Diseño de Máquinas de Estado Finito: FSM

- *Diseñar una FSM para un motor asíncrono*

- *X2X2X1X2 arranca en un sentido*
- *X1X1X2X1 arranca en sentido contrario*
- *X2X1X1 se detiene*
- *X1X2X2X1 cambia de giro*

Diagrama de Estados

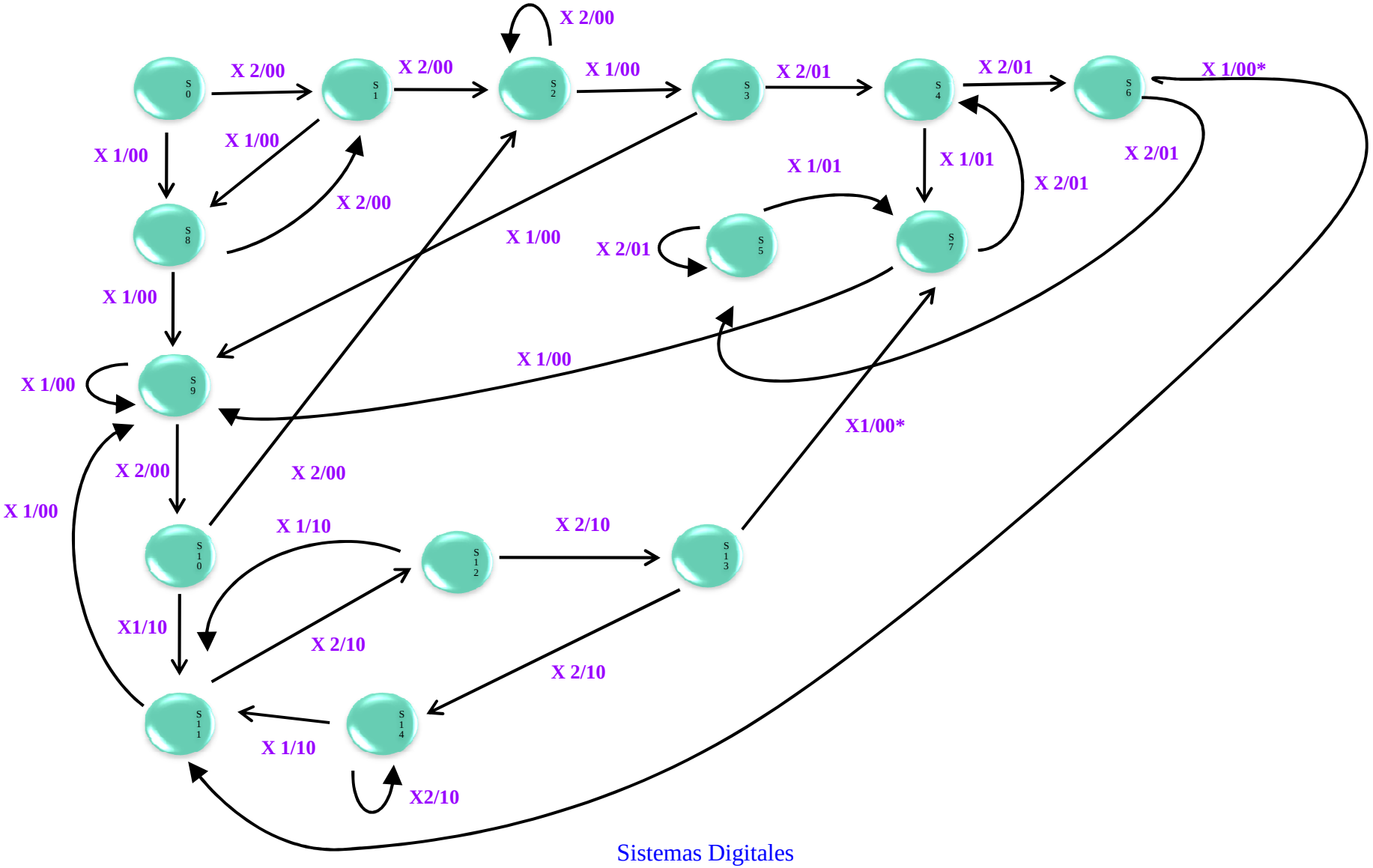


Tabla de Estados para el FF D

	X1		X2	
$q_3\ q_2\ q_1\ q_0$	$q_{3+}\ q_{2+}\ q_{1+}\ q_{0+}$ /	$Z_1\ Z_0$	$q_{3+}\ q_{2+}\ q_{1+}\ q_{0+}$ /	$Z_1\ Z_0$
0 0 0 0	1 0 0 0	0 0	0 0 0 1	0 0
0 0 0 1	1 0 0 0	0 0	0 0 1 0	0 0
0 0 1 0	0 0 1 1	0 0	0 0 1 0	0 0
0 0 1 1	1 0 0 1	0 0	0 1 0 0	0 1
0 1 0 0	0 1 1 1	0 1	0 1 1 0	0 1
0 1 0 1	0 1 1 1	0 1	0 1 0 1	0 1
0 1 1 0	1 0 1 1	00*	0 1 0 1	0 1
0 1 1 1	1 0 0 1	0 0	0 1 0 0	0 1
1 0 0 0	1 0 0 1	0 0	0 0 0 1	0 0
1 0 0 1	1 0 0 1	0 0	1 0 1 0	0 0
1 0 1 0	1 0 1 1	1 0	0 0 1 0	0 0
1 0 1 1	1 0 0 1	0 0	1 1 0 0	1 0
1 1 0 0	1 0 1 1	1 0	1 1 0 1	1 0
1 1 0 1	0 1 1 1	00*	1 1 1 0	1 0
1 1 1 0	1 0 1 1	1 0	1 1 1 0	1 0
1 1 1 1	x x x x	x x	x x x x	x x

Tabla de Estados para el FF D

X1								X2							
D_3	D_2	D_1	D_0	C_3	C_2	C_1	C_0	D_3	D_2	D_1	D_0	C_3	C_2	C_1	C_0
1	x	x	x	1	0	0	0	1	x	x	x	1	0	0	0
1	x	x	0	1	0	0	1	1	x	x	0	1	0	0	1
x	x	x	1	0	0	0	1	x	x	x	1	0	0	0	1
1	x	0	x	1	0	1	0	1	1	0	0	1	1	1	1
x	x	1	1	0	0	1	1	x	x	1	1	0	0	1	1
x	x	1	x	0	0	1	0	x	x	1	x	0	0	1	0
1	0	x	1	1	1	0	1	1	0	0	1	1	1	1	1
1	0	0	x	1	1	1	0	1	0	0	0	1	1	1	1
x	x	x	1	0	0	0	1	x	x	x	1	0	0	0	1
x	x	x	x	0	0	0	0	x	x	x	0	0	0	0	1
x	x	x	1	0	0	0	1	x	x	x	1	0	0	0	1
x	x	0	x	0	0	1	0	x	1	0	0	0	1	1	1
x	0	1	1	0	1	1	1	x	0	1	1	0	1	1	1
0	x	1	x	1	0	1	0	0	x	1	0	1	0	1	1
x	0	x	1	0	1	0	1	x	0	x	1	0	1	0	1
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Mapas de K

X1

$q_3\ q_2$

$q_1\ q_0$	00	01	11	10
00	1 (0)	x (4)	x_{12}	X_8
01	1 (1)	x (5)	0_{13}	X_9
11	1 (3)	1 (7)	X_{15}	X_{11}
10	x (2)	1 (6)	X_{14}	X_{10}

X2

$q_3\ q_2$

$q_1\ q_0$	00	01	11	10
00	1 (0)	x (4)	X_{12}	X_8
01	1 (1)	X (5)	0_{13}	X_9
11	1 (3)	1 (7)	X_{15}	X_{11}
10	x (2)	1 (6)	x_{14}	x_{10}

$$d_3 = X1\ (\ nq_3\ ) + X2\ (\ nq_1\ )$$

X1

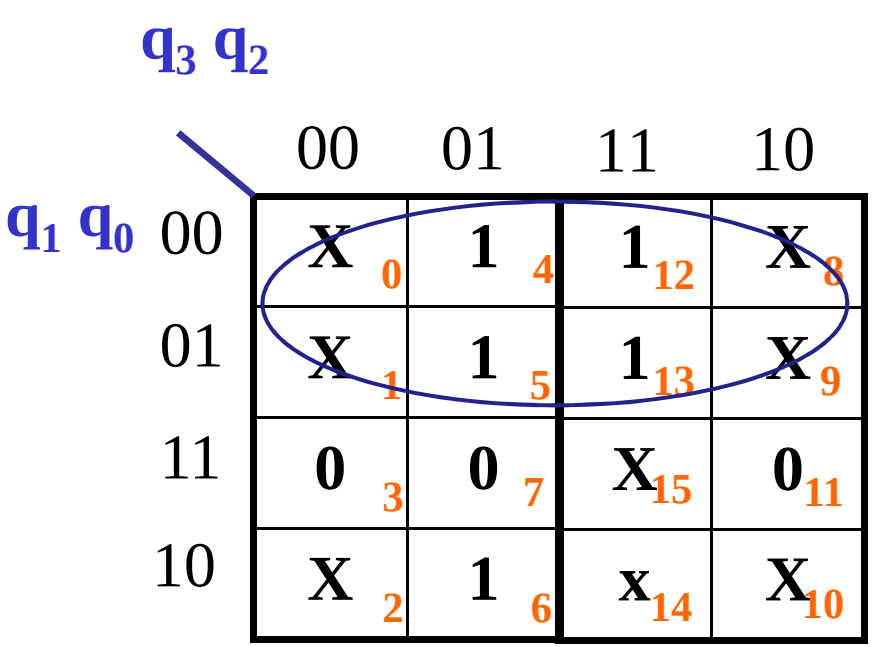
$q_3\,q_2$ / $q_1\,q_0$	00	01	11	10
00	X 0	x 4	0 12	X 8
01	X 1	X 5	x 13	X 9
11	X 3	0 7	X 15	X 11
10	x 2	0 6	0 14	x 10

