Lecture Outline

Reminders to self:

- ❑ Turn on lecture recording to Cloud
- ❑ Turn on Zoom microphone

- Last Lecture
  - Finished Shift Registers
  - Started Counters
    - Three-bit synchronous binary counter
    - Brief look at binary ripple counter (not synchronous)
    - Formal design procedures
- Today's Lecture
  - Review HW 11-1
  - Continue Counters
    - Other count sequences
    - Counter design with other types of flip-flops (D first)
    - Up and Down counter

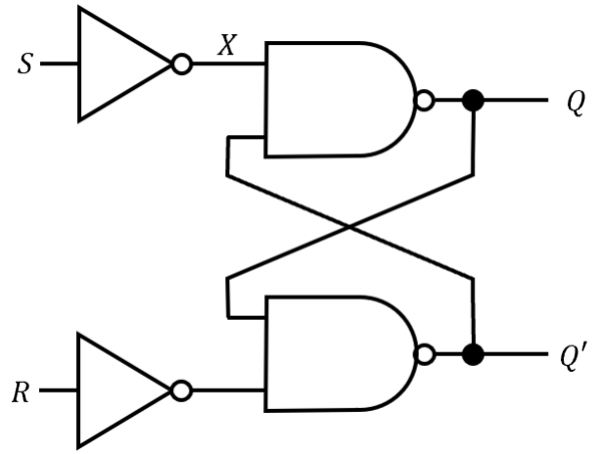
Handouts and Announcements

- Announcements
  - Homework Problems 12-2 and 12-3
    - Posted on Carmen this morning
    - Due: 11:59pm Thursday 3/9
  - Homework Reminder
    - HW 12-1 posted on Carmen 3/1
    - Due: 11:25am Wednesday 3/8
  - Read for Monday: No new reading assignment
    Previous assignment was pages 395-402
  - Mini-Exam 3 regrade continuing
    - A-some C regraded
    - W-Z regraded

Handouts and Announcements

- Announcements
  - Mini-Exam 4 Reminder
    - Available 5pm Monday 3/6 through 5:00pm Tuesday 3/7
    - Due in Carmen PROMPTLY at 5:00pm on 3/7
    - Designed to be completed in ~36 min, but you may use more
    - When planning your schedule:
      - I recommend building in 10-15 min extra
      - To allow for downloading exam, signing and dating honor pledge, saving solution as pdf, and uploading to Carmen
    - I also recommend not procrastinating
  - Exam review topics available on Carmen
  - Sample Mini-Exams 5 and 6 from Au20 also available

