

CS221: Digital Design

Digital Counter

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Outline

- Counter
- Asynchronous or Ripple Counter
 - Binary
 - Modulo Counter : Count decimal 000 to 999
- Synchronous counter
 - Binary , Modulo, Up-Down
- Ring Counter, Register based counter
- Case Study: Design of Digital Clock

Counter

- It simply count: 4 bit counter : count 0000 to 1111 & repeat
- Other optional functions and variations
 - Start count at Specific point (say from 5 : 0101)
 - Stop count at Specific point (Say at 9: 1001)
 - Count only even numbers: 0, 2, 4, ..14, 0, 2
 - Count only odd numbers: 1, 3, 5,..15, 1
 - Count specific num in specific order & repeat:
1, 9, 4, 6, 7, 8. 3, 1, 9 ,4,...

Mostly used 4 bit counter

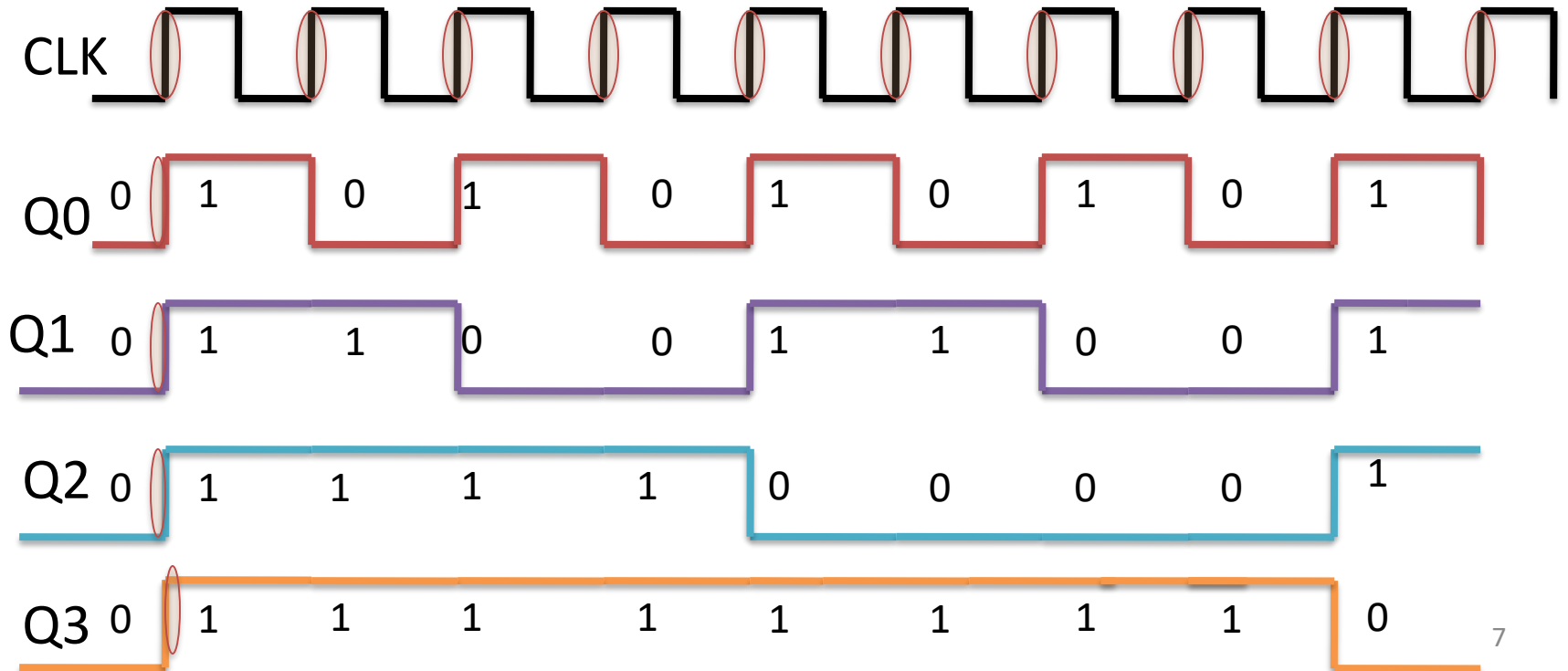
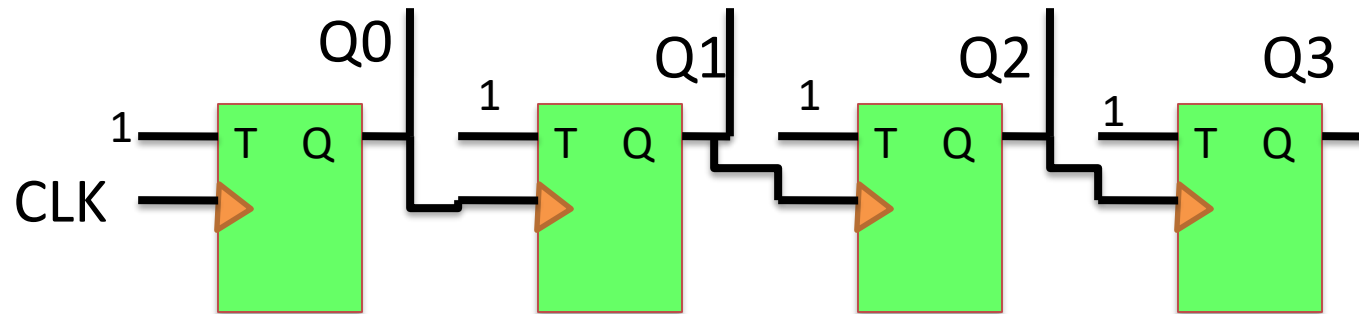
- Example of 4 bit counter
- Count from 0000 to 1111 and repeat
- Up counter : 0000 to 1111
- Down counter : 1111 to 0000
- Mod N counter:
 - Mod 10 counter : 0000 to 1001 (0 to 9) and repeat (Decimal Number)
 - Mod 6 counter : 000 to 101 (0 to 5) and repeat (Digital Clock 60 second, 60 minutes, 12)

How to design a simple counter

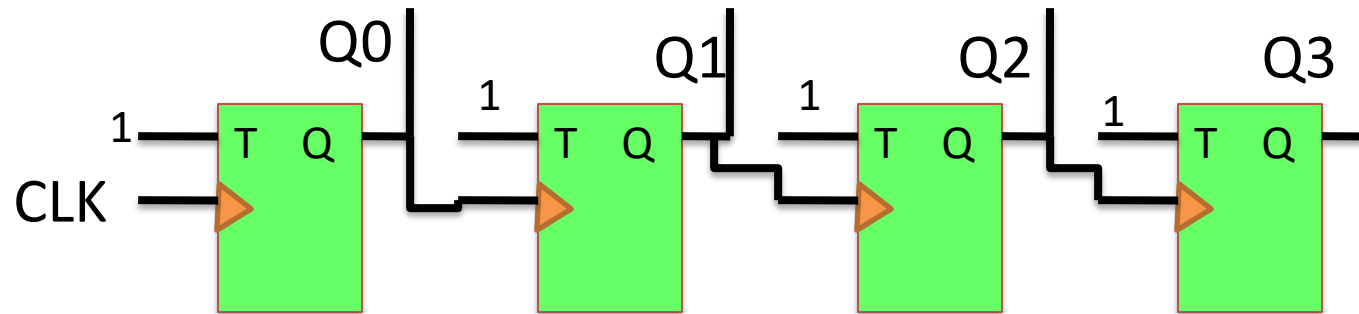
- Q0 change every time
- Q1 change in two time
- Q2 change in every four time
- Q3 changes in every eight time
- Q0, Q1, Q2 and Q3 changes can be modeled
 - Q0 can be modeled using T FF
 - Q1 : in term of Q0 and T FF
 - Q2 : in term of Q1 and T FF...
 - Q3 : in term of Q2 and T FF...