X2

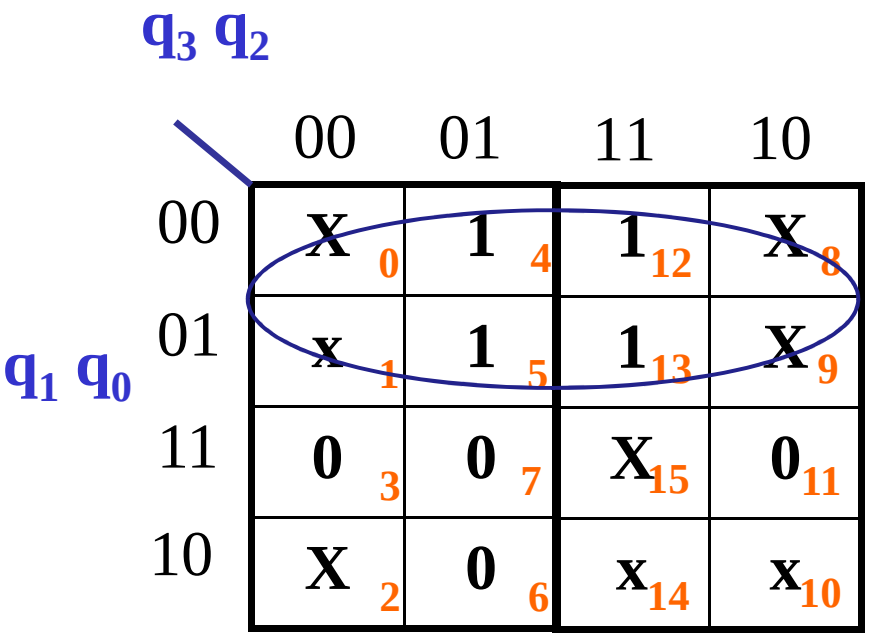
$q_3\,q_2$ / $q_1\,q_0$	00	01	11	10
00	X 0	X 4	0 12	X 8
01	X 1	X 5	X 13	1 9
11	1 3	0 7	x 15	X 11
10	x 2	0 6	0 14	x 10

$d_2 = X2\,(q_2)$

X1



X2



$d_1 = X1(nq_1) + X2 (nq_1)$

X1

$q_3\ q_2$

	00	01	11	10
00	x 0	1 4	1 12	1 8
01	0 1	x 5	x 13	X 9
11	x 3	x 7	X 15	X 11
10	1 2	1 6	1 14	1 10

X2

$q_3\ q_2$

$q_1\ q_0$

	00	01	11	10
00	x 0	1 4	1 12	1 8
01	0 1	X 5	0 13	0 9
11	0 3	0 7	X 15	0 11
10	1 2	1 6	1 14	1 10

$$d_0 = X1\ (\ nq_0\ ) + X2\ (\ nq_0\ )$$

X1

$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	0 0	0 4	1 12	0 8
01	0 1	0 5	0 13	0 9
11	0 3	0 7	0 15	0 11
10	0 2	0 6	1 14	0 10

X2

$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	0 0	0 4	1 12	0 8
01	0 1	0 5	1 13	0 9
11	0 3	0 7	1 15	1 11
10	0 2	0 6	1 14	0 10

$$Z_1 = X_1(q_3q_2nq_0 + q_3q_1nq_0) + X2 (q_3q_2 + q_3q_1q_0)$$

X1

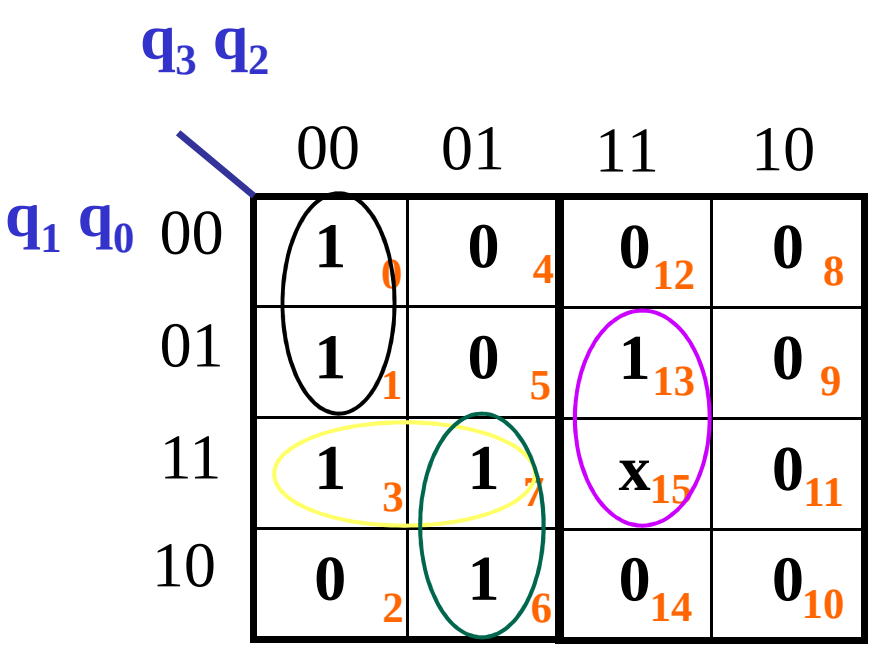
$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	0 0	1 4	0 12	0 8
01	0 1	1 5	0 13	0 9
11	0 3	0 7	x 15	0 11
10	0 2	0 6	0 14	0 10

X2

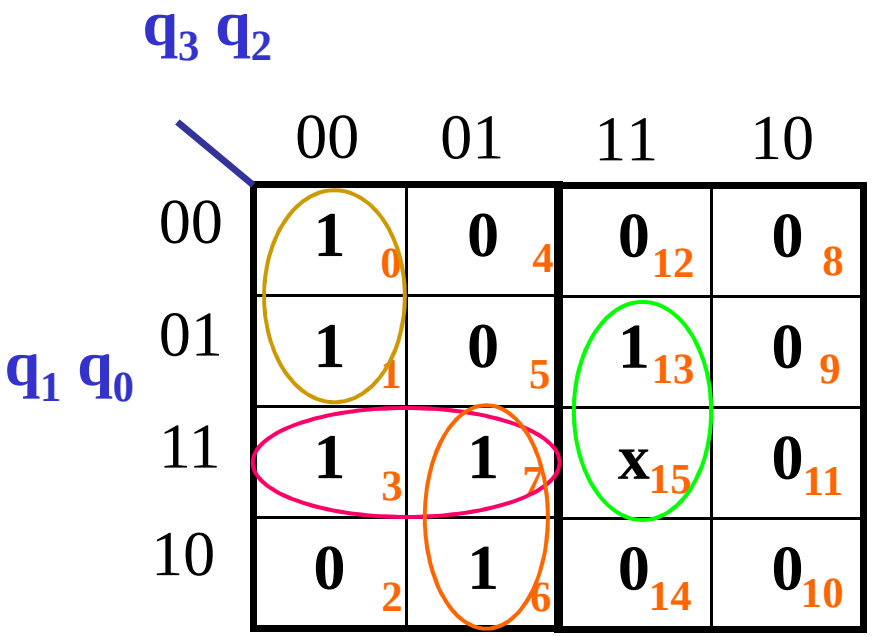
$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	0 0	1 4	0 12	0 8
01	0 1	1 5	0 13	0 9
11	1 3	1 7	x 15	0 11
10	0 2	1 6	0 14	0 10

$$Z_0 = X1(nq_3q_2q_1) + X2 (nq_3q_2 + nq_3q_1q_0)$$

X1

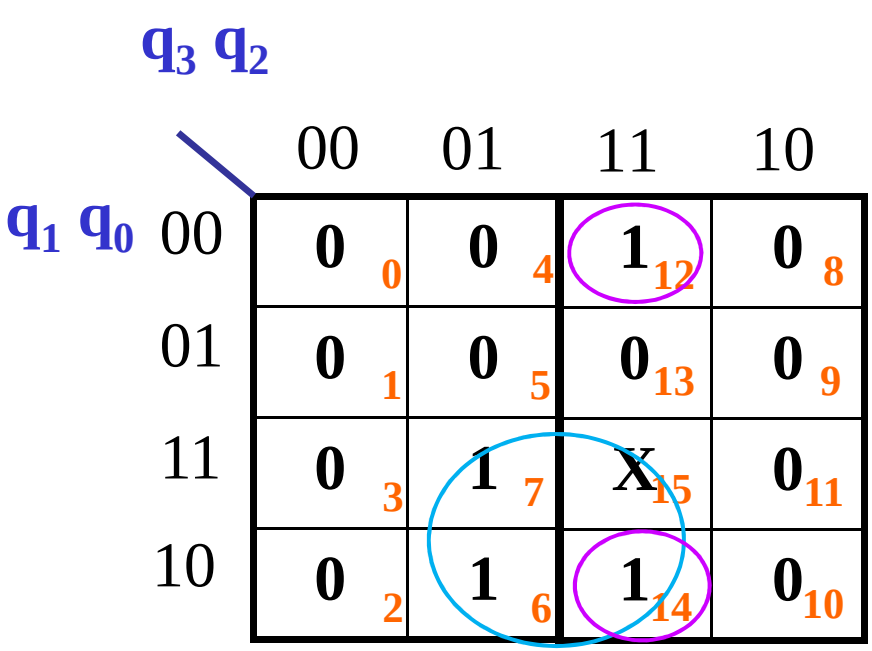


X2

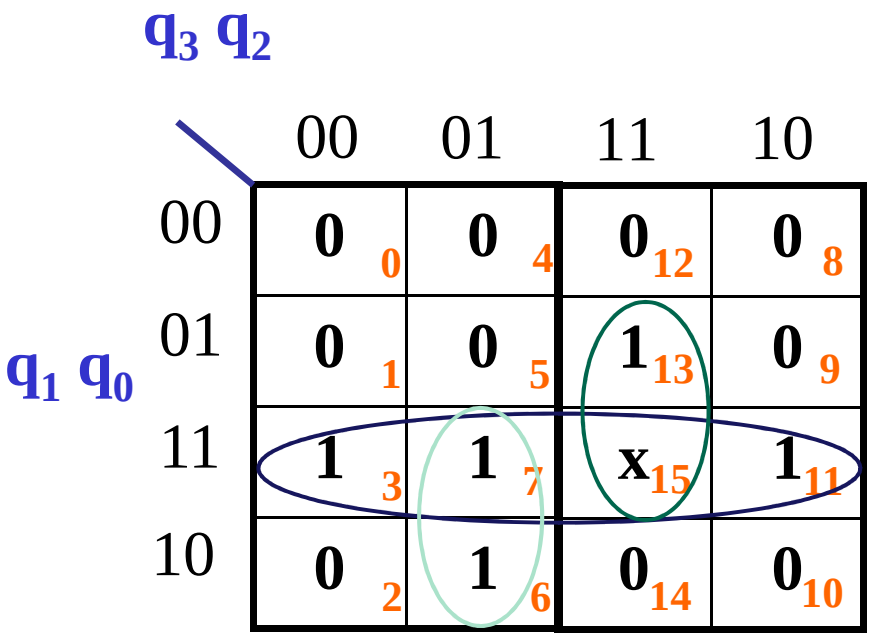


$$C_3 = X1(nq_3nq_2nq_1+q_3q_2q_0+nq_3q_2q_1+nq_3q_1q_0) + X2 (nq_3nq_2nq_1+q_3q_2q_0+nq_3q_2q_1+nq_3q_1q_0)$$