Homework 11-1



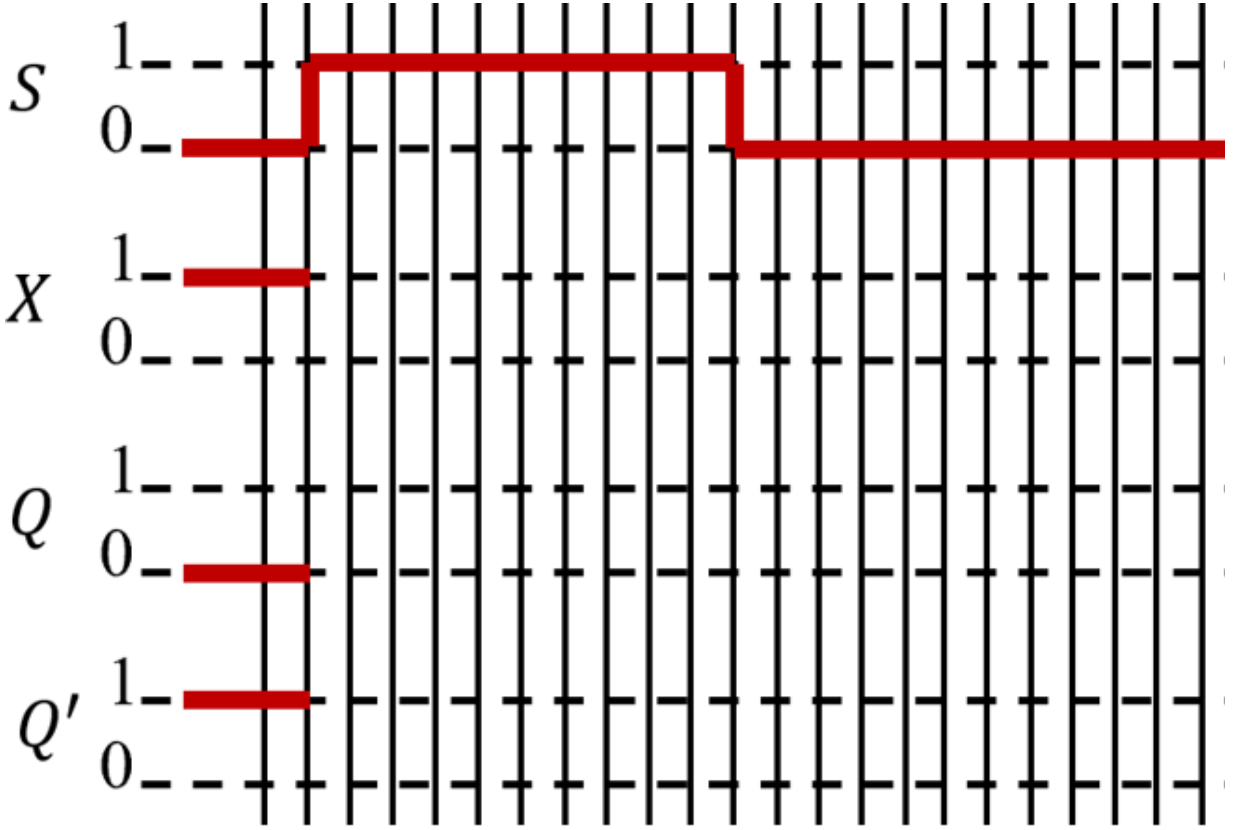
The inverters have a propagation delay of 3 ns.

The two-input NAND gates have a propagation delay of 4 ns.

Complete the timing diagrams for each of the input pulses shown for Part a) and Part b).

The vertical lines are spaced 1ns apart.

The reset input has $R = 0$ at all times in this problem.



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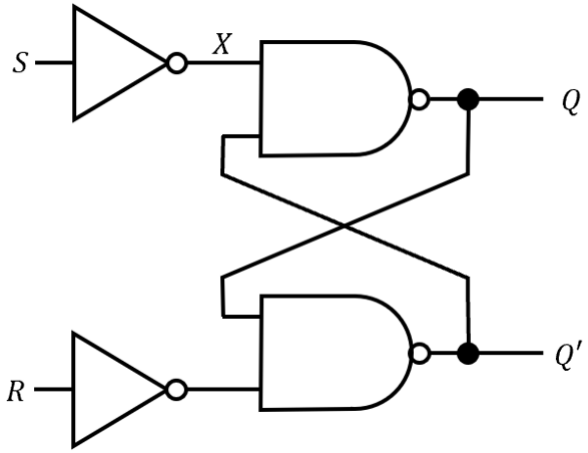
Homework 11-1



