Up-Down Decade Counter using JK-FlipFlops

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BCSE-II

Hardware Design Lab.

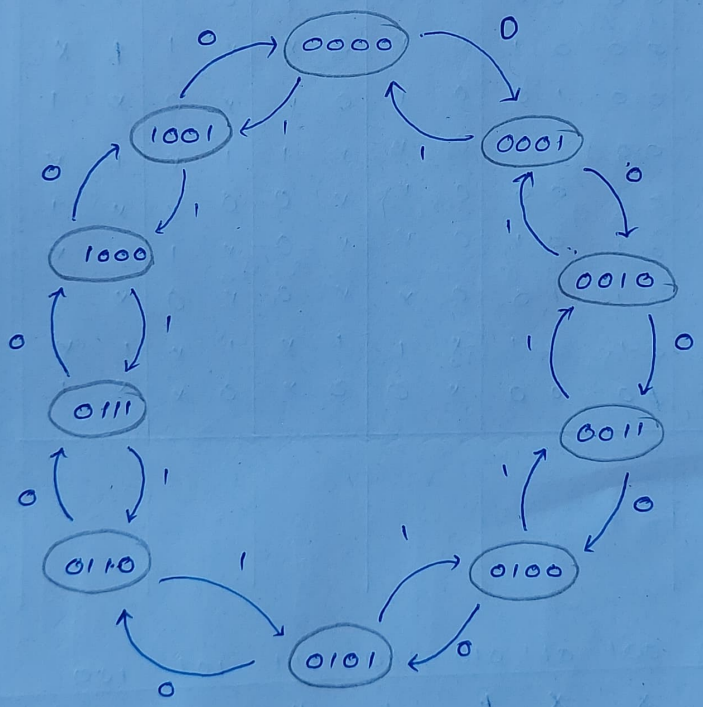
Design an up and down (as selected by a control line) decade counter using JK-FlipFlop.

– the up-down decade counter has 10 states. If n flipflops are needed, then $2^n \geq 10$.

$\therefore$ $n = 4$, i.e. 4 J-K flipflops are needed.

Now, when the input/control signal is 0, the counter counts up, and when input is 1, the counter counts down.

State Diagram:



4 flipflops can handle $2^4 = 16$ states. So there will be 6 invalid states in the state table.

Excitation Table:

control	PS	NS	Flip-flops					
C	$Q_3\ Q_2\ Q_1\ Q_0$	$Q_3^+\ Q_2^+\ Q_1^+\ Q_0^+$	J_3	K_3	J_2	K_2	J_1	K_1	J_0	K_0
0	0 0 0 0	0 0 0 1	0	x	0	x	0	x	1	x
0	0 0 0 1	0 0 1 0	0	x	0	x	1	x	x	1
0	0 0 1 0	0 0 1 1	0	x	0	x	x	0	1	x
0	0 0 1 1	0 1 0 0	0	x	1	x	x	1	x	1
0	0 1 0 0	0 1 0 1	0	x	x	0	0	x	1	x
0	0 1 0 1	0 1 1 0	0	x	x	0	1	x	x	1
0	0 1 1 0	0 1 1 1	0	x	x	0	x	0	1	x
0	0 1 1 1	1 0 0 0	1	x	x	1	x	1	x	1
0	1 0 0 0	1 0 0 1	x	0	0	x	0	x	1	x
0	1 0 0 1	0 0 0 0	x	1	0	x	0	x	x	1
↓	0 0 0 0	1 0 0 1	1	x	0	x	0	x	1	x
↓	0 0 0 1	0 0 0 0	0	x	0	x	0	x	x	1
↓	0 0 1 0	0 0 0 1	0	x	0	x	x	1	x	x
↓	0 0 1 1	0 0 1 0	0	x	0	x	x	0	x	1
↓	0 1 0 0	0 0 1 1	0	x	x	1	1	x	1	x
↓	0 1 0 1	0 1 0 0	0	x	x	0	0	x	x	1
↓	0 1 1 0	0 1 0 1	0	x	x	0	x	1	1	x
↓	0 1 1 1	0 1 1 0	0	x	x	0	x	0	x	1
↓	1 0 0 0	0 1 1 1	x	1	1	x	1	x	1	x
↓	1 0 0 1	0 0 0 0	x	0	0	x	0	x	x	1