X1

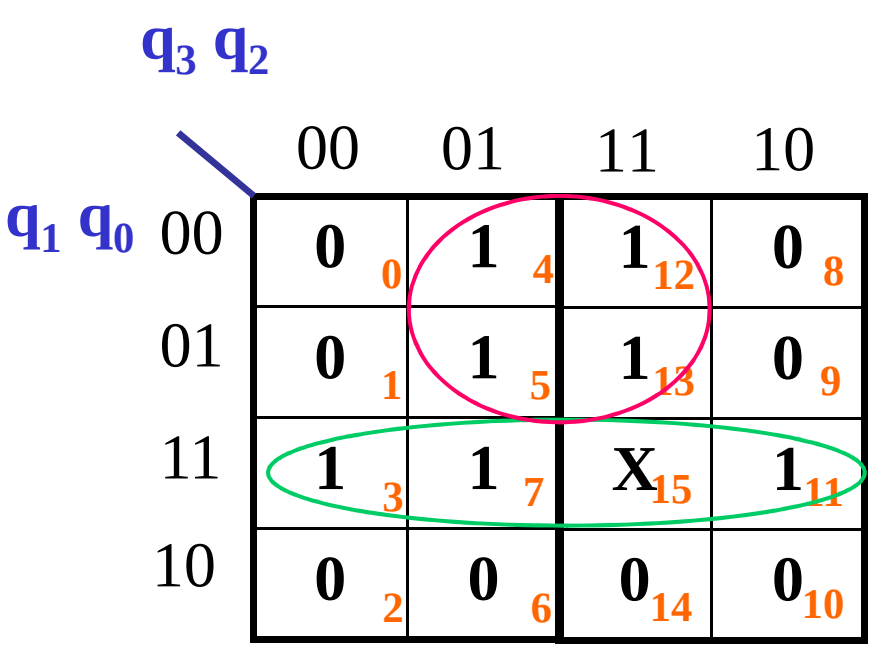


X2

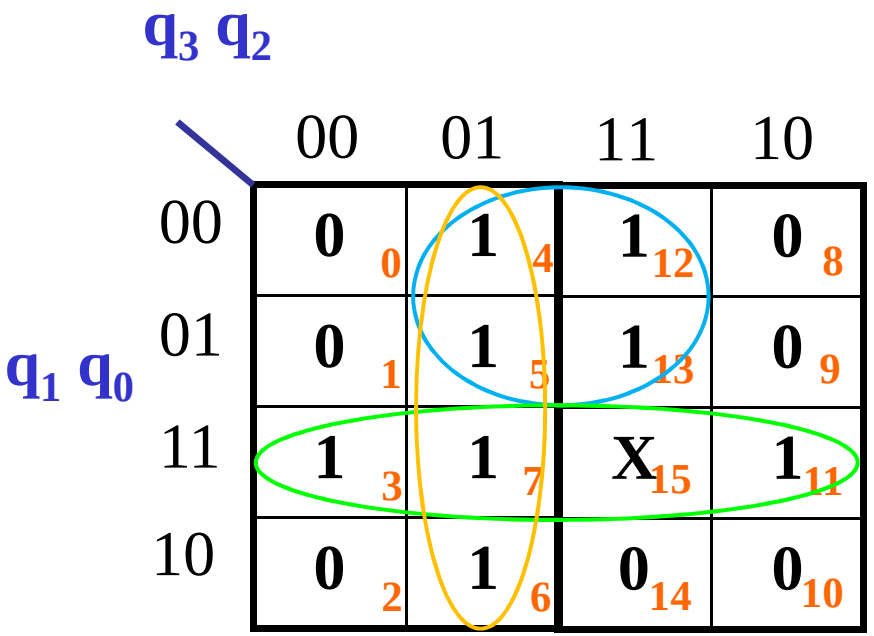


$$C_2 = X1(q_2q_1 + q_3q_2nq_0) + X2 (nq_3q_2q_1 + q_3q_2q_0 + q_1q_0)$$

X1

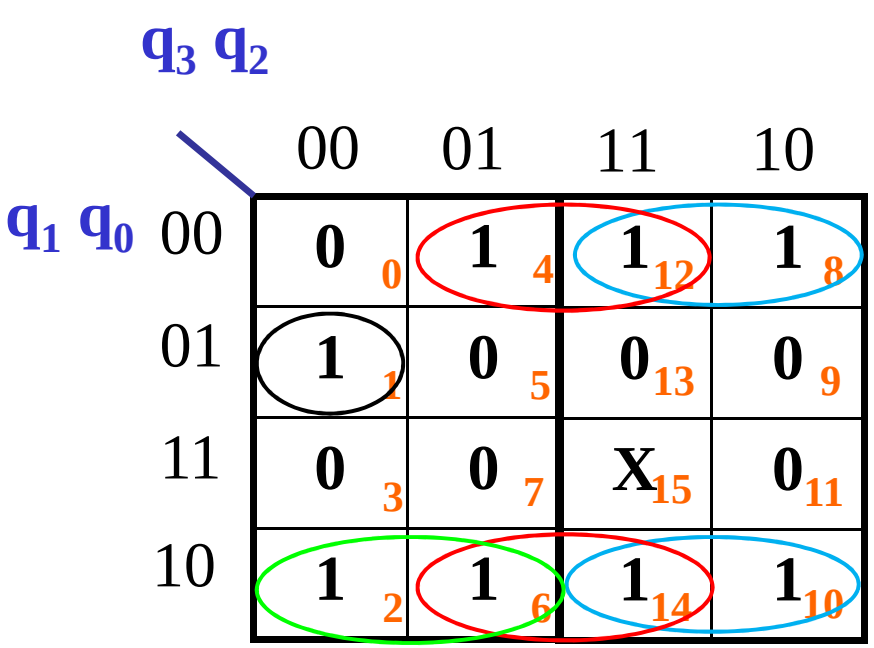


X2

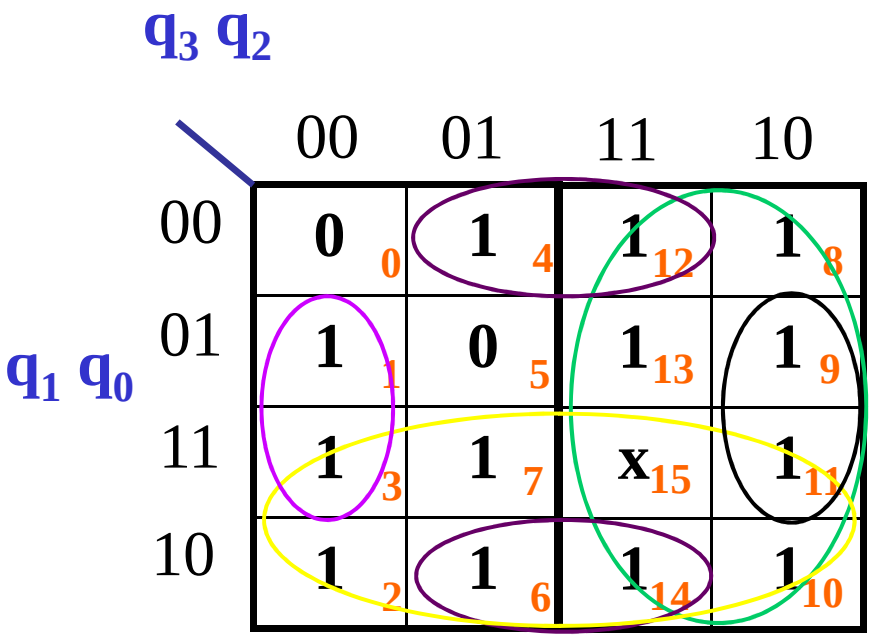


$$C_1 = X1(q_2 n q_1 + q_1 q_0) + X2(q_2 n q_1 + q_1 q_0 + n q_3 q_2)$$

X1



X2



$$C_0 = X1(nq_3nq_2nq_1q_0 + q_3nq_0 + q_2nq_0nq_3q_1nq_0) + X2(q_1 + q_3 + nq_2q_0 + q_2nq_0)$$

Una vez obtenidas las ecuaciones de excitación y de salida, se puede dibujar el diagrama lógico del circuito.