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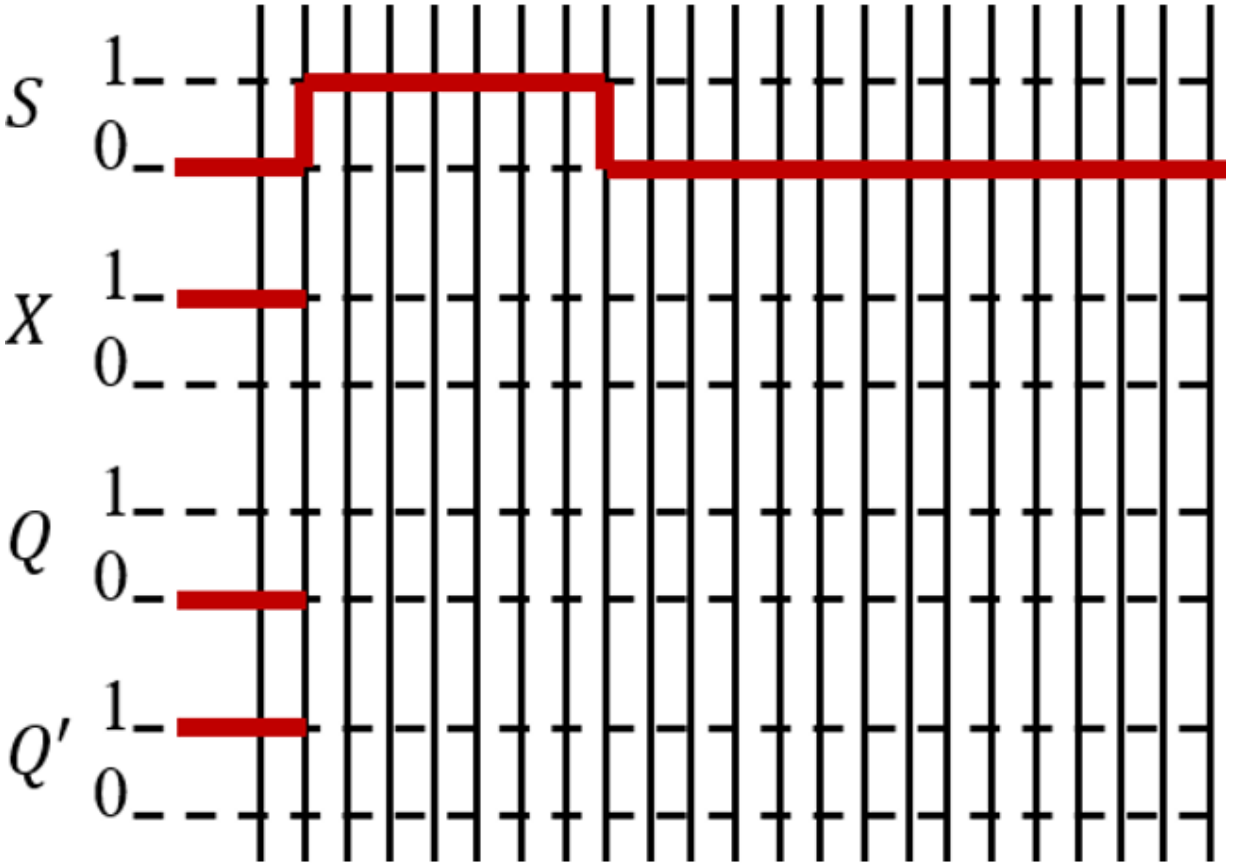
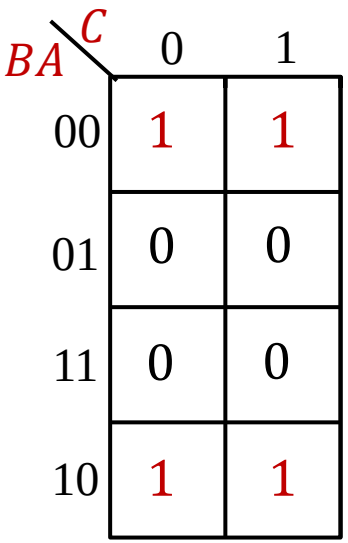
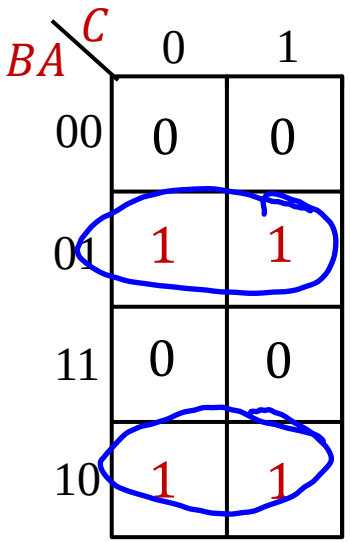


Counters

- Implementation of the 3-bit binary counter using D flip-flops: $Q^+ = D$
- $D_A = A^+; D_B = B^+; D_C = C^+$
- Inspecting the transition table to fill the K-maps