Q3	Q2	Q1	Q0
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

Binary Counter: using T FF

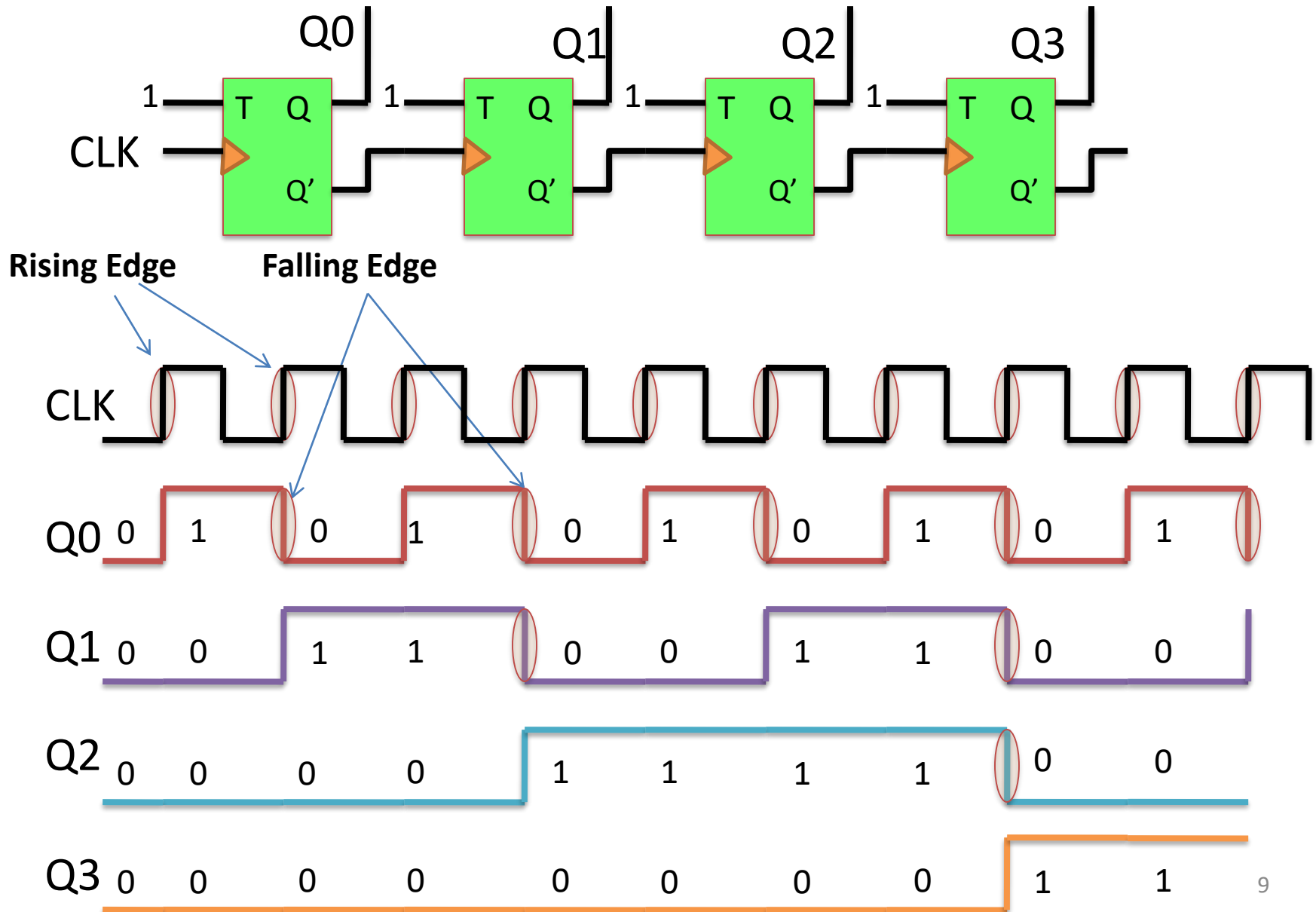


Binary Counter: using T FF



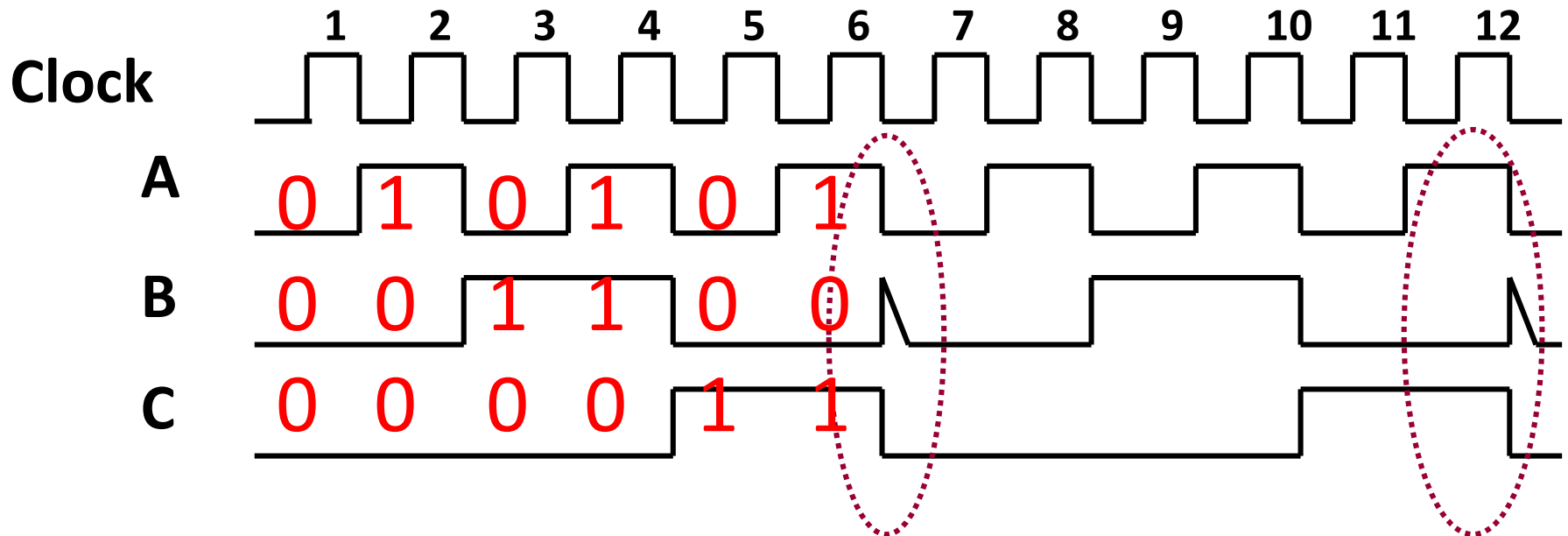
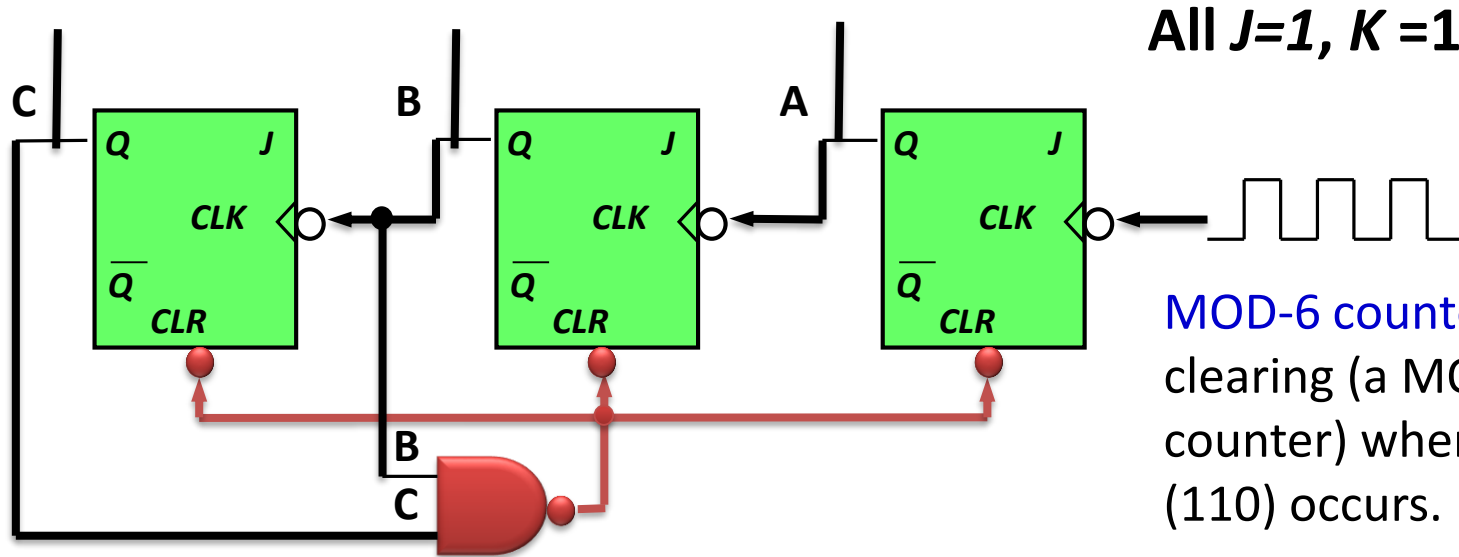
What is the problem
with this?