Minimization:

For J_0:

$Q_2Q_1Q_0$ / CQ_3	000	001	011	010	110	111	101	100
00	1	x	x	1	1	x	x	1
01	1	x	x	x	x	x	x	x
11	1	x	x	x	x	x	x	x
10	1	x	x	1	1	x	x	1

$J_0 = 1$

For K_0:

$Q_2Q_1Q_0$ / CQ_3	000	001	011	010	110	101	101	100
00	x	1	1	x	x	1	1	x
01	x	1	x	x	x	x	x	x
11	x	1	x	x	x	x	x	x
10	x	1	1	x	x	1	1	x

$K_0 = 1$.

For J_1

Q_3 \ $Q_2Q_1Q_0$	000	001	011	010	110	111	101	100
00	0	1	X	X	X	X	1	0
01	0	0	X	X	X	X	X	X
11	1	0	X	X	X	X	X	X
10	0	0	X	X	X	X	0	1

$$J_1 = \bar{c}\,\bar{Q}_3 Q_0 + cQ_2\bar{Q}_0 + cQ_3\bar{Q}_0$$

For K_1

Q_3 \ $Q_2Q_1Q_0$	000	001	011	010	110	111	101	100
00	X	X	1	0	0	1	X	X
01	X	X	X	X	X	X	X	X
11	X	X	X	X	X	X	X	X
10	X	X	0	1	1	0	X	X

$$K_1 = \bar{c}Q_0 + c\bar{Q}_0$$

For J_2

Q_3 \ $Q_2Q_1Q_0$	000	001	011	010	110	111	101	100
00	0	0	1	0	X	X	X	X
01	0	0	X	X	X	X	X	X
11	1	0	X	X	X	X	X	X
10	0	0	0	0	X	X	X	X

$$J_2 = \bar{c}Q_1Q_0 + cQ_3\bar{Q}_0$$

For K_2

Q_3 \ $Q_2Q_1Q_0$	000	001	011	010	110	111	101	100
00	X	X	X	X	0	1	0	0
01	X	X	X	X	X	X	X	X
11	X	X	X	X	X	X	X	X
10	X	X	X	X	0	0	0	1

$$K_2 = \bar{c}Q_1Q_0 + c\bar{Q}_1\bar{Q}_0$$

For J_3

Q_3 \ $Q_2Q_1Q_0$	000	001	011	010	110	111	101	100
00	0	0	0	0	0	1	0	0
01	X	X	X	X	X	X	X	X
11	X	X	X	X	X	X	X	X
10	1	0	0	0	0	0	0	0

$$J_3 = \bar{c}Q_2Q_1Q_0 + c\bar{Q}_2\bar{Q}_1\bar{Q}_0$$

For K_3

$Q_2Q_1Q_0$ / CQ_3	000	001	011	010	110	111	101	100
00	X	X	X	X	X	X	X	X
01	0	1	X	X	X	X	X	X
11	1	0	X	X	X	X	X	X
10	X	X	X	X	X	X	X	X

$$K_3 = \bar{C}Q_0 + C\bar{Q}_0$$

Expressions:

$$J_0 = 1$$

$$K_0 = 1$$

$$J_1 = \bar{C}\bar{Q}_3Q_0 + CQ_2\bar{Q}_0 + CQ_3\bar{Q}_0$$

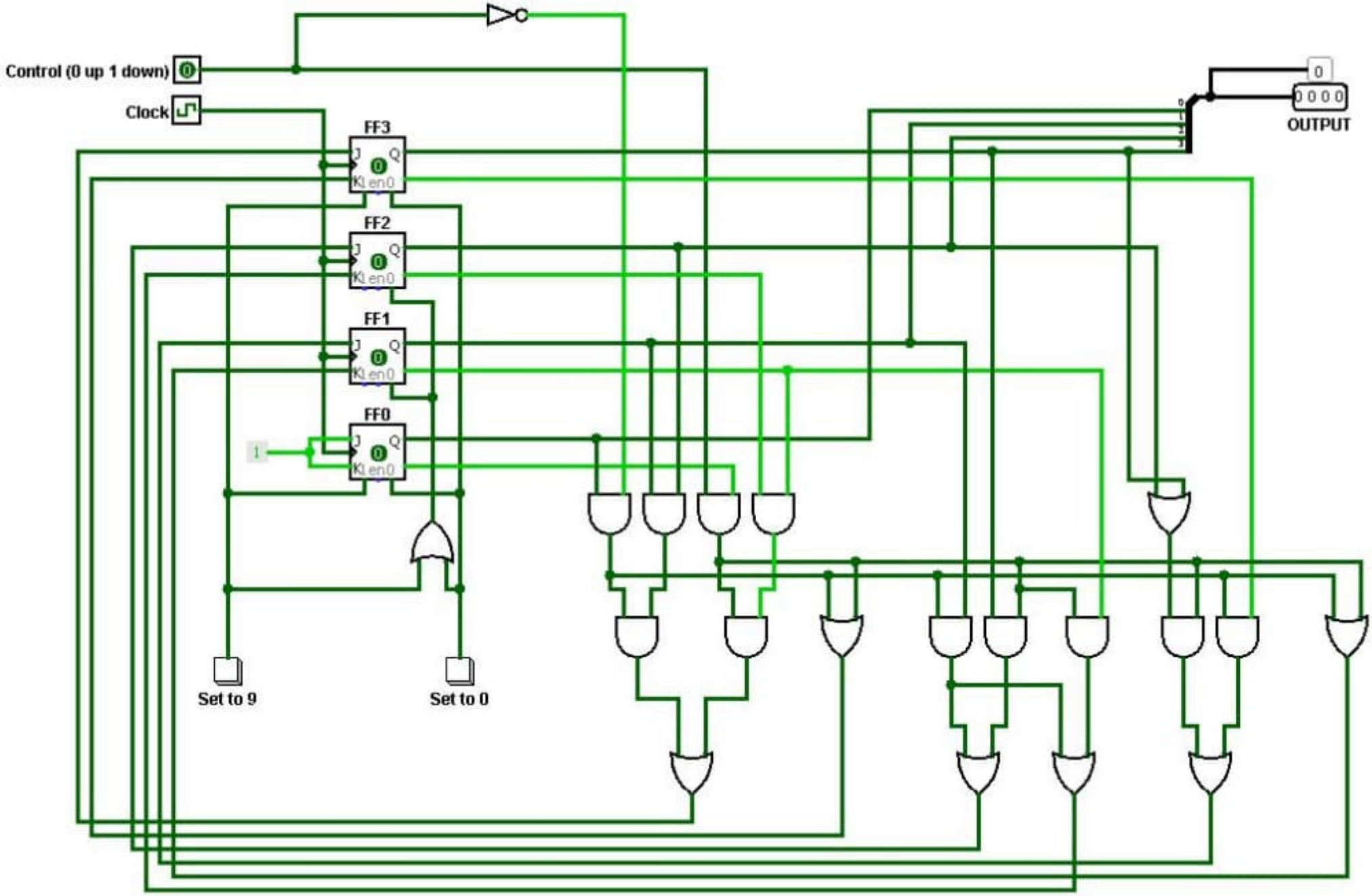
$$K_1 = \bar{C}Q_0 + C\bar{Q}_0$$

$$J_2 = \bar{C}Q_1Q_0 + CQ_3\bar{Q}_0$$

$$K_2 = \bar{C}Q_1Q_0 + C\bar{Q}_1\bar{Q}_0$$

$$J_3 = \bar{C}Q_2Q_1Q_0 + C\bar{Q}_2\bar{Q}_1\bar{Q}_0$$

$$K_3 = \bar{C}Q_0 + C\bar{Q}_0$$



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