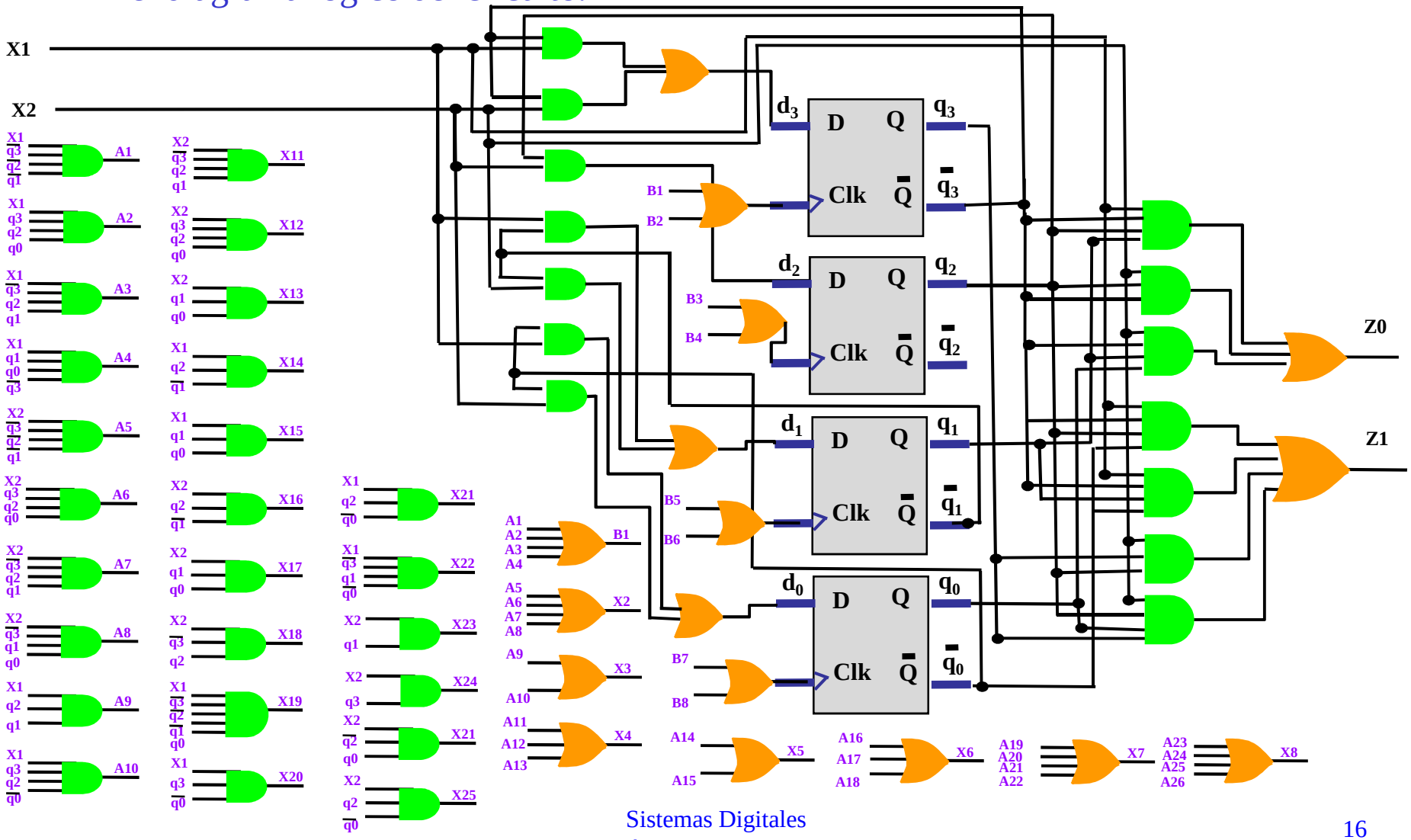


Diagrama de simulación

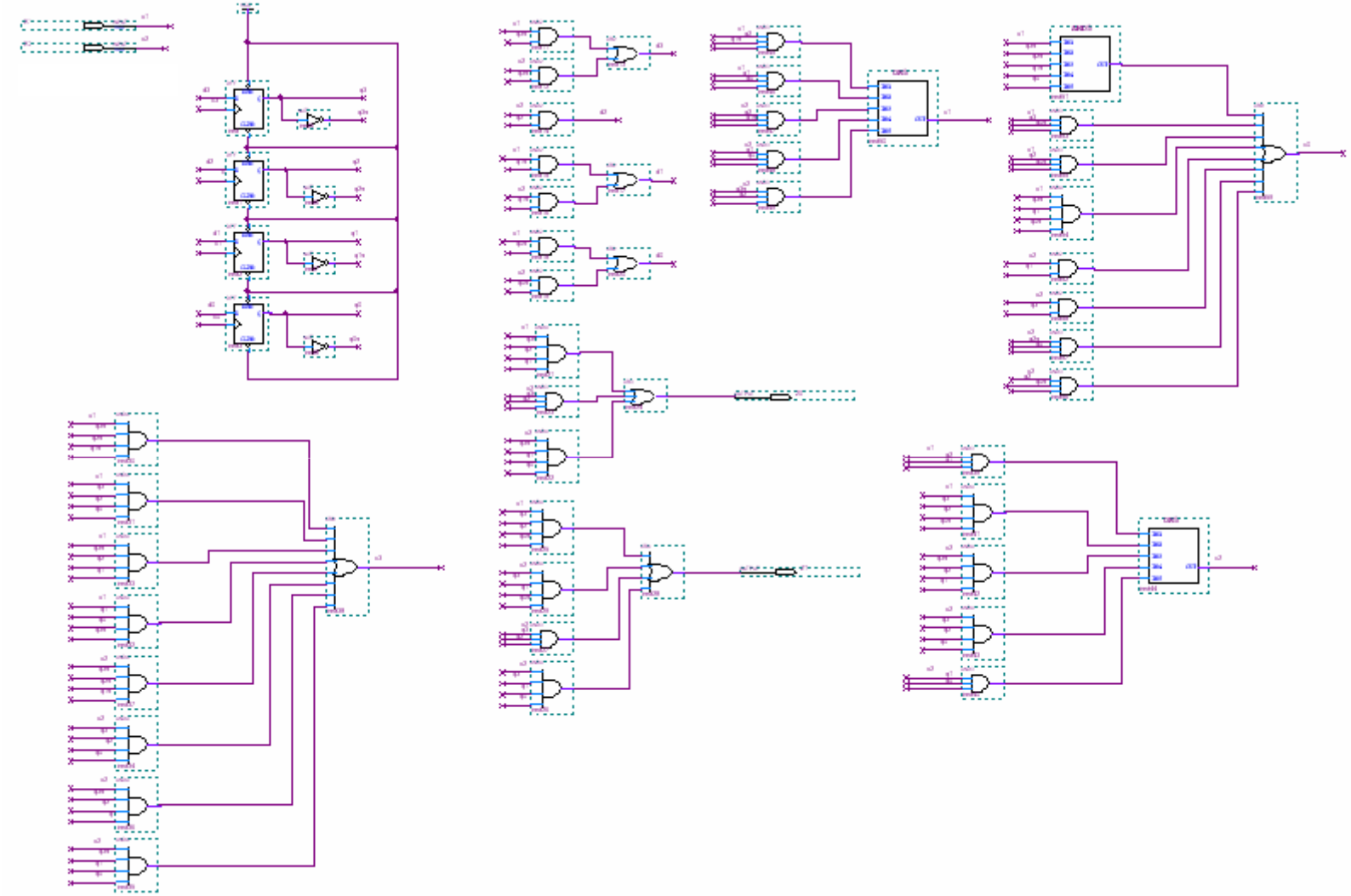


Diagrama de tiempo

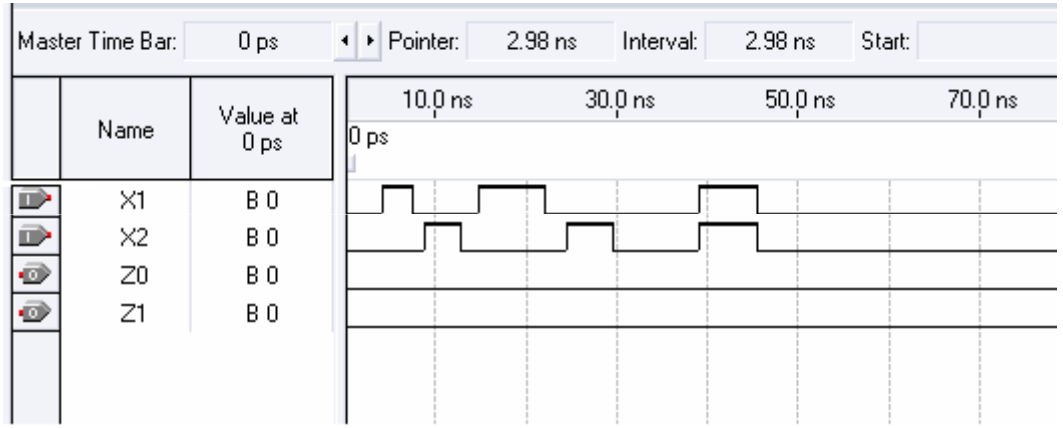


Tabla de estados para el FF T

$q_3\ q_2\ q_1\ q_0$	$q_{3+}\ q_{2+}\ q_{1+}\ q_{0+}$ /	$Z_1\ Z_0$	$q_{3+}\ q_{2+}\ q_{1+}\ q_{0+}$ /	$Z_1\ Z_0$	$T_3\ T_2\ T_1\ T_0$	$T_3\ T_2\ T_1\ T_0$
0 0 0 0	1 0 0 0	0 0	0 0 0 1	0 0	1 0 0 0	0 0 0 1
0 0 0 1	1 0 0 0	0 0	0 0 1 0	0 0	1 0 0 1	0 0 1 1
0 0 1 0	0 0 1 1	0 0	0 0 1 0	0 0	0 0 0 1	0 0 0 0
0 0 1 1	1 0 0 1	0 0	0 1 0 0	0 1	1 0 1 0	0 1 1 1
0 1 0 0	0 1 1 1	0 1	0 1 1 0	0 1	0 0 1 1	0 0 1 0
0 1 0 1	0 1 1 1	0 1	0 1 0 1	0 1	0 0 1 0	0 0 0 0
0 1 1 0	1 0 1 1	00*	0 1 0 1	0 1	1 1 0 1	0 0 1 1
0 1 1 1	1 0 0 1	0 0	0 1 0 0	0 1	1 1 1 0	0 0 1 1
1 0 0 0	1 0 0 1	0 0	0 0 0 1	0 0	0 0 0 1	1 0 0 1
1 0 0 1	1 0 0 1	0 0	1 0 1 0	0 0	0 0 0 0	0 0 1 1
1 0 1 0	1 0 1 1	1 0	0 0 1 0	0 0	0 0 0 1	1 0 0 0
1 0 1 1	1 0 0 1	0 0	1 1 0 0	1 0	0 0 1 0	0 1 1 1
1 1 0 0	1 0 1 1	1 0	1 1 0 1	1 0	0 1 1 1	0 0 0 1
1 1 0 1	0 1 1 1	00*	1 1 1 0	1 0	1 0 1 0	0 0 1 1
1 1 1 0	1 0 1 1	1 0	1 1 1 0	1 0	0 1 0 1	0 0 0 0
1 1 1 1	x x x x	x x	x x x x	x x	X X X X	X X X X

