THE OHIO STATE UNIVERSITY

COLLEGE OF ENGINEERING

ECE 3561
Advanced Digital Design
Class 11: Counters 2 – Other Sequences Counter Design

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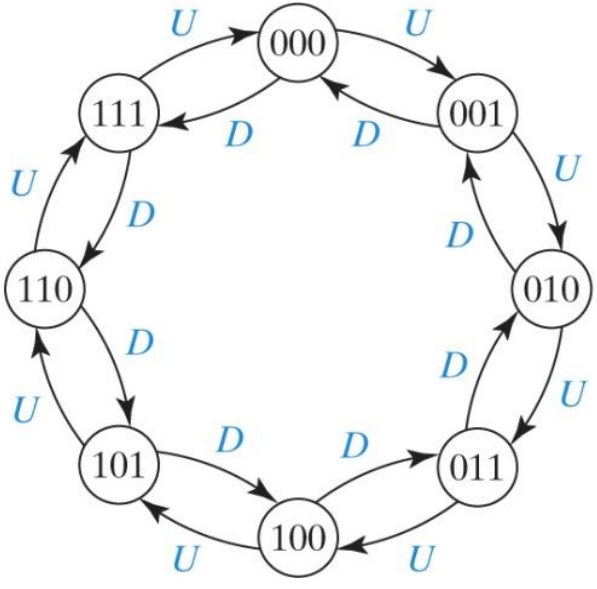
Spring 2024

Counter Design Procedure Summary

1) Determine counting sequence.
2) Determine number (and type) of FFs.
3) Construct truth table with state and next state combinations.
4) Determine FF input excitations for each state to next state transition and add to truth table.
5) Determine FF input excitation equations using K-map.
6) Draw the counter circuit logic diagram using the FFs and the combinational logic from the excitation equations.

Ex 3: Up-Down Modulo-8 Counter

FIGURE 12-18
Transition Graph and Table for Up-Down Counter



	$C^+B^+A^+$	
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

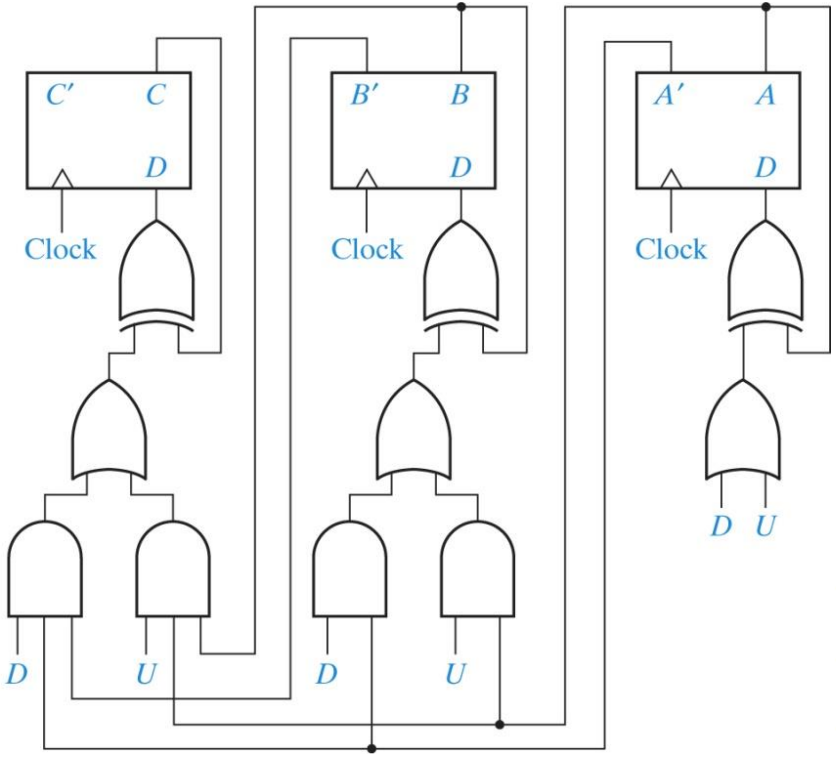
U: counting up
D: counting down

Observe when counting down:

$$D_A = A^+ = A \oplus 1 = A' \quad (A \text{ changes state every clock cycle})$$
$$D_B = B^+ = B \oplus A' \quad (B \text{ changes state when } A = 0)$$
$$D_C = C^+ = C \oplus B'A' \quad (C \text{ changes state when } B = A = 0)$$

Ex 3: Up-Down Modulo-8 Counter

FIGURE 12-19
Binary Up-Down Counter



Note that now we only transition states when U or D is set.

$$D_A = A^+ = A \oplus (U + D)$$
$$D_B = B^+ = B \oplus (UA + DA')$$
$$D_C = C^+ = C \oplus (UBA + DB'A')$$

Ex 4: Other Sequence Counter

- Count sequence:

  0 → 4 → 7 → 2 → 3 → 0 → …

- Not used:

  1, 5, 6: these states don't have next states (they are "don't cares")