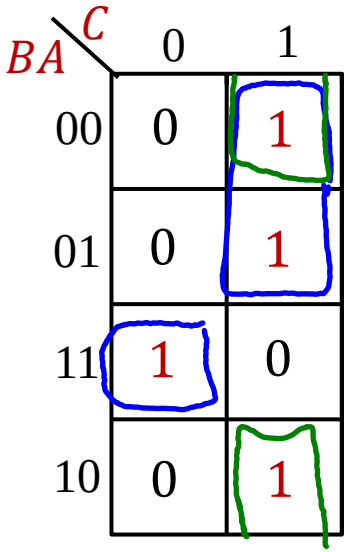
Present State			Next State		
C	B	A	C^+	B^+	A^+
0	0	0	0	0	1
0	0	1	0	1	0
0	1	0	0	1	1
0	1	1	1	0	0
1	0	0	1	0	1
1	0	1	1	1	0
1	1	0	1	1	1
1	1	0	0	0	0





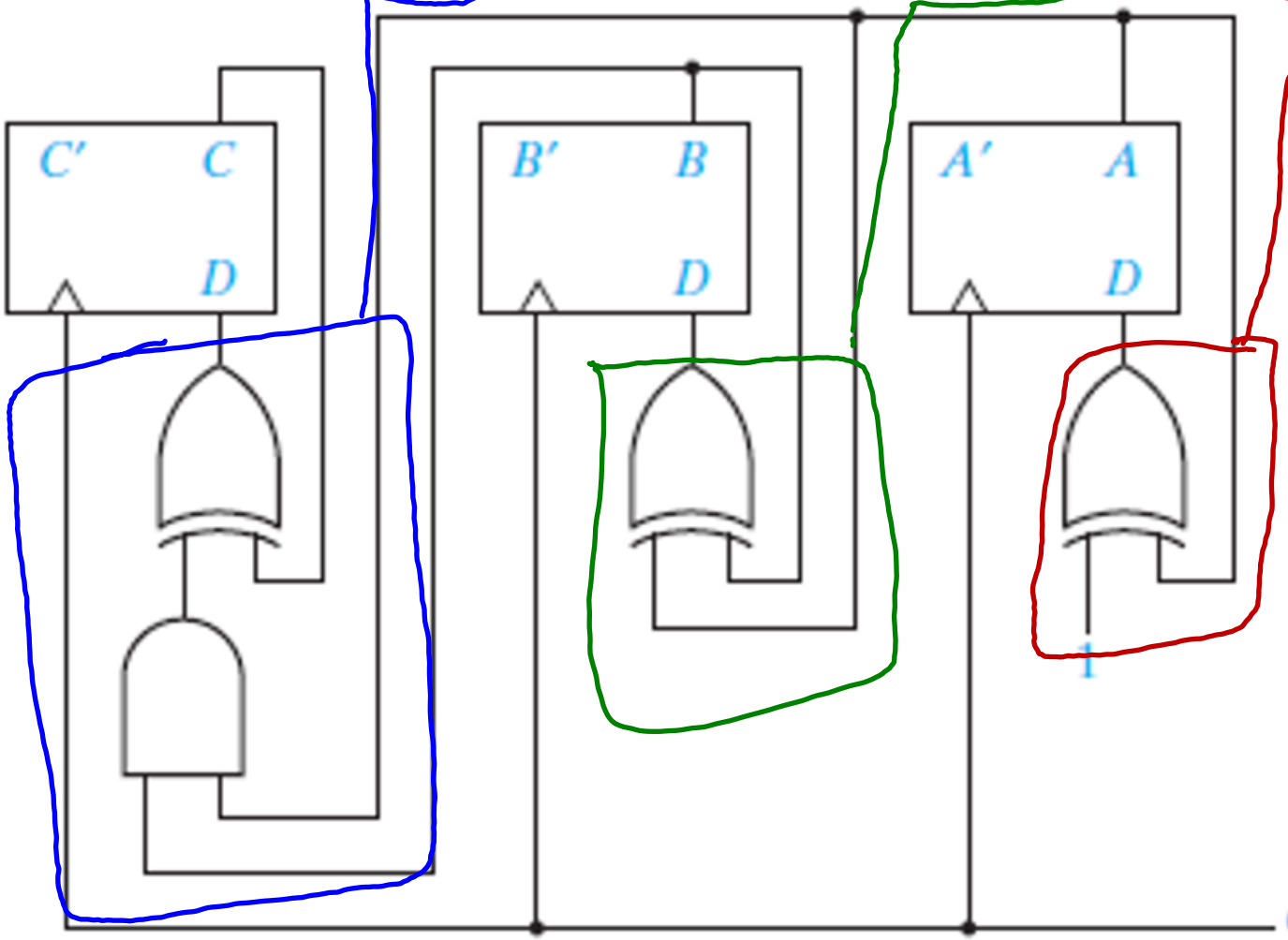
$D_B = AB' + A'B$
$= A \oplus B$

$D_C = A'C + B'C + ABC'$
$= C(A' + B') + ABC'$
$= C(AB)' + C'(AB)$
$= C \oplus AB$



Counters

- Implementation of the 3-bit binary counter using D flip-flops
- $D_C = C \oplus AB;$ $D_B = A \oplus B;$ $D_A = A' = A \oplus 1$



- This figure from textbook uses same XOR input structure to D_A as for D_B and D_C to invert A
- An inverter could be used instead
- Or the A' output of the flip flop
- See last paragraph of Section 11.7 for conversion of D flip-flop to T flip-flop using XOR

Counters

4-bit BCD counter using T flip-flops

