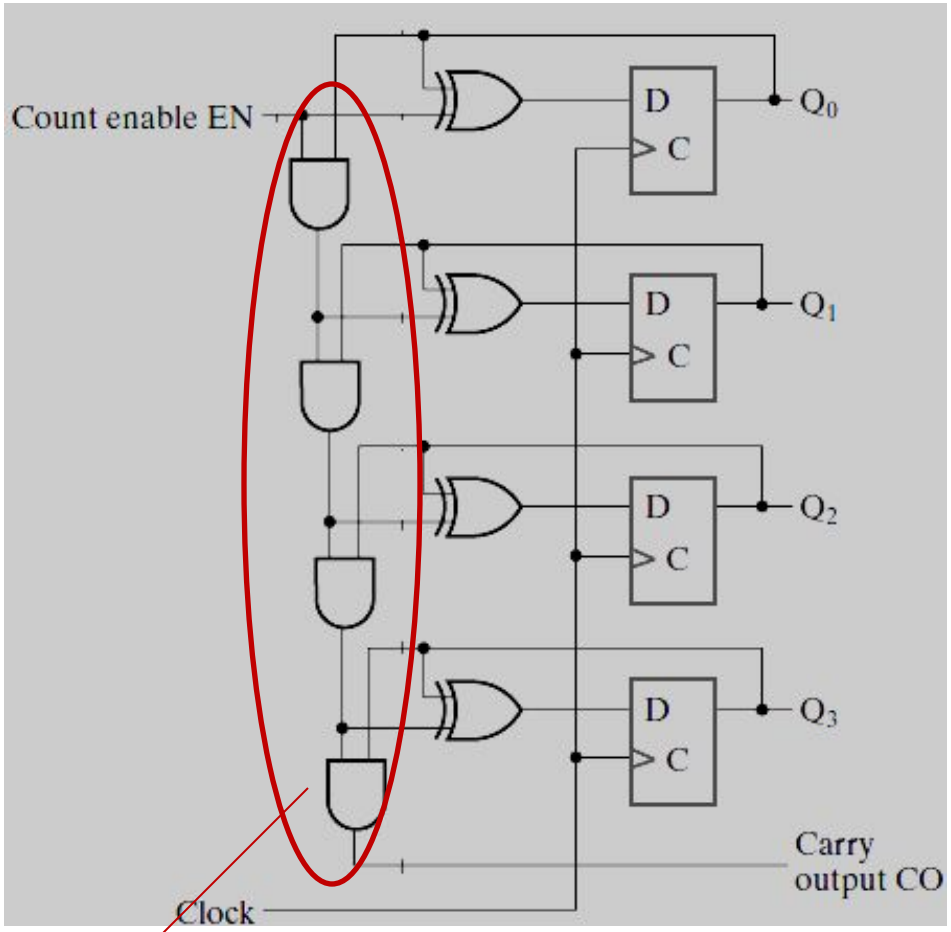
Serial VS Parallel Counter

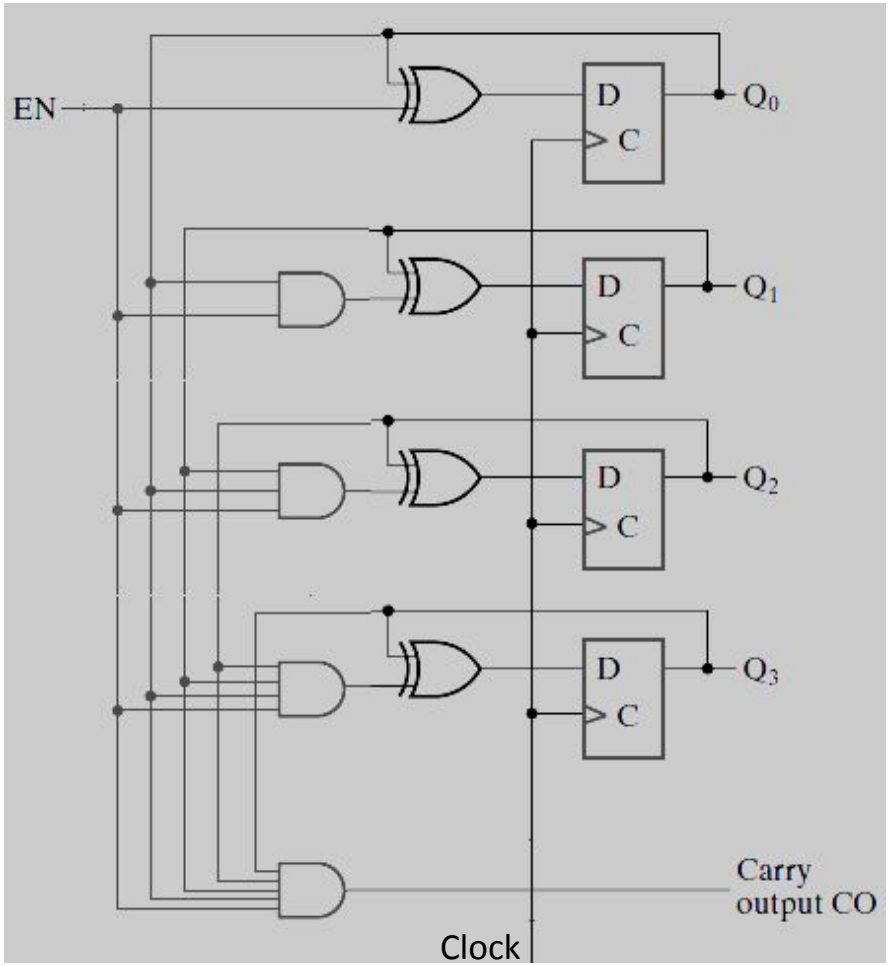




Gate delay being accumulated in Serial Counter as last AND is at level 4 of gating.
For example, going from state 1111 to state 0000.

Serial VS Parallel Counter





Output of 4th AND gate depends on the outputs of all previous AND gates.
i.e. Delay of four AND Gates being accumulated.

Practice Problems

1. **Arbitrary Count Sequence:** Design a synchronous counter which follows sequence given below:

   0, 2, 4, 6, 8, 0, 2,…

2. **BCD Counter:** Design a BCD synchronous counter which follows the sequence given below:

   0,1,2,3,4,5,6,7,8,9,0,1,2,…

Practice Problems

3. **<u>Modulo-7 Counter:</u>** Which follows the sequence 0,1,2,3,4,5,6,0,1,2,…

4. **Digital Watch**

   For your convenience consider we have 64 seconds in one minute, 64 minutes in one hour and total 32 hours in a day.

Practice Problems

5. Automatic Parking Control

Take CarIn and CarOut signals from sensors at Entry and Exit Gates respectively. Parking area has total capacity of 32 cars, when total count of cars in the plaza reaches 32 lock the Entry Door otherwise the door will remain unlocked.

6. Counter with Parallel Load

Register composed of **D Flip-Flops** which loads the data if Load = 1 otherwise behaves like a binary counter.

Practice Problems

7. Counter composed of **D Flip-Flops** which takes X and Y selection inputs and performs following operations:

X	Y	Operation
0	0	Count
0	1	Shift Right
1	0	Shift Left
1	1	Parallel Load