Binary Counter: using T FF

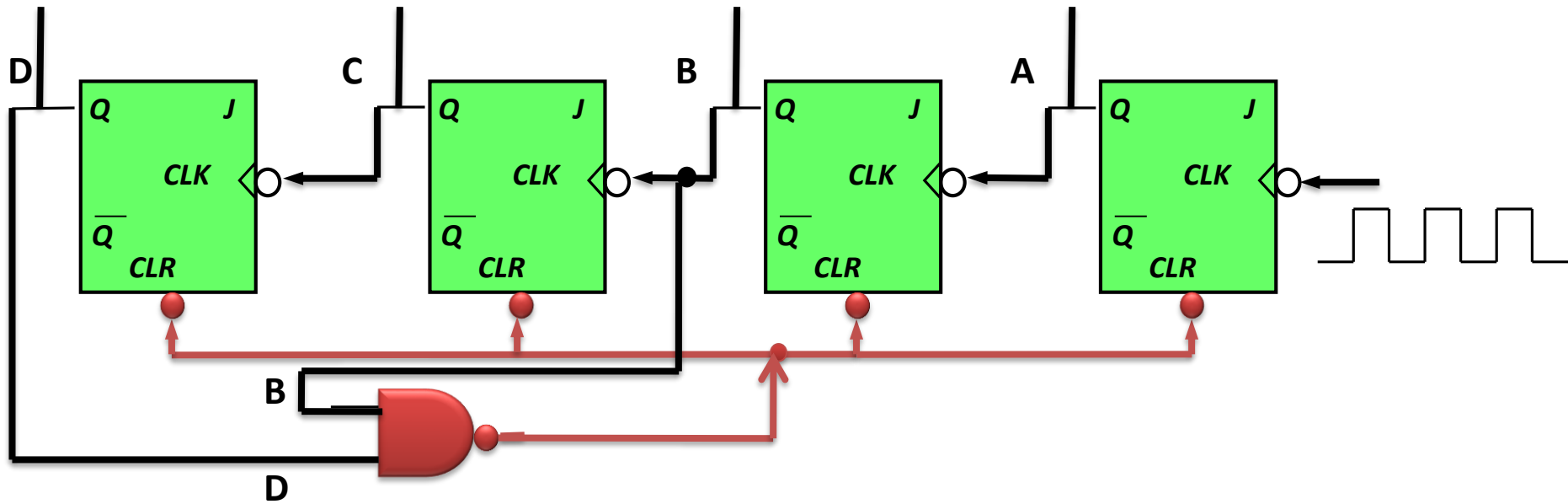


Asyn. Counters with MOD no. $< 2^n$

Asyn. Counters with MOD 6



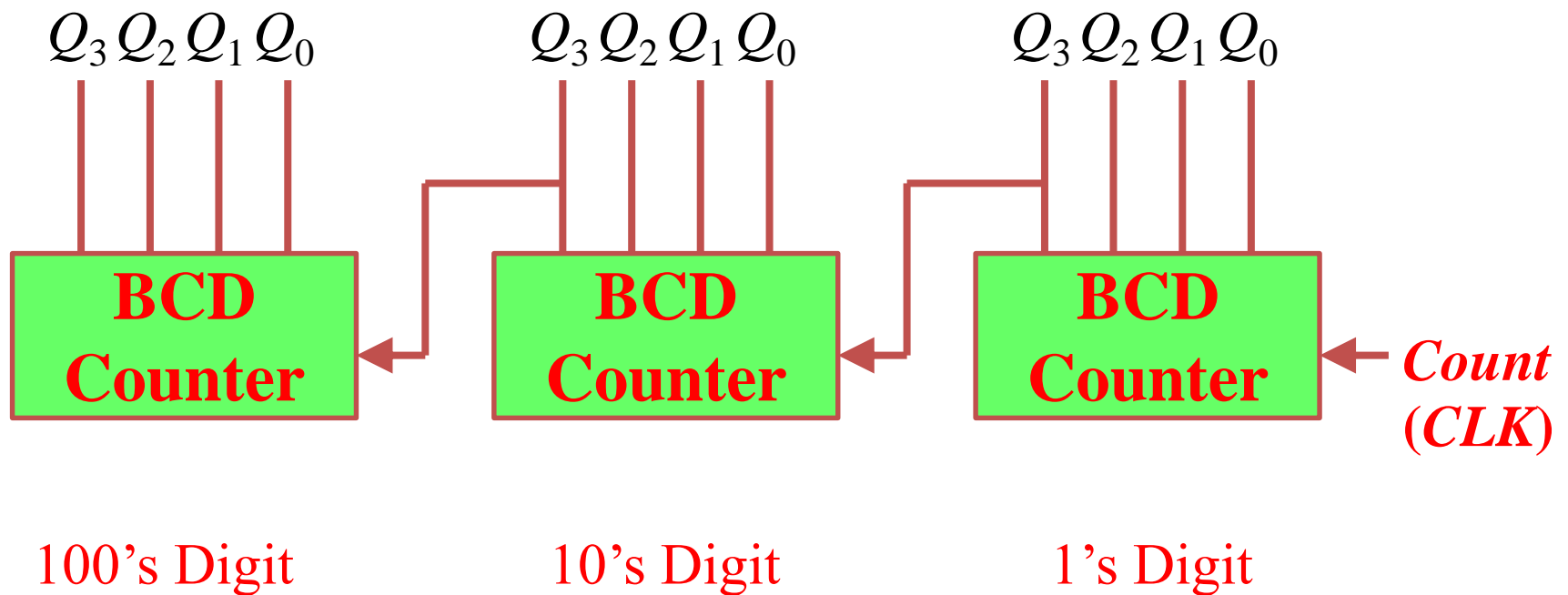
Asyn. Counters with MOD 10: BCD Ctr



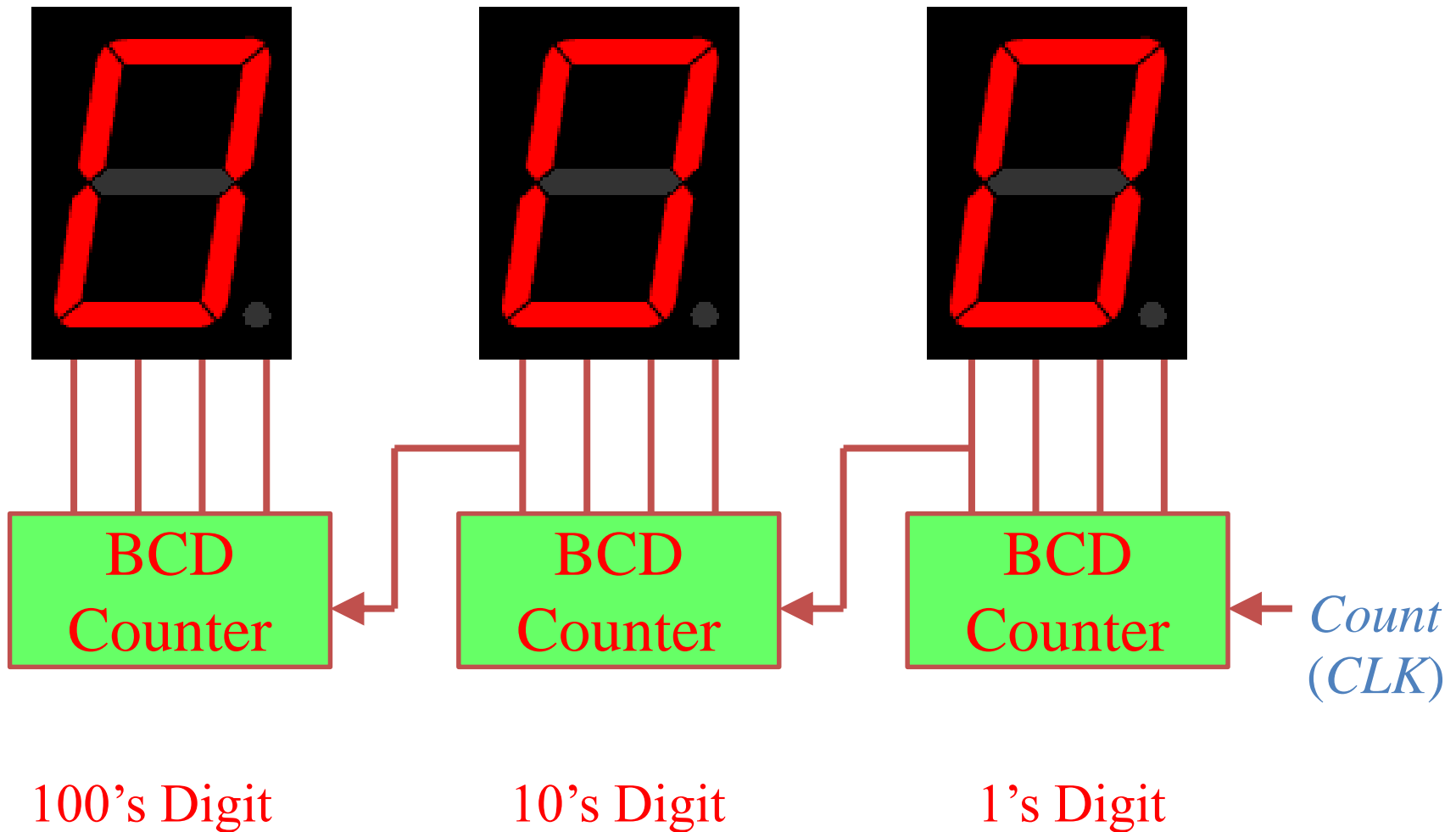
All $J=1$, $K=1$

MOD-10 counter produced by clearing (a MOD-16 binary counter) when count of six (1010) occurs.

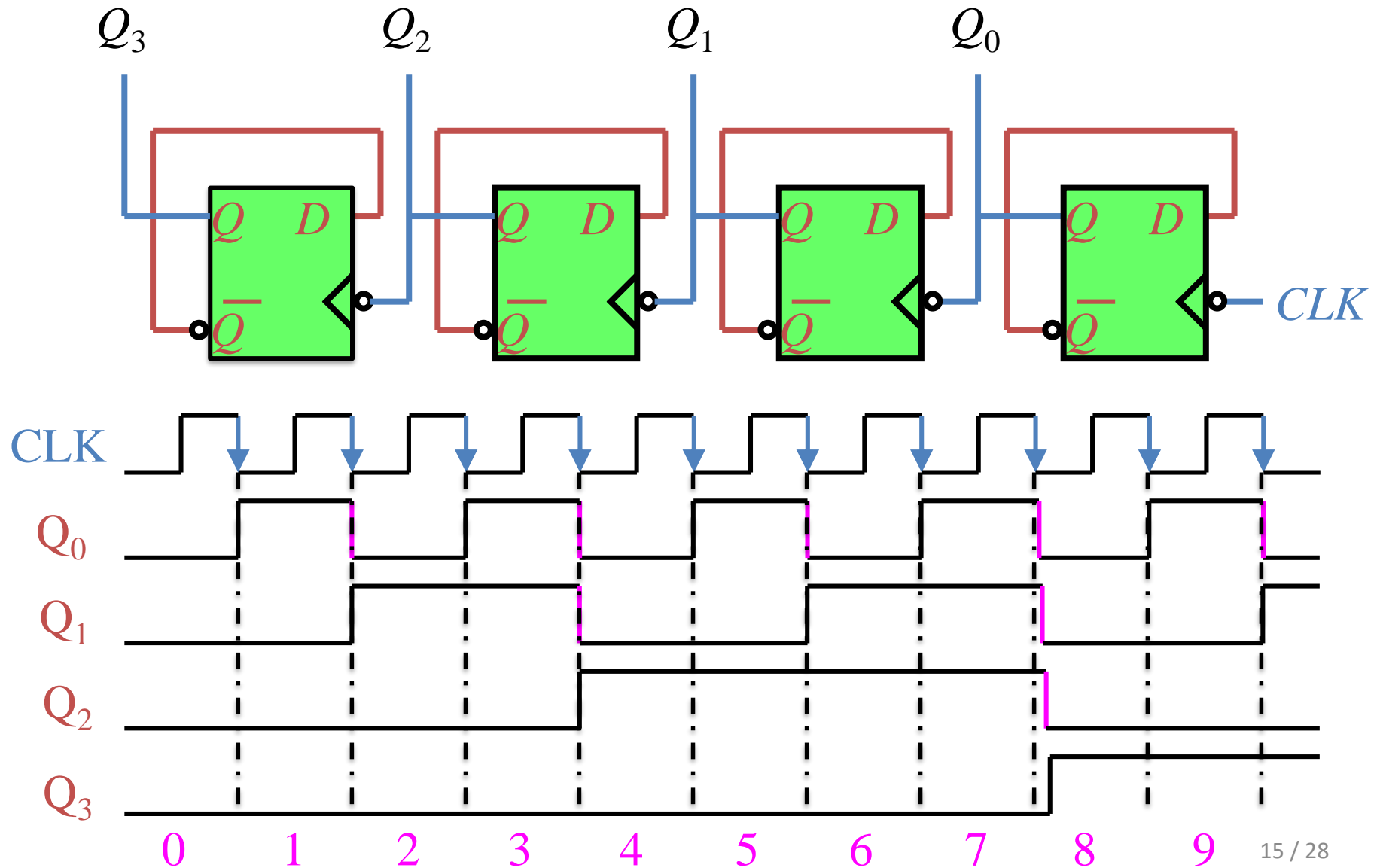
Decade Counter



Decade Counter: Interfaced BCDto7Seg Decoder +7Seg



Ripple Counters using D-FFs



Binary Counter: using T FF

- It is very easy to design Ripple counter

Is there any Issue
with this ?
If yes, what?

Binary Counter: using T FF

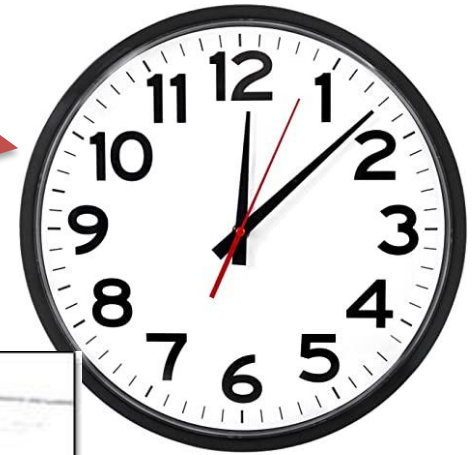
- It is very easy to design Ripple counter

First thing: we should not play with clock but make change to the Circuit..