D	C	B	A	D^+	C^+	B^+	A^+	T_D	T_C	T_B	T_A
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
1	0	1	0	-	-	-	-	X	X	X	X
1	0	1	1	-	-	-	-	X	X	X	X
1	1	0	0	-	-	-	-	X	X	X	X
1	1	0	1	-	-	-	-	X	X	X	X
1	1	1	0	-	-	-	-	X	X	X	X
1	1	1	1	-	-	-	-	X	X	X	X

Remember the requirement for counters with T flip-flops from last lecture:

$T = 1$ whenever next state is different from current state

$$T_A(D,C,B,A) = 1$$

$$T_B(D,C,B,A) = \sum m(1,3,5,7) + \sum d(10,11,12,13,14,15)$$

$$T_C(D,C,B,A) = \sum m(3,7) + \sum d(10,11,12,13,14,15)$$

$$T_D(D,C,B,A) = \sum m(7,9) + \sum d(10,11,12,13,14,15)$$

4-bit BCD counter using T flip-flops

$$T_A(D,C,B,A) = 1$$
$$T_B(D,C,B,A) = \sum m(1,3,5,7) + \sum d(10,11,12,13,14,15)$$
$$T_C(D,C,B,A) = \sum m(3,7) + \sum d(10,11,12,13,14,15)$$
$$T_D(D,C,B,A) = \sum m(7,9) + \sum d(10,11,12,13,14,15)$$