Mapas de K

X1

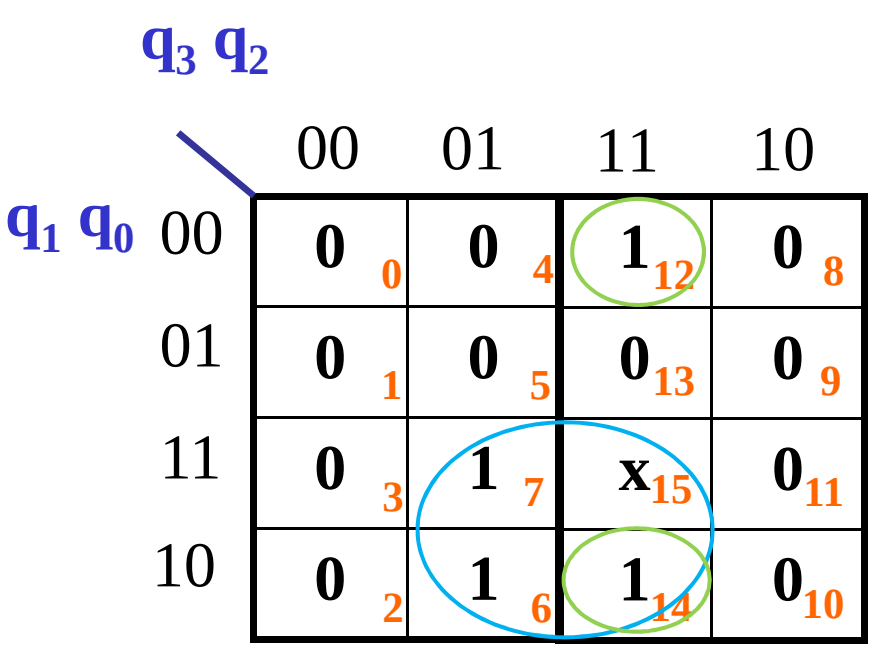
$q_1\,q_0$ \ $q_3\,q_2$	00	01	11	10
00	1 0	0 4	0 12	0 8
01	1 1	0 5	1 13	0 9
11	1 3	1 7	x 15	0 11
10	0 2	1 6	0 14	0 10

X2

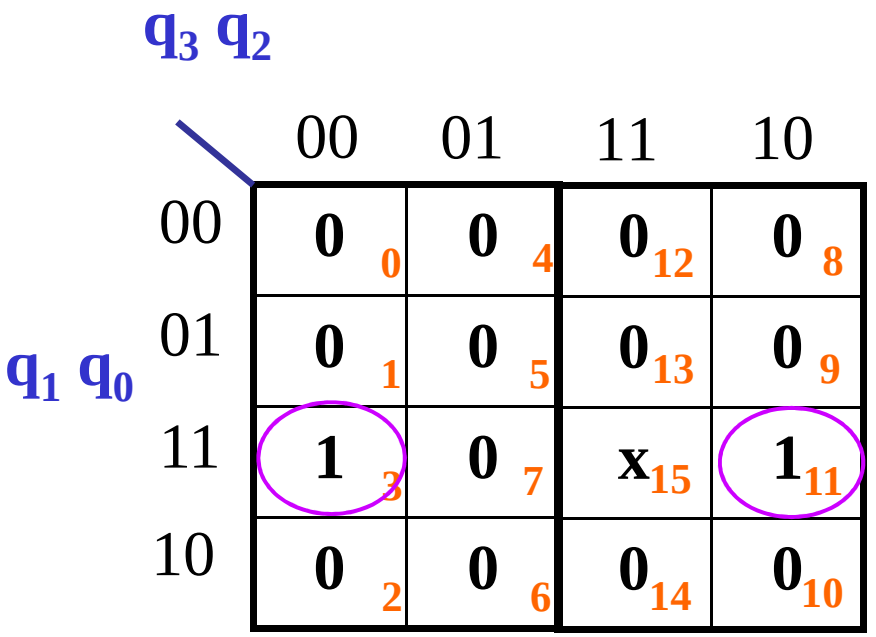
$q_1\,q_0$ \ $q_3\,q_2$	00	01	11	10
00	0 0	0 4	0 12	1 8
01	0 1	0 5	0 13	0 9
11	0 3	0 7	x 15	0 11
10	0 2	0 6	0 14	1 10

$$T_3 = X1(\, nq_3nq_2nq_1 + nq_3q_1q_0 + q_3q_2q_0\,) + X2\,(\, q_3nq_2nq_0 + \,)$$