Synchronized and Unsynchronized Classic

Example: Clock at Railway Station

- Unsynchronized Analog
- Synchronized Digital Clock



Problem with Ripple Counter

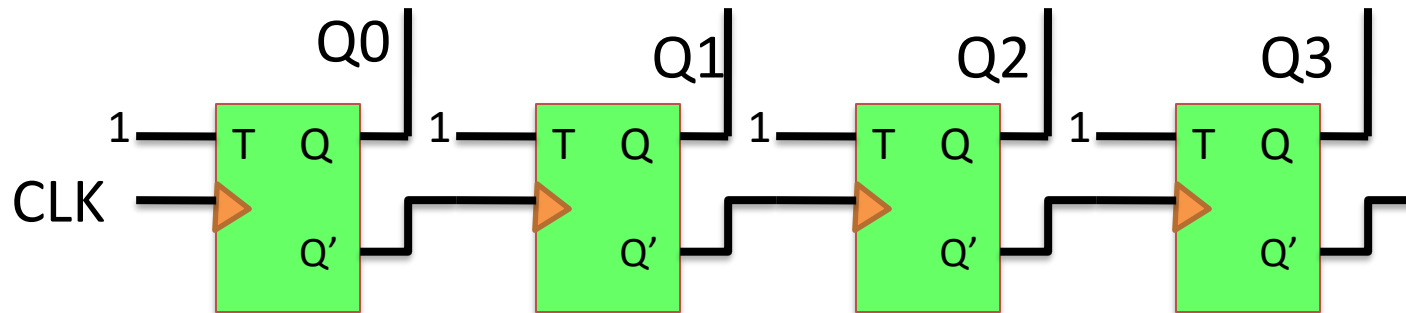
- FFs are not synchronized 😊 😞
- Even “Wall Clocks” of our examination halls are synchronized now a days.
 - Railway clocks : Synched Clock with Network time
 - NTP : network time protocol
- You can Sync clock of “Smart Mobile” with Network Clock which is in Sync with India Clock and World Clock



Problem with Ripple Counter

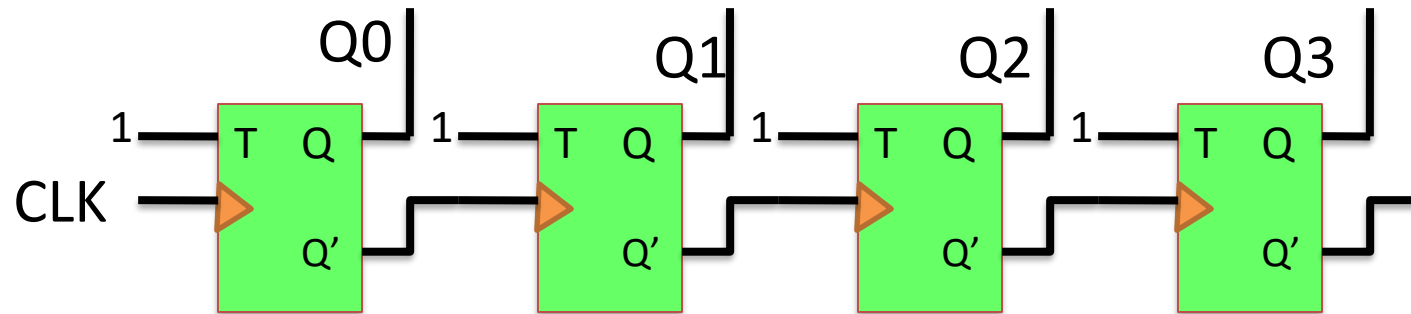
- Student A copies Solution from B with some error, C copies from B with some error and continues..
 - What will be the solution of Z. ($=\text{Sol} + 26 * \text{error}$)
 - Communication Gap
- So, all the FFs should take same clock signal

Ripple Counter : Asynchronous



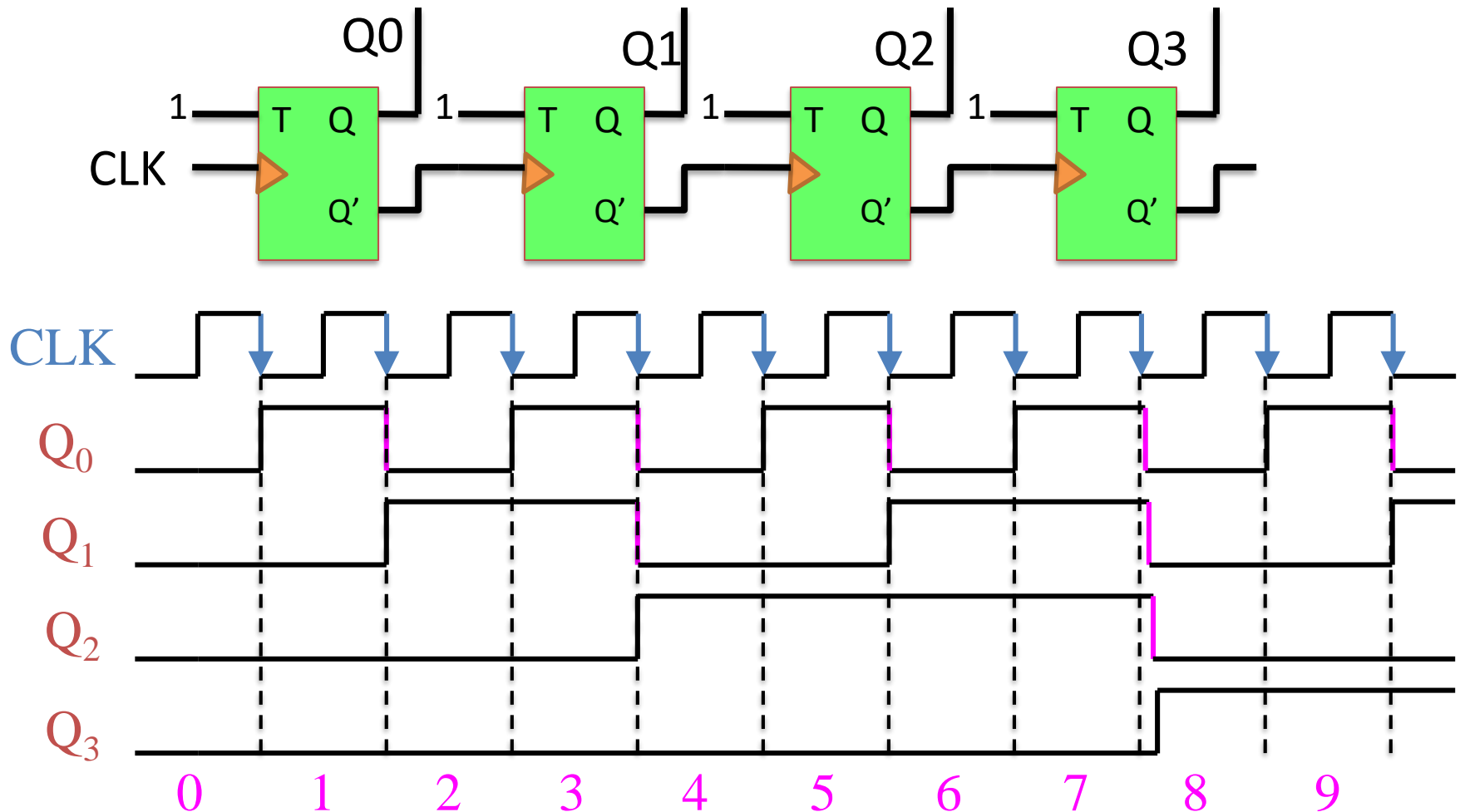
- Clock is applied at FF0, it propagate through to FF_n
- Change in State of Q_{i-1} is used to Toggle Q_i
- Input Clock to FF1= Skewed version of Clk of FF0
 - Clock + Propagation delay of FF