T_D

BA \ DC	00	01	11	10
00	m_0		X	
01	m_1		X	1
11	etc	1	X	X
10	m_2		X	X

$T_D = AD + \bar{A}BC$

Counters

4-bit BCD counter using T flip-flops

Hw 12-3

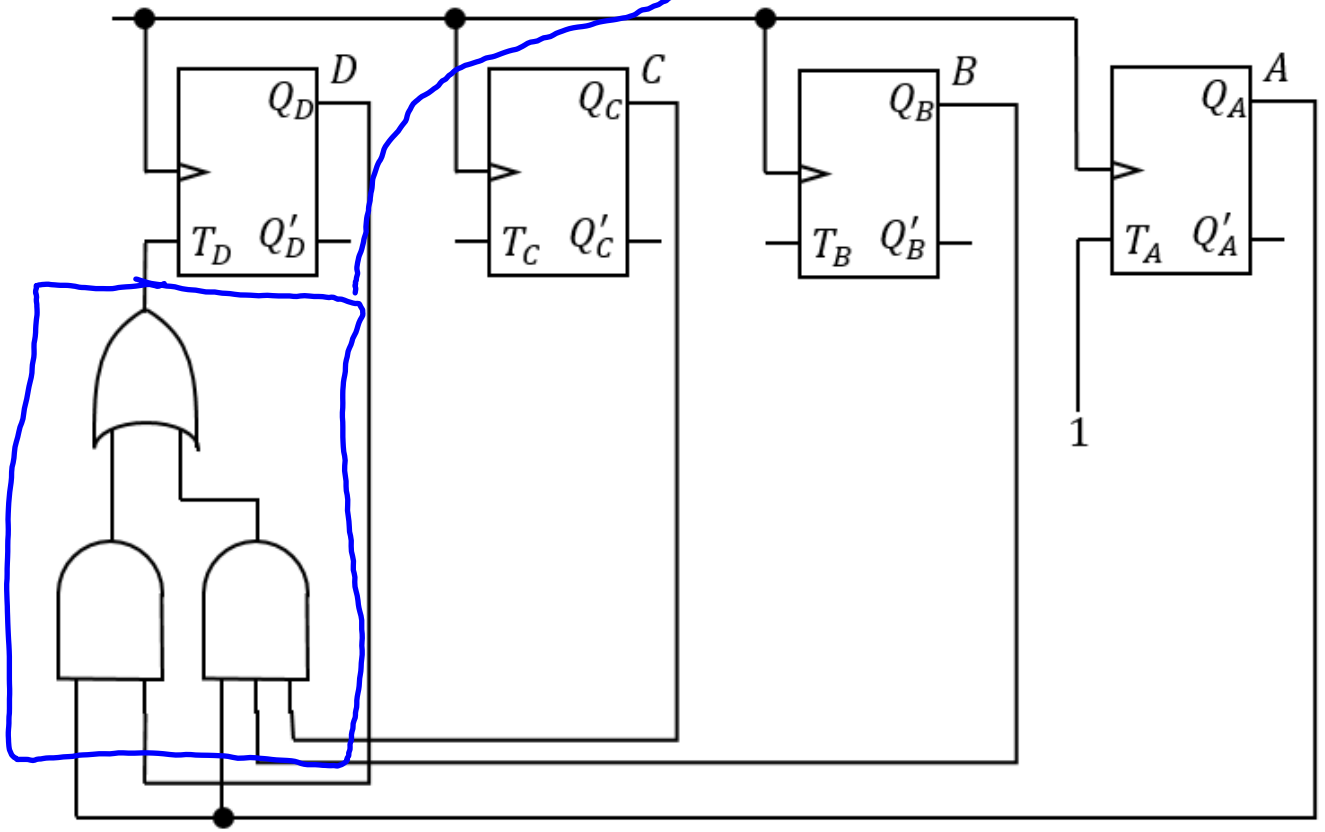
$T_A(D,C,B,A) = 1$

$T_B(D,C,B,A) = \sum m(1,3,5,7) + \sum d(10,11,12,13,14,15)$

$T_C(D,C,B,A) = \sum m(3,7) + \sum d(10,11,12,13,14,15)$

$T_D(D,C,B,A) = \sum m(7,9) + \sum d(10,11,12,13,14,15) = AD + ABC$

The design of the rest of this BCD counter is left as homework

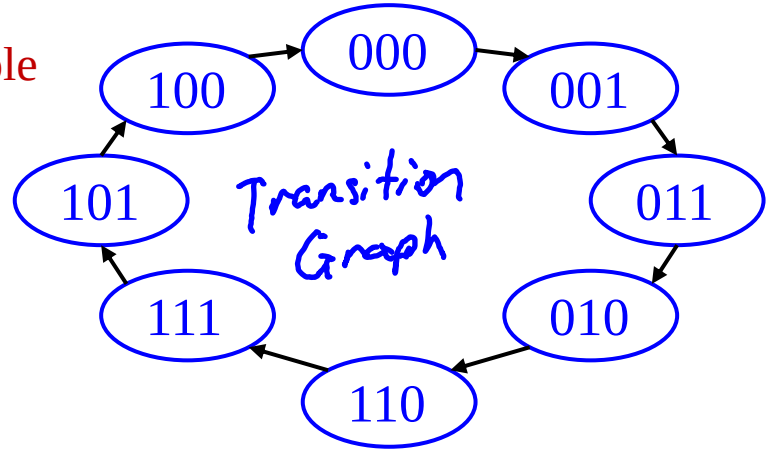


Counters

3-bit Gray-Code counter using T flip-flops

Count sequence does not have to be straight binary: Gray-Code as an example

C	B	A	C^+	B^+	A^+	T_C	T_B	T_A
0	0	0	0	0	1	0	0	1
0	0	1	0	1	1	0	1	0
0	1	0	1	1	0	1	0	0
0	1	1	0	1	0	0	0	1
1	0	0	0	0	0	1	0	0
1	0	1	1	0	0	0	0	1
1	1	0	1	1	1	0	0	1
1	1	1	1	0	1	0	1	0



$$T_A(C,B,A) = \sum m(0,3,5,6)$$

$$T_B(C,B,A) = \sum m(1,7)$$

$$T_C(C,B,A) = \sum m(2,4)$$

Counters

$$T_A(C,B,A) = \sum m(0,3,5,6)$$
$$T_B(C,B,A) = \sum m(1,7)$$
$$T_C(C,B,A) = \sum m(2,4)$$