X1

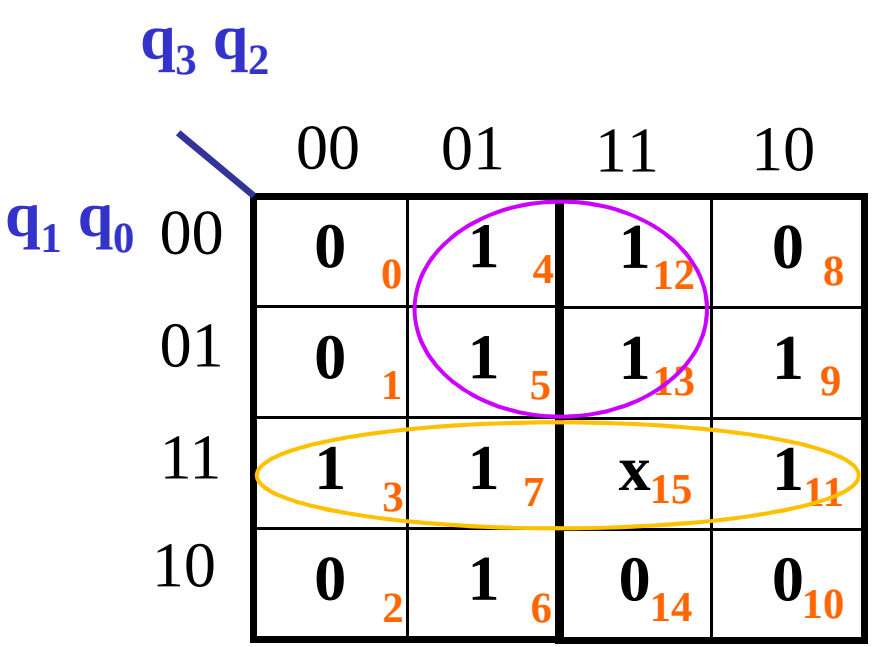


X2

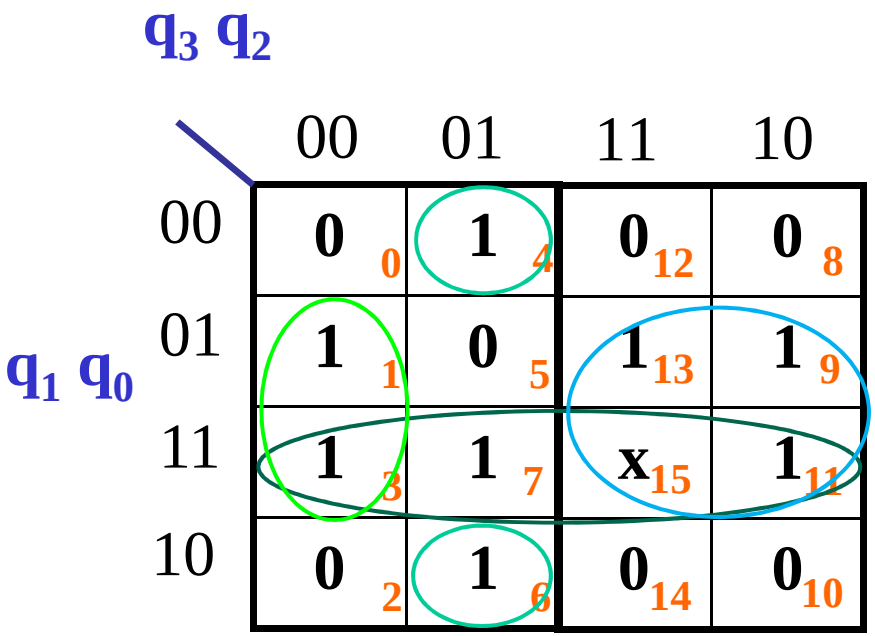


$$T_2 = X1(q_1q_2 + q_3q_2nq_0) + X2 (nq_2q_1q_0)$$

X1

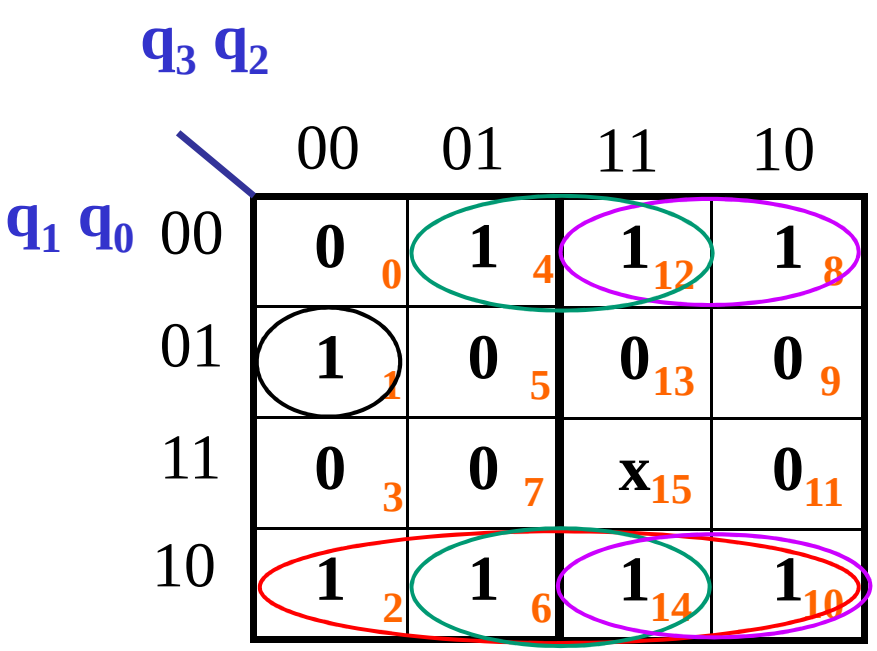


X2

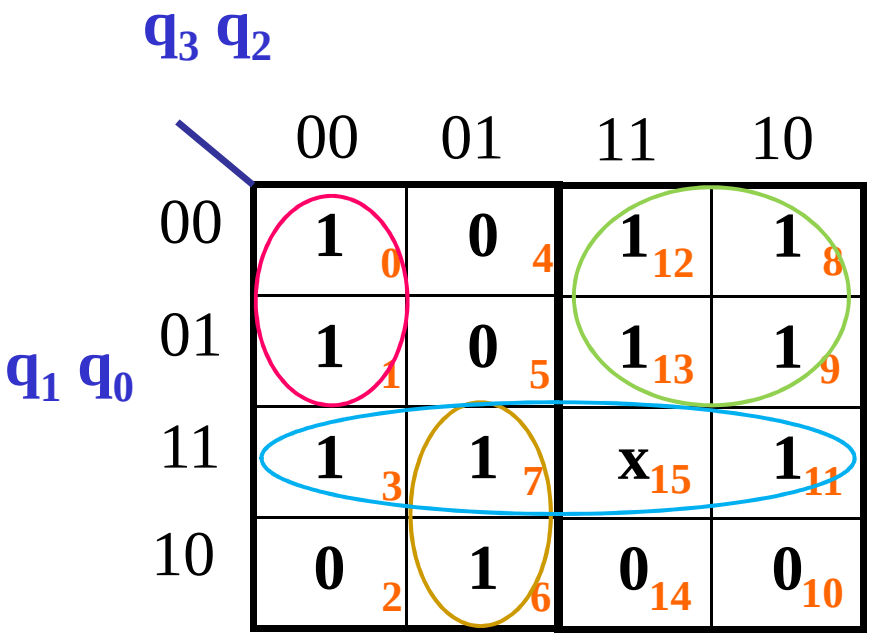


$$T_1 = X1(q_2 n q_1 + q_1 q_0) + X2\,(q_3 q_0 + n q_3 n q_2 q_0 + q_1 q_0 + n q_3 q_2 n q_0)$$

X1



X2



$$T_0 = X1\,(q_3nq_0 + q_2nq_0 + q_1nq_0 + nq_3nq_2nq_1q_0) + X2\,(q_3nq_1 + q_1q_0 + nq_3nq_2nq_1 + nq_3q_2q_1)$$

X1

$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	0 0	0 4	1 12	0 8
01	0 1	0 5	0 13	0 9
11	0 3	0 7	0 15	0 11
10	0 2	0 6	1 14	0 10

X2

$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	0 0	0 4	1 12	0 8
01	0 1	0 5	1 13	0 9
11	0 3	0 7	1 15	1 11
10	0 2	0 6	1 14	0 10

$$Z_1 = X_1(q_3q_2nq_0 + q_3q_1nq_0) + X2 (q_3q_2 + q_3q_1q_0)$$

X1

$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	0 0	1 4	0 12	0 8
01	0 1	1 5	0 13	0 9
11	0 3	0 7	x 15	0 11
10	0 2	0 6	0 14	0 10

X2

$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	0 0	1 4	0 12	0 8
01	0 1	1 5	0 13	0 9
11	1 3	1 7	x 15	0 11
10	0 2	1 6	0 14	0 10

$$Z_0 = X1(nq_3q_2q_1) + X2 (nq_3q_2 + nq_3q_1q_0)$$

Una vez obtenidas las ecuaciones de excitación y de salida, se puede dibujar el diagrama lógico del circuito.

