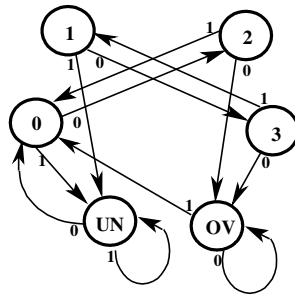
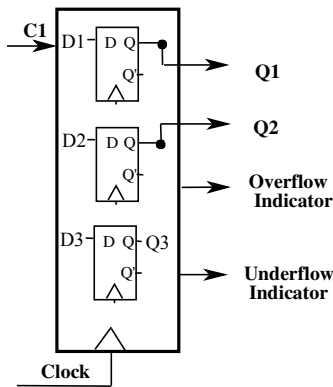


## Tutorial 5: Two Mode Counter Design



The task is to design a two-bit controlled counter which has two counting bits ( $Q_2, Q_1$ ), has one control input  $C_1$ , and also two extra outputs, one indicating **overflow**, the other **underflow**. When  $C_1=0$  the counter counts up by 2s; i.e. 0 becomes 2, 1 becomes 3. In this mode the values 2 and 3 go to the **overflow** state. When the control input  $C_1=1$ , the counter counts down by 2s, i.e. 3 becomes 1, and 2 becomes 0, and 1 and 0 go to the **underflow** state. The counter remains in one of these "error" states until the control bit  $C_1$  is changed at which point it goes to state 0. The finite state machine

shows this operating sequence. One way to design this circuit is to set up **six** states. These are the four output count states: **0, 1, 2, 3**, and the two "error" states: **OV** (overflow) and **UN** (underflow). In order to provide six internal states, we need a minimum of three flip-flops. In the following incomplete transition table six flip-flop outputs are assigned, two are left as **don't cares**.

1 Complete the transition table by showing the  $Q_3, Q_2, Q_1$  outputs of the "next" state.

C1	Current State				Next State			
	State	Q3	Q2	Q1	State	Q3	Q2	Q1
0	0	0	0	0	2			
0	1	0	0	1	3			
0	2	0	1	0	OV			
0	3	0	1	1	OV			
0	UN	1	0	0	0			
0	X	1	0	1	X	X	X	X
0	X	1	1	0	X	X	X	X
0	OV	1	1	1	OV			
1	0	0	0	0	UN			
1	1	0	0	1	UN			
1	2	0	1	0	0			
1	3	0	1	1	1			
1	UN	1	0	0	UN			
1	X	1	0	1	X	X	X	X
1	X	1	1	0	X	X	X	X
1	OV	1	1	1	0			

2. Fill in the K-Maps for the D-type flip-flop inputs  $D_3, D_2$ , and  $D_1$ . (ie the next state  $Q_3, Q_2, Q_1$  values) and determine the minimised expressions for  $D_3, D_2$ , and  $D_1$  ;

C1 \ Q2,Q1

Q3 \ 00	01	11	10
00			
01			
11			
10			

D3

C1 \ Q2,Q1

Q3 \ 00	01	11	10
00			
01			
11			
10			

D2

C1 \ Q2,Q1

Q3 \ 00	01	11	10
00			
01			
11			
10			

D1

D3 =

D2 =

D1 =

3. Determine the necessary output circuits which provide the required output signals: **Overflow Indicator** and **Underflow Indicator**.

**Optional:**

4. Determine the actual K-maps (replace the Xs with their correct values) and find the final finite state machine diagram. Will the circuit get stuck in a wrong state?