BA \ C	0	1
00	1	
01		1
11	1	
10		1

- Note that each of the 8 minterms appears exactly once.
- No Reduction for SOP form
- But do you see the useful pattern?

BA \ C	0	1
00		
01	1	
11		1
10		

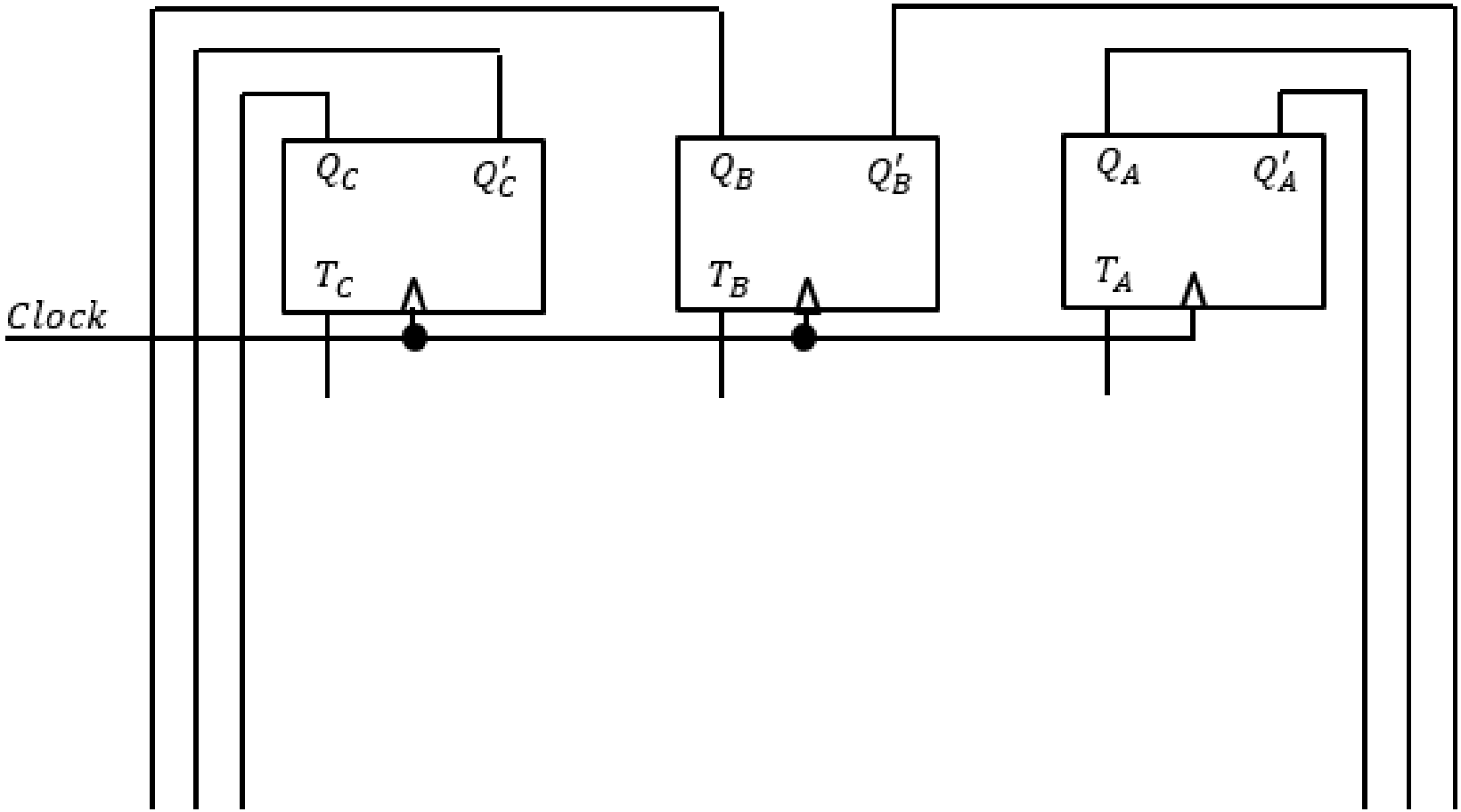
BA \ C	0	1
00		1
01		
11		
10	1	

Counters

$T_C = C'BA' + CB'A'$

$T_B = C'B'A + CBA$

$T_A = C'B'A' + C'BA + CB'A + CBA'$



Counters

3-bit Binary Up-Down counter using D flip-flops

Bi-directional Transition Graph

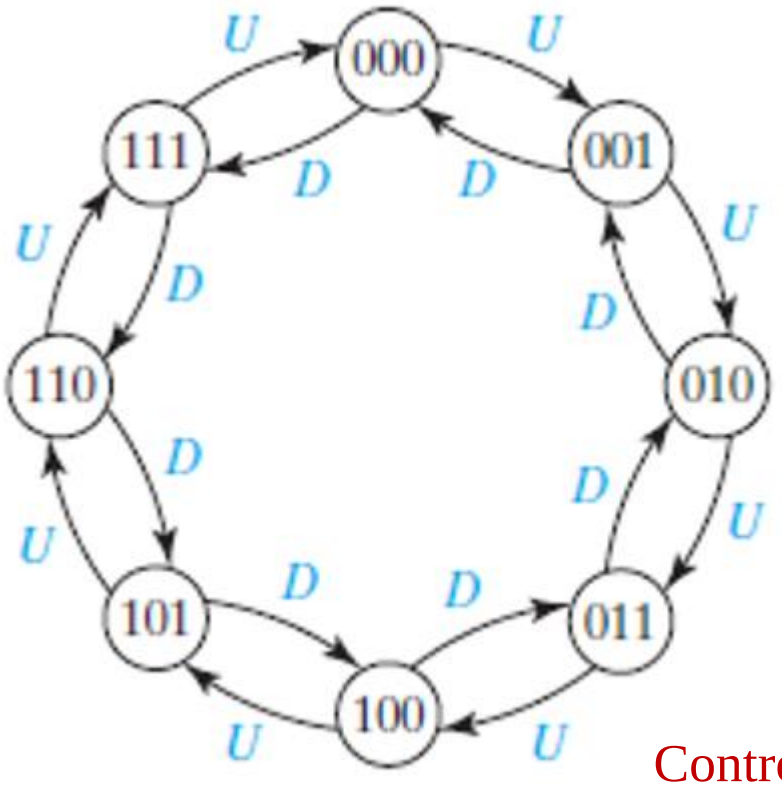


Table of Present and Next States for both directions

	$C^+B^+A^+$	
CBA	U	D
000	001	111
001	010	000
010	011	001
011	100	010
100	101	011
101	110	100
110	111	101
111	000	110

Control Bits U and D

- $U = D = 0$ ⇨
- $U = 1; D = 0$ ⇨
- $U = 0; D = 1$ ⇨
- $U = D = 1$ ⇨ **not allowed**

Counters

3-bit Binary Up-Down counter using D flip-flops

	$C^+B^+A^+$	
CBA	U	D
000	001	111
001	010	000
010	011	001
011	100	010
100	101	011
101	110	100
110	111	101
111	000	110

Next state of A is A' either Up or Down

$D_A = A^+ = A \oplus (U + D)$

$D_B = B^+ = B \oplus (UA + DA')$

$D_C = C^+ = C \oplus (UAB + DA'B')$

When $U = 1, D = 0$ these equations reduce to the same expressions on slides 6 & 7

When $U = 0, D = 1$ these equations reduce to

$D_A = A^+ = A \oplus 1 = A'$

$D_B = B^+ = B \oplus A'$

$D_C = C^+ = C \oplus A'B'$

Counters

3-bit Binary Up-Down counter using D flip-flops

$$D_A = A^+ = A \oplus (U + D)$$

$$D_B = B^+ = B \oplus (UA + DA')$$

$$D_C = C^+ = C \oplus (UAB + DA'B')$$