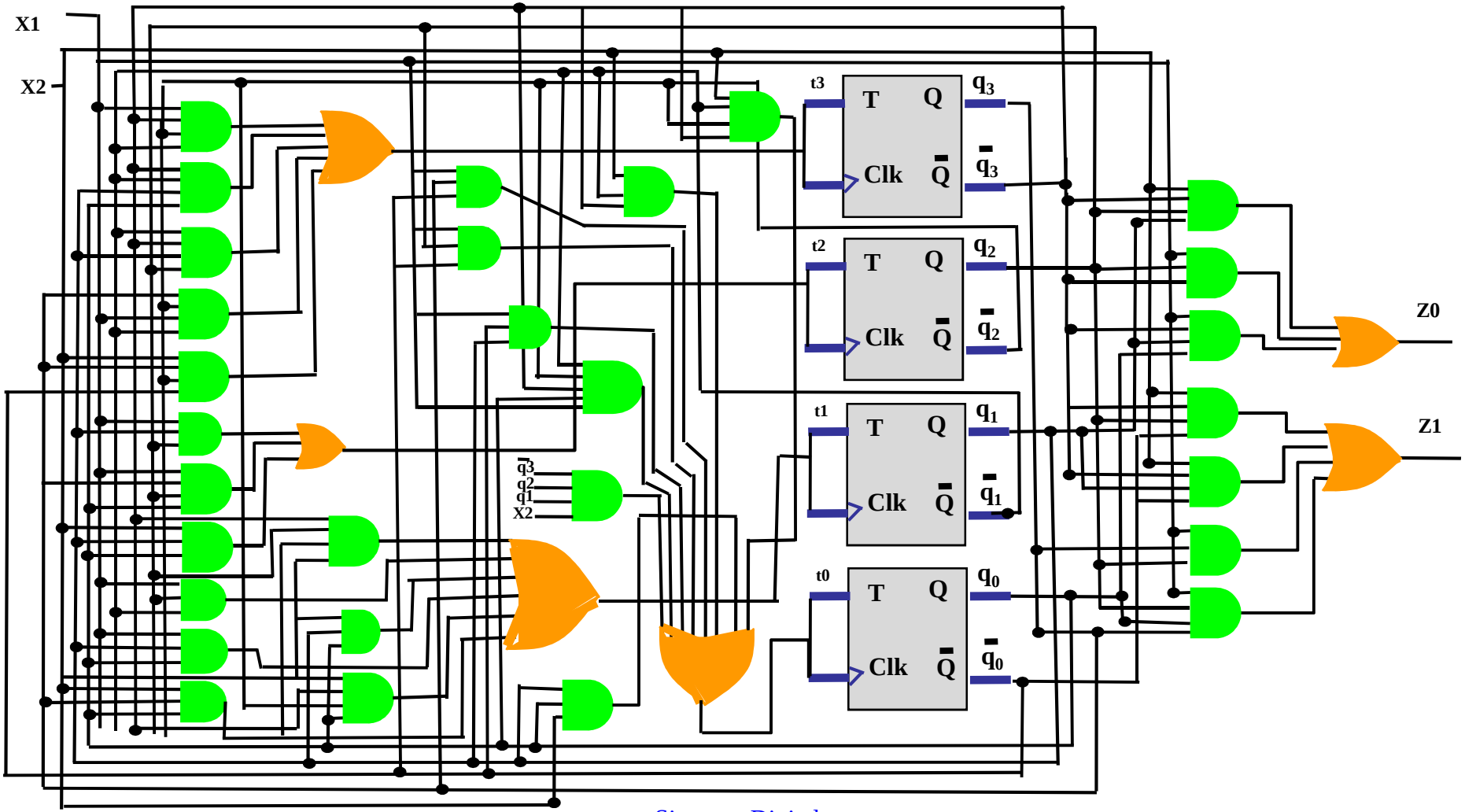


Diagrama de simulación

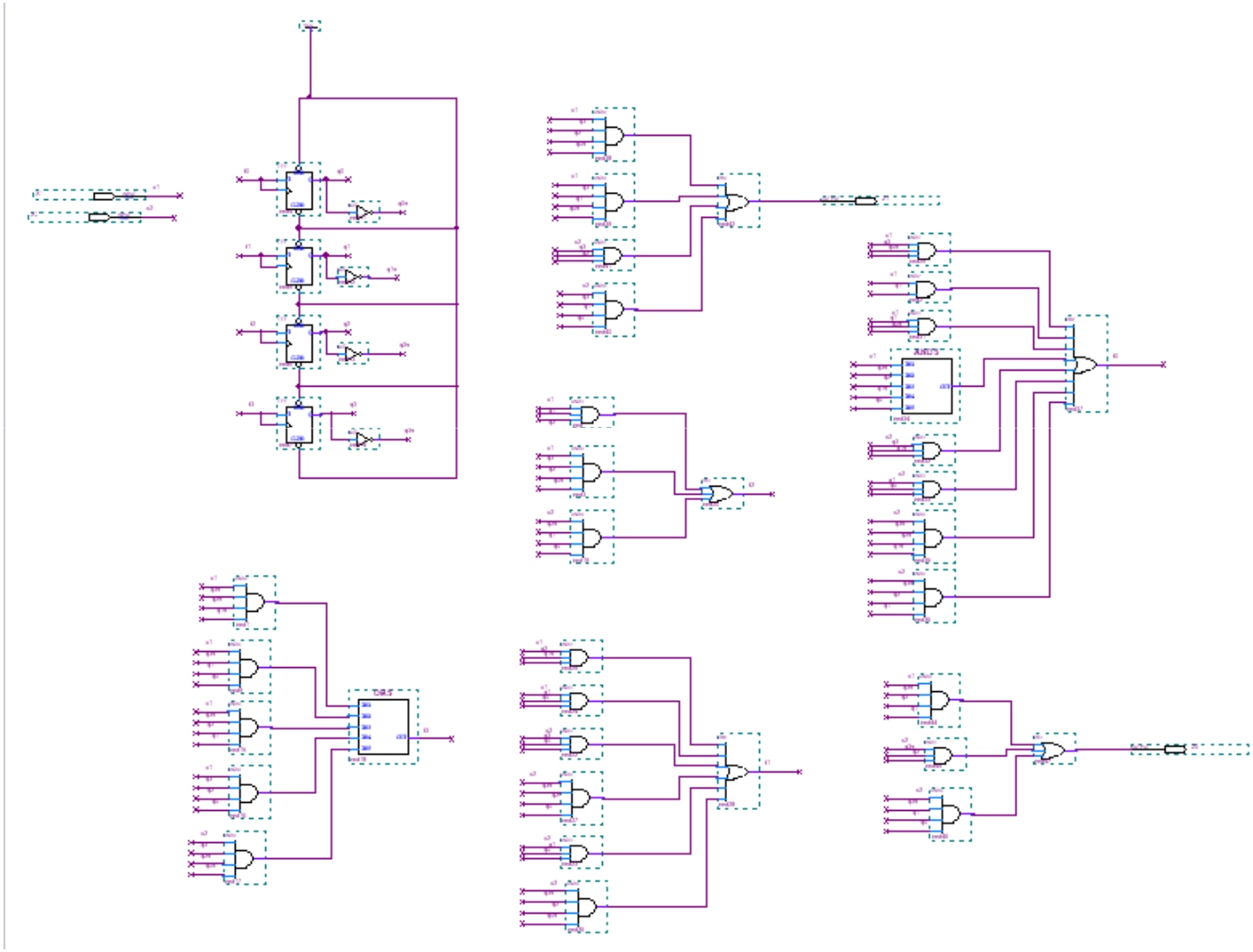


Diagrama de tiempo

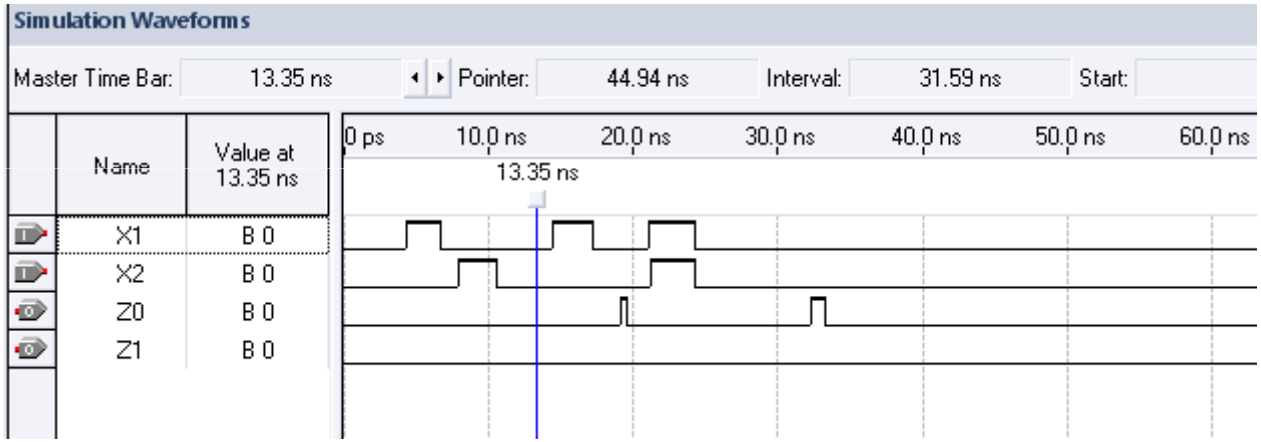


Tabla de estados para el FF JK

$q_3\ q_2\ q_1\ q_0$	$J_3\ K_3\ J_2\ K_2$	$J_1\ K_1\ J_0\ K_0$ / $Z_1\ Z_0$	$J_3\ K_3\ J_2\ K_2$	$J_1\ K_1\ J_0\ K_0$ / $Z_1\ Z_0$
0 0 0 0	1 X 0 X	0 X 0 X / 0 0	0 X 0 X	0 X 1 X / 0 0
0 0 0 1	1 X 0 X	X 1 X 1 / 0 0	0 X 0 X	1 X X 1 / 0 0
0 0 1 0	0 X 0 X	X 0 1 X / 0 0	0 X 0 X	X 0 0 X / 0 0
0 0 1 1	1 X 0 X	X 1 X 0 / 0 0	0 X 1 X	X 1 X 1 / 0 1
0 1 0 0	0 X X 0	1 X 1 X / 0 1	0 X X 0	1 X 0 X / 0 1
0 1 0 1	0 X X 0	1 X X 0 / 0 1	0 X X 0	0 X X 0 / 0 1
0 1 1 0	1 X X 1	X 0 1 X / 00*	0 X X 0	X 1 1 X / 0 1
0 1 1 1	1 X X 1	X 1 X 0 / 0 0	0 X X 0	X 1 X 1 / 0 1
1 0 0 0	X 0 0 X	0 X 1 X / 0 0	X 1 0 X	0 X 1 X / 0 0
1 0 0 1	X 0 0 X	0 X X 0 / 0 0	X 0 0 X	1 X X 1 / 0 0
1 0 1 0	X 0 0 X	X 0 1 X / 1 0	X 1 0 X	X 0 0 X / 0 0
1 0 1 1	X 0 0 X	X 1 X 0 / 0 0	X 0 1 X	X 1 X 1 / 1 0
1 1 0 0	X 0 X 1	1 X 1 X / 1 0	X 0 X 0	0 X 1 X / 1 0
1 1 0 1	X 1 X 0	1 X X 0 / 00*	X 0 X 0	1 X X 1 / 1 0
1 1 1 0	X 0 X 1	X 0 1 X / 1 0	X 0 X 0	X 0 0 X / 1 0
1 1 1 1	X X X X	X X X X / X X	X X X X	x x x x / x x

Mapas de K

X1

$q_3\ q_2$

$q_1\ q_0$	00	01	11	10
00	1 0	0 4	X 12	X 8
01	1 1	0 5	X 13	X 9
11	1 3	1 7	X 15	X 11
10	0 2	1 6	X 14	X 10

X2

$q_3\ q_2$

$q_1\ q_0$	00	01	11	10
00	0 0	0 4	X 12	X 8
01	0 1	0 5	X 13	X 9
11	0 3	0 7	X 15	X 11
10	0 2	0 6	X 14	X 10

$J_3 = X1\ (\ nq_2nq_1 + q_0q_1 + q_2q_1\ )$

X1

$q_3\ q_2$ \ $q_1\ q_0$

	00	01	11	10
00	X 0	X 4	0 12	0 8
01	X 1	X 5	1 13	0 9
11	X 3	X 7	X 15	0 11
10	X 2	X 6	0 14	0 10

X2

$q_3\ q_2$ \ $q_1\ q_0$

	00	01	11	10
00	X 0	X 4	0 12	1 8
01	X 1	X 5	0 13	0 9
11	X 3	X 7	X 15	0 11
10	X 2	X 6	0 14	1 10

$$k_3 = X1\ (q_2 q_0) + X2\ (n q_2 n q_0)$$

X1

$q_3\ q_2$

$q_1\ q_0$	00	01	11	10
00	**0** 0	**X** 4	**X**12	**0** 8
01	**0** 1	**X** 5	**X**13	**0** 9
11	**0** 3	**X** 7	**X**15	**0**11
10	**0** 2	**X** 6	**X**14	**0**10

X2

$q_3\ q_2$

$q_1\ q_0$	00	01	11	10
00	**0** 0	**X** 4	**X**12	**0** 8
01	**0** 1	**X** 5	**X**13	**0** 9
11	**1** 3	**X** 7	**X**15	**1**11
10	**X** 2	**X** 6	**X**14	**X**10

$J_2 = X2\ (\ q_1 q_0\ )$

X1

$q_3\ q_2$

$q_1\ q_0$	00	01	11	10
00	X 0	0 4	1 12	X 8
01	X 1	0 5	0 13	X 9
11	X 3	x 7	X 15	X 11
10	X 2	1 6	1 14	X 10

X2

$q_3\ q_2$

$q_1\ q_0$	00	01	11	10
00	X 0	0 4	0 12	X 8
01	X 1	0 5	0 13	X 9
11	X 3	0 7	X 15	X 11
10	X 2	0 6	0 14	X 10

$K_2 = X1\ (q_1 + q_3 q_2\ nq_0)$

X1

$q_3\ q_2$

$q_1\ q_0$	00	01	11	10
00	0 0	1 4	1 12	0 8
01	0 1	1 5	1 13	0 9
11	X 3	X 7	X 15	X 11
10	X 2	X 6	X 14	X 10

X2

$q_3\ q_2$

$q_1\ q_0$	00	01	11	10
00	0 0	1 4	0 12	0 8
01	1 1	0 5	1 13	1 9
11	X 3	X 7	X 15	X 11
10	X 2	X 6	X 14	X 10

$$J_1 = X1\ (\ q_2\ ) + X2\ (\ nq_3q_2nq_0 + q_0q_3 + nq_2nq_1q_0\ )$$

X1

$q_3\ q_2$

$q_1\ q_0$	00	01	11	10
00	X 0	X 4	X 12	X 8
01	X 1	X 5	X 13	X 9
11	1 3	1 7	X 15	1 11
10	0 2	0 6	0 14	0 10

X2

$q_3\ q_2$

$q_1\ q_0$	00	01	11	10
00	X 0	X 4	X 12	X 8
01	X 1	X 5	X 13	X 9
11	1 3	1 7	X 15	1 11
10	0 2	1 6	0 14	0 10

$$K_1 = X1\ (\ q_0\ ) + X2\ (\ q_0 + nq_3q_2\ )$$

X1

$q_3\ q_2$

$q_1\ q_0$	00	01	11	10
00	0 (0)	1 (4)	X (12)	1 (8)
01	X (1)	X (5)	0 (13)	X (9)
11	X (3)	X (7)	X (15)	X (11)
10	1 (2)	1 (6)	1 (14)	1 (10)