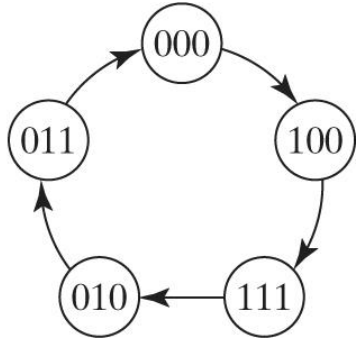
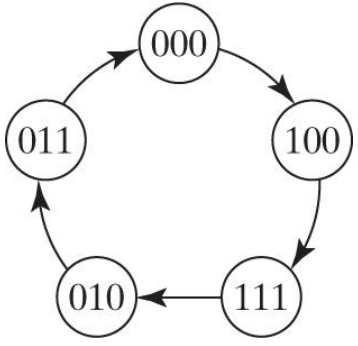


FIGURE 12-22
Transition Graph for Counter

Ex 4: Other Sequence Counter



C	B	A	C^+	B^+	A^+
0	0	0			
0	0	1			
0	1	0			
0	1	1			
1	0	0			
1	0	1			
1	1	0			
1	1	1			

Q	Q^+	T
0	0	0
0	1	1
1	0	1
1	1	0

$T = Q^+ \oplus Q$

Ex 4: Other Sequence Counter

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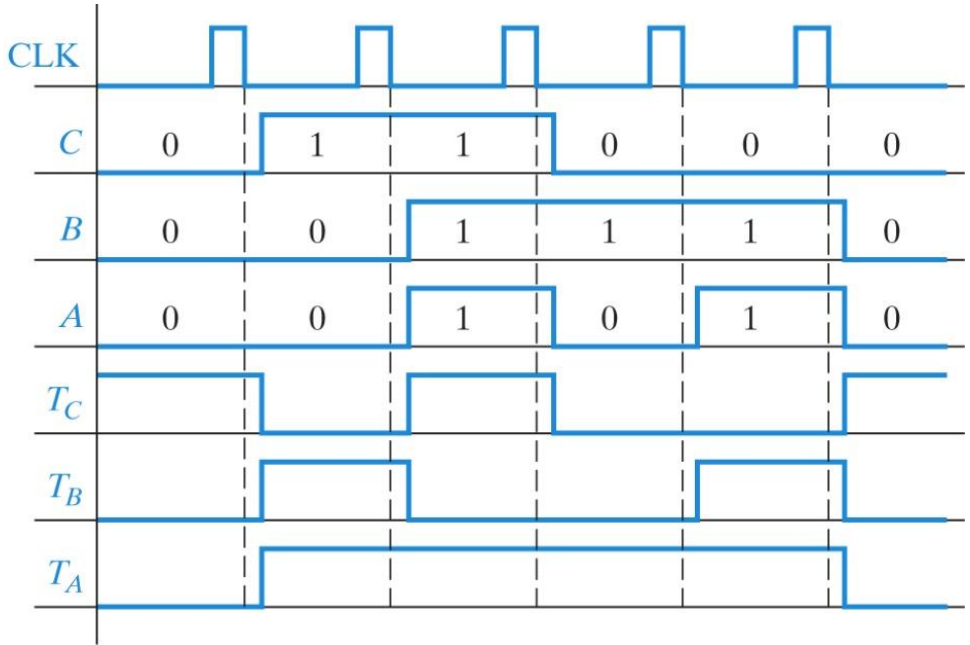
Ex 4: Other Sequence Counter

- Could you design the counter if you were given only the timing diagram?

FIGURE 12-25
Timing Diagram for Figure 12-24



The complete timing diagram shows the counting sequence and the FF excitation signals.

Counter Design with SR/JK FFs

TABLE 12-7
J-K Flip-Flop Inputs

(a)

J	K	Q	Q^+
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

(b)

Q	Q^+	J	K
0	0	0	0
		0	1
0	1	1	0
		1	1
1	0	0	1
		1	1
1	1	0	0
		1	0

(c)

Q	Q^+	J	K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0

Compare Excitation Signals

TABLE 12-5
S-R Flip-Flop Inputs

(a)

S	R	Q	Q^+	
0	0	0	0	
0	0	1	1	
0	1	0	0	
0	1	1	0	
1	0	0	1	
1	0	1	1	
1	1	0	–	inputs not allowed
1	1	1	–	

(b)

Q	Q^+	S	R
0	0	0	0
		0	1
0	1	1	0
1	0	0	1
1	1	0	0
		1	0

(c)

Q	Q^+	S	R
0	0	0	X
0	1	1	0
1	0	0	1
1	1	X	0

Ex 5/6: Redesign with SR/JK FFs

Counter sequence: 0 → 4 → 7 → 2 → 3 → 0 → ...

C	B	A	C^+	B^+	A^+	S_C	R_C	S_B	R_B	S_A	R_A
0	0	0	1	0	0						
0	0	1	–	–	–						
0	1	0	0	1	1						
0	1	1	0	0	0						
1	0	0	1	1	1						
1	0	1	–	–	–						
1	1	0	–	–	–						
1	1	1	0	1	0						

C	B	A	C^+	B^+	A^+	J_C	K_C	J_B	K_B	J_A	K_A
0	0	0	1	0	0						
0	0	1	–	–	–						
0	1	0	0	1	1						
0	1	1	0	0	0						
1	0	0	1	1	1						
1	0	1	–	–	–						
1	1	0	–	–	–						
1	1	1	0	1	0						

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