Ripple Counter : Asynchronous



- Rippling : Overall time delay of occurrence of count pulse and when stabilized count appear at O/P
- When counter : 1111..11 to 0000..00, toggle signal must propagate through all FFs
- **Worst case Settling time: $n \times t_{pd}$**
where t_{pd} = Propagation delay of a FF

Ripple Counter : Asynchronous



Synchronous Counter

- **Synchronous Counter:** One single clock to all the FFs of the Counter
- Need to design and add Extra Circuitry to make it synchronous

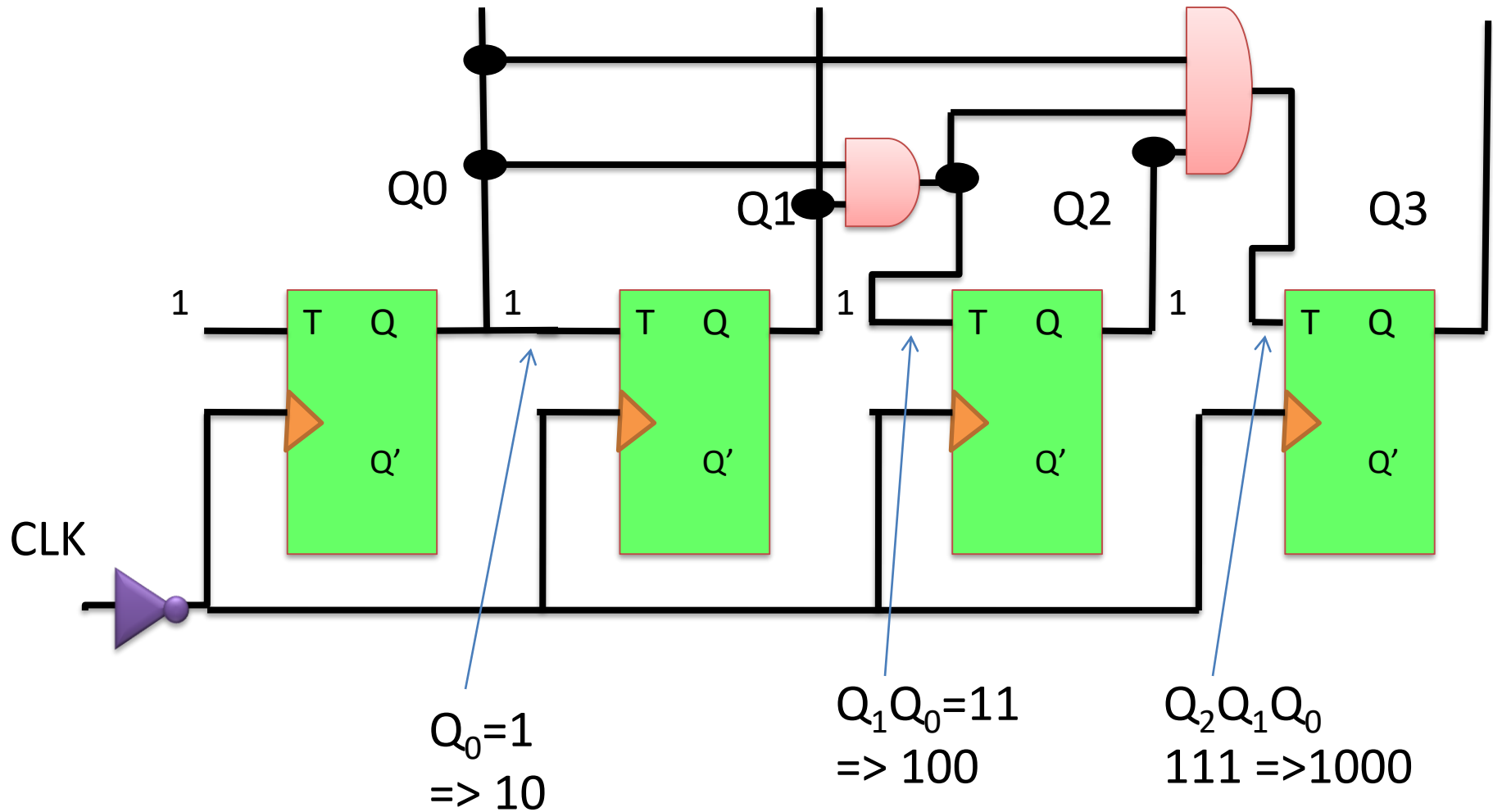
How to Design and put
extra circuitry?

How to design a simple counter

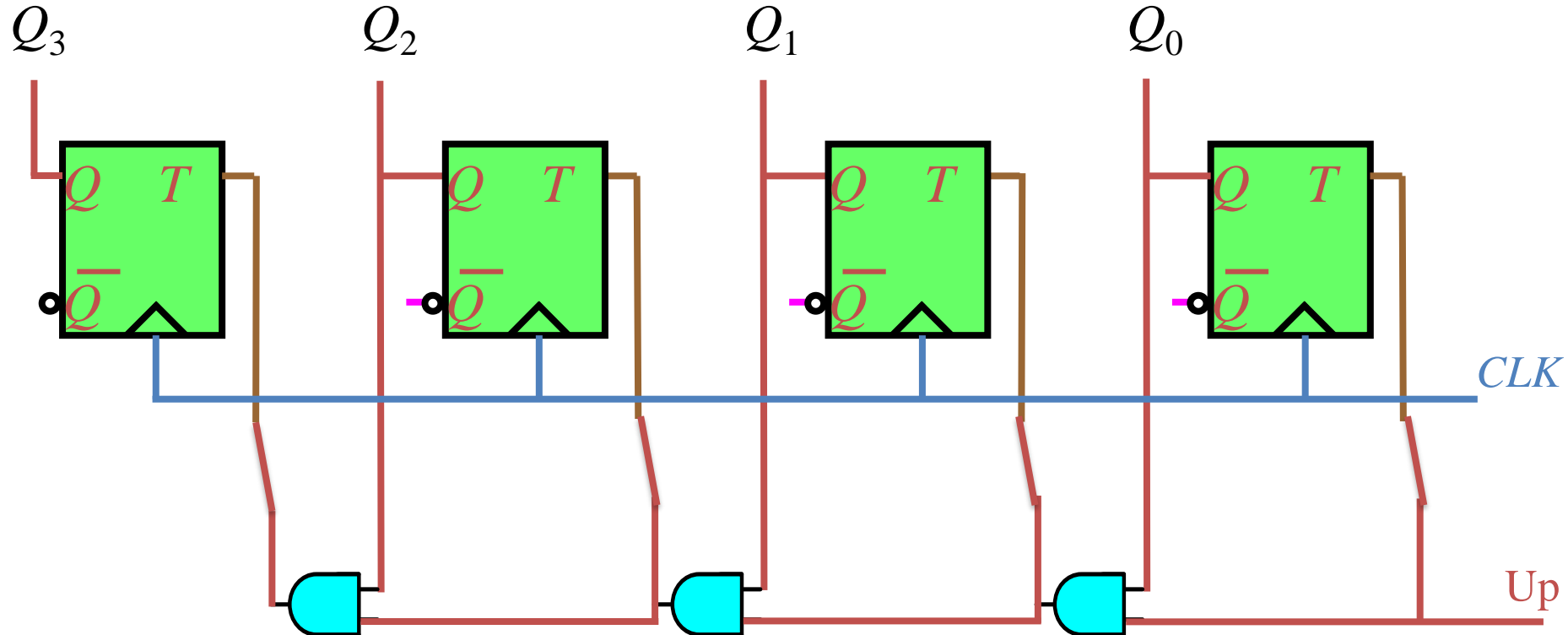
- Q0 change every time
- Q1 change when
 - Q0=1
- Q2 changes when
 - Q0=1 and Q1=1
- Q3 changes when
 - Q0=1 and Q1=1 and Q2=1

Q3	Q2	Q1	Q0
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

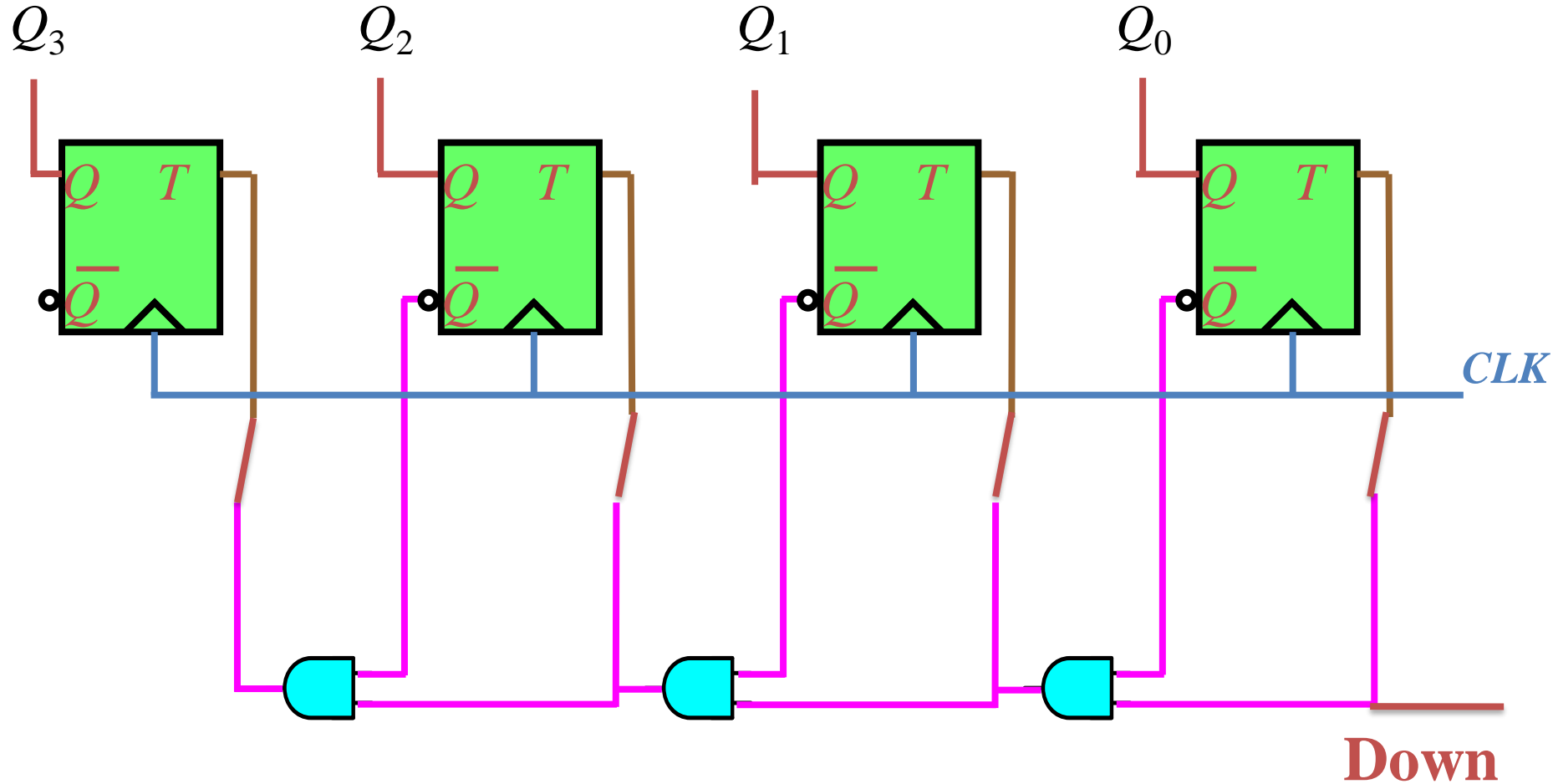
Binary Counter: Synchronous



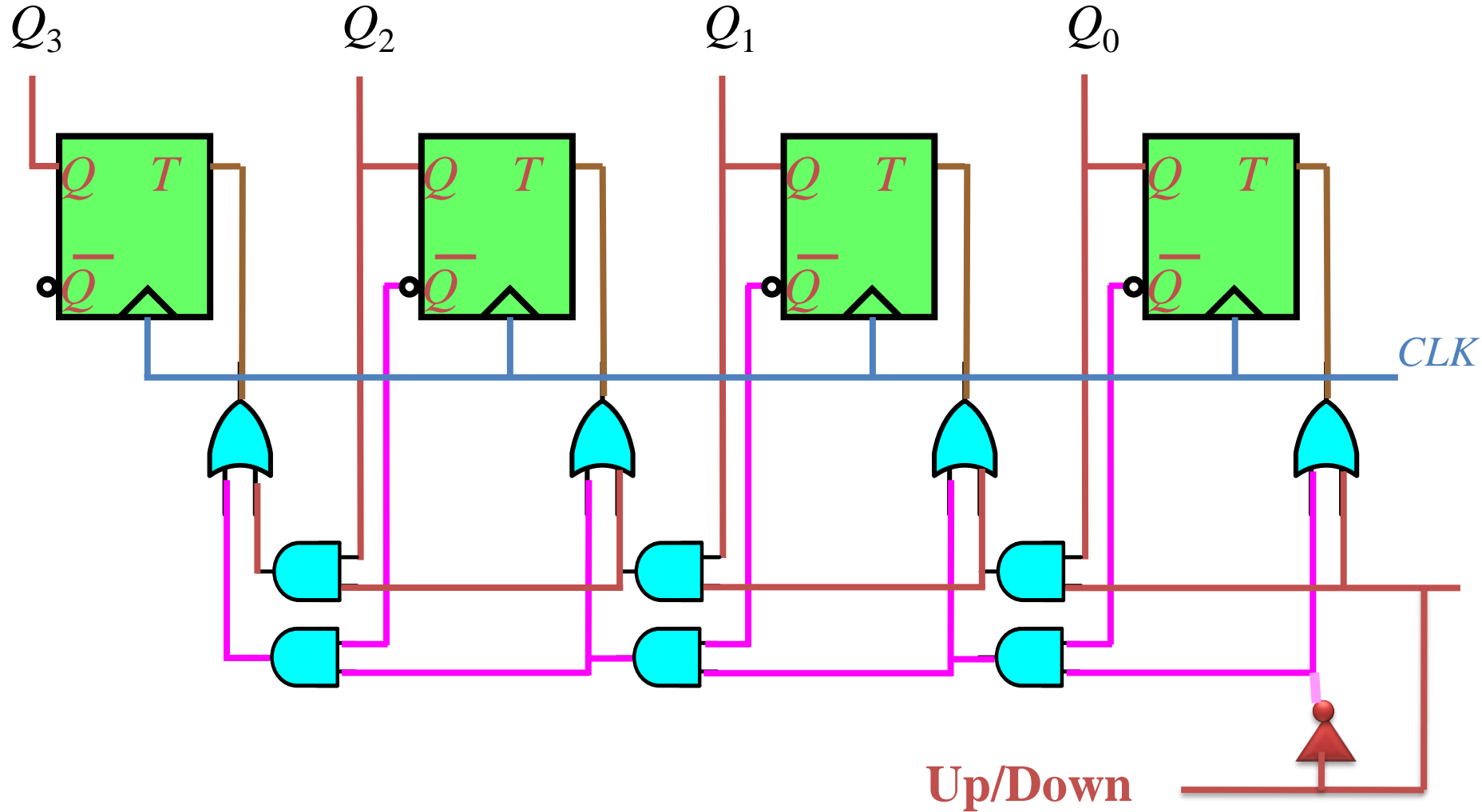
Sync: Binary UP Counter



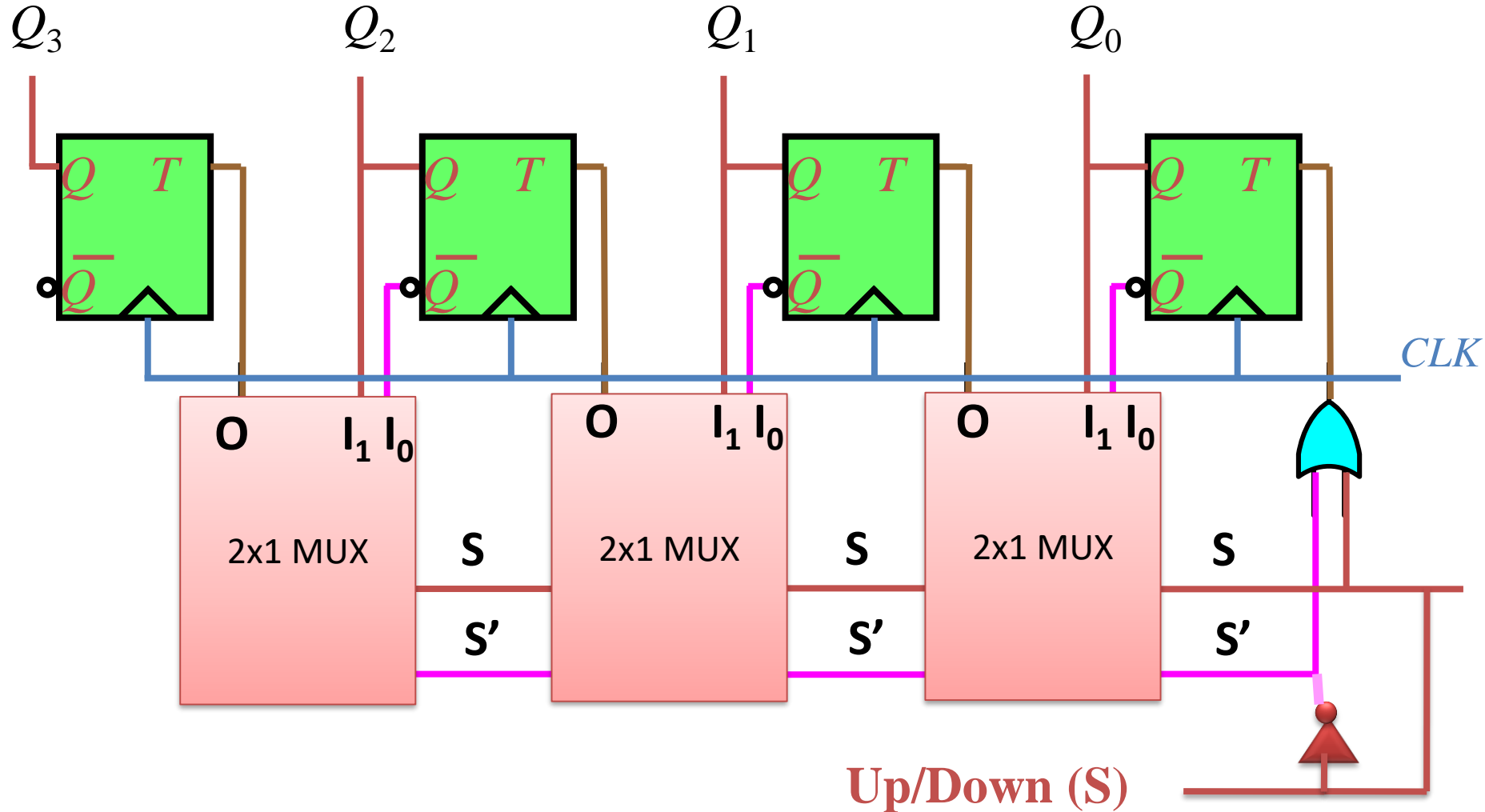
Sync: Binary Down Counter



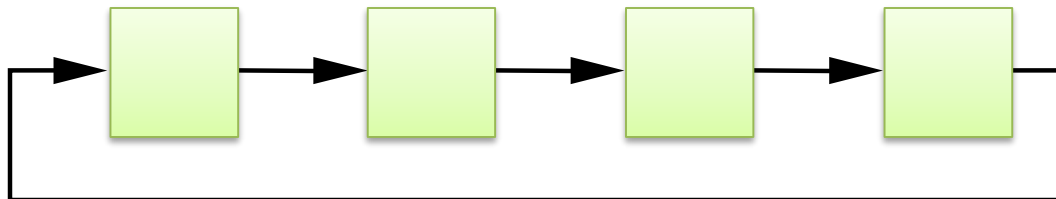
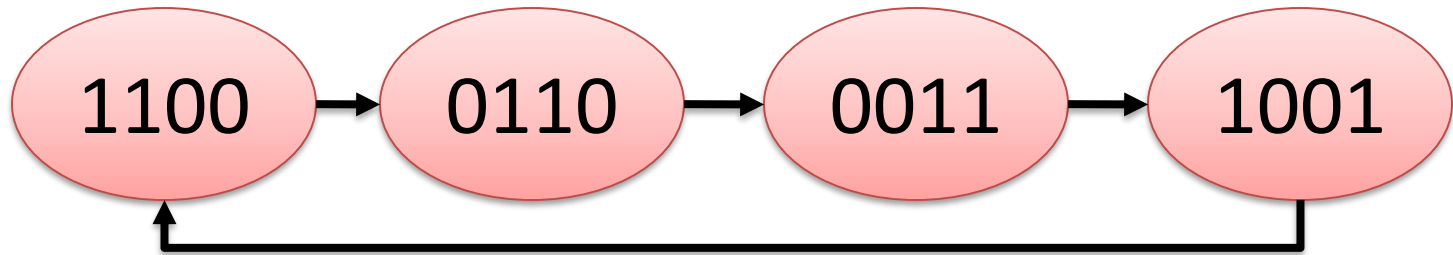
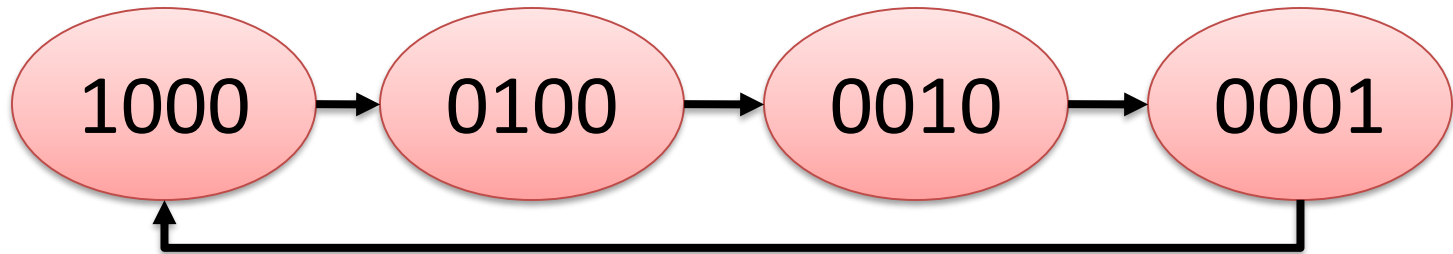
Sync: Up/Down Binary Counter



Sync: Up/Down Binary Counter



Counter Based on Shift Register



Design of Digital Wall Clock

- Given 256 Hz Clock Quartz and other Digital components
- Design a Wall Clock
 - To display time : HH : MM :SS format
 - Should support Reset/Adjust of time using selectable switch
 - Button 1: for select the Mod Ctr
 - 3 for SS, 2 for MM, 1 for HH, 0 for X
 - Button 2: increasing select mod Ct