X2

$q_3\ q_2$

$q_1\ q_0$	00	01	11	10
00	1 (0)	0 (4)	1 (12)	1 (8)
01	X (1)	X (5)	X (13)	X (9)
11	X (3)	X (7)	X (15)	X (11)
10	0 (2)	1 (6)	0 (14)	0 (10)

$$J_0 = X1\,(\,q_1 n q_0 + n q_3 q_2 + q_3 n q_2\,) + X2\,(\,n q_2 n q_1 + q_3 + n q_1 + n q_3 q_2 q_1\,)$$

X1

$q_3\ q_2$

$q_1\ q_0$	00	01	11	10
00	X 0	X 4	0 12	X 8
01	1 1	0 5	X 13	0 9
11	0 3	0 7	X 15	0 11
10	X 2	X 6	X 14	X 10

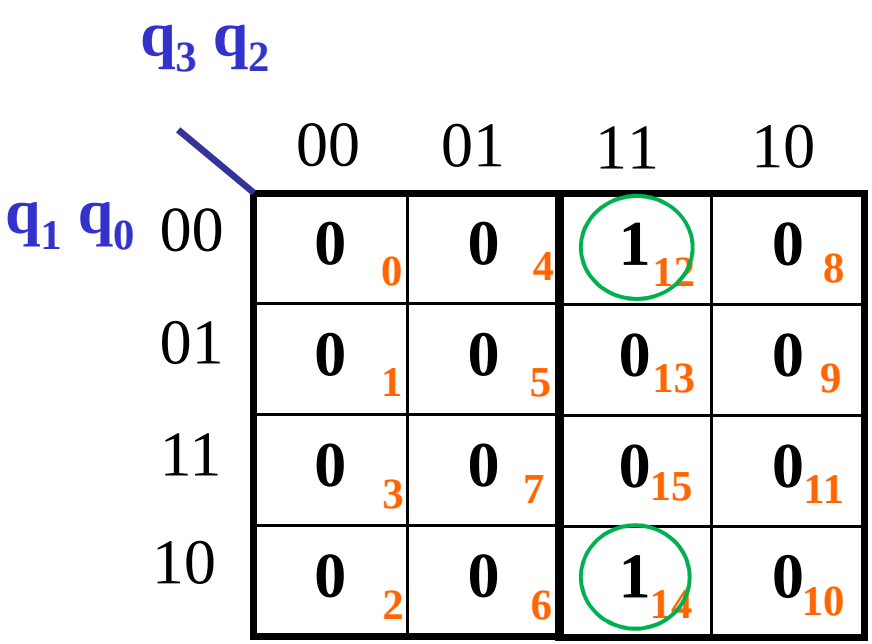
X2

$q_3\ q_2$

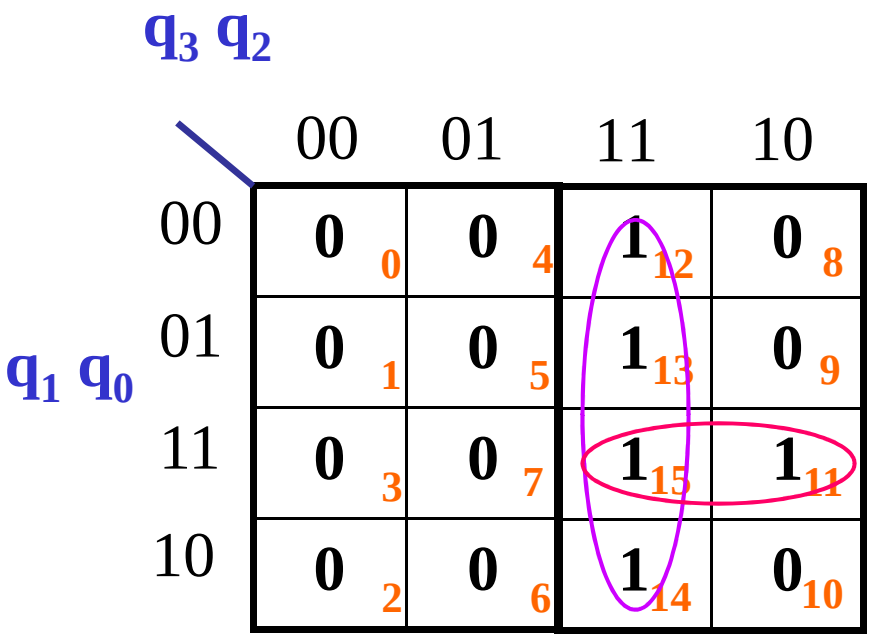
$q_1\ q_0$	00	01	11	10
00	X 0	X 4	X 12	X 8
01	1 1	0 5	1 13	1 9
11	1 3	1 7	X 15	1 11
10	X 2	X 6	X 14	X 10

$$K_0 = X1\,(\,nq_3nq_2nq_1\,) + X2\,(\,q_1 + q_3nq_1 + nq_2q_0\,)$$

X1



X2



$$Z_1 = X_1(q_3q_2nq_0 + q_3q_1nq_0) + X2\ (q_3q_2 + q_3q_1q_0)$$

X1

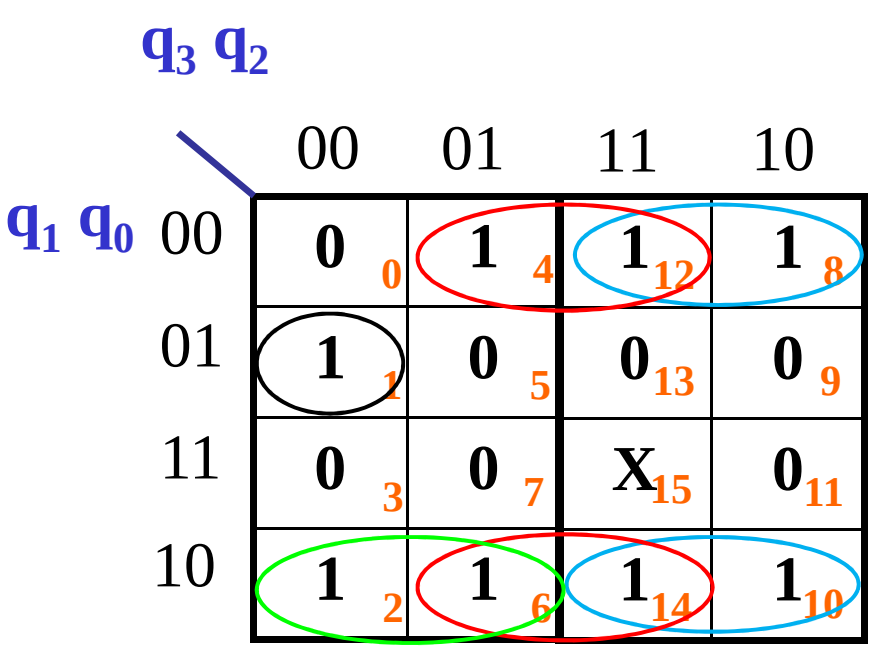
$q_3\,q_2$ / $q_1\,q_0$	00	01	11	10
00	0 (0)	1 (4)	0 (12)	0 (8)
01	0 (1)	1 (5)	0 (13)	0 (9)
11	0 (3)	0 (7)	x (15)	0 (11)
10	0 (2)	0 (6)	0 (14)	0 (10)

X2

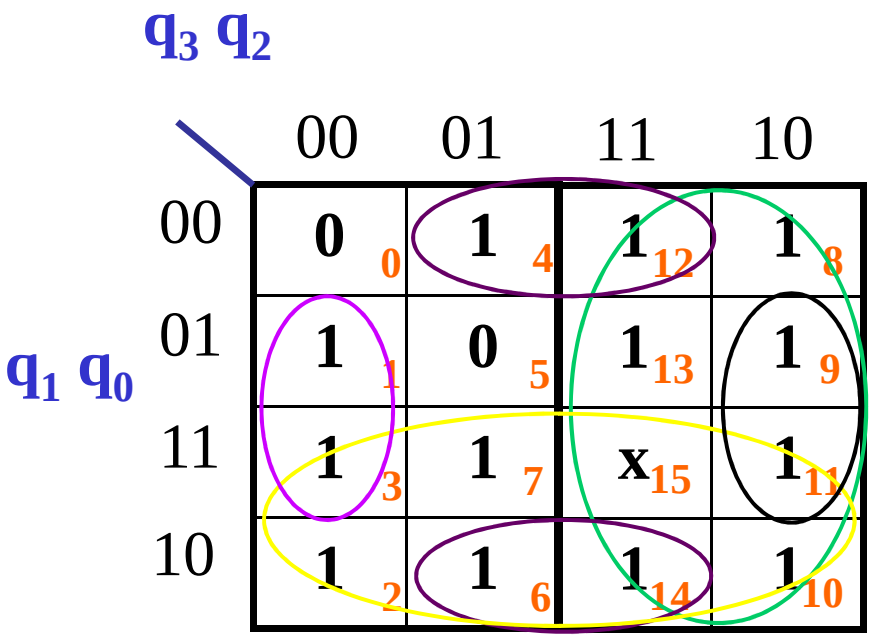
$q_3\,q_2$ / $q_1\,q_0$	00	01	11	10
00	0 (0)	1 (4)	0 (12)	0 (8)
01	0 (1)	1 (5)	0 (13)	0 (9)
11	1 (3)	1 (7)	x (15)	0 (11)
10	0 (2)	1 (6)	0 (14)	0 (10)

$$Z_0 = X1(nq_3q_2q_1) + X2 (nq_3q_2 + nq_3q_1q_0)$$

X1



X2



$$C_0 = X1(nq_3nq_2nq_1q_0 + q_3nq_0 + q_2nq_0nq_3q_1nq_0) + X2(q_1 + q_3 + nq_2q_0 + q_2nq_0)$$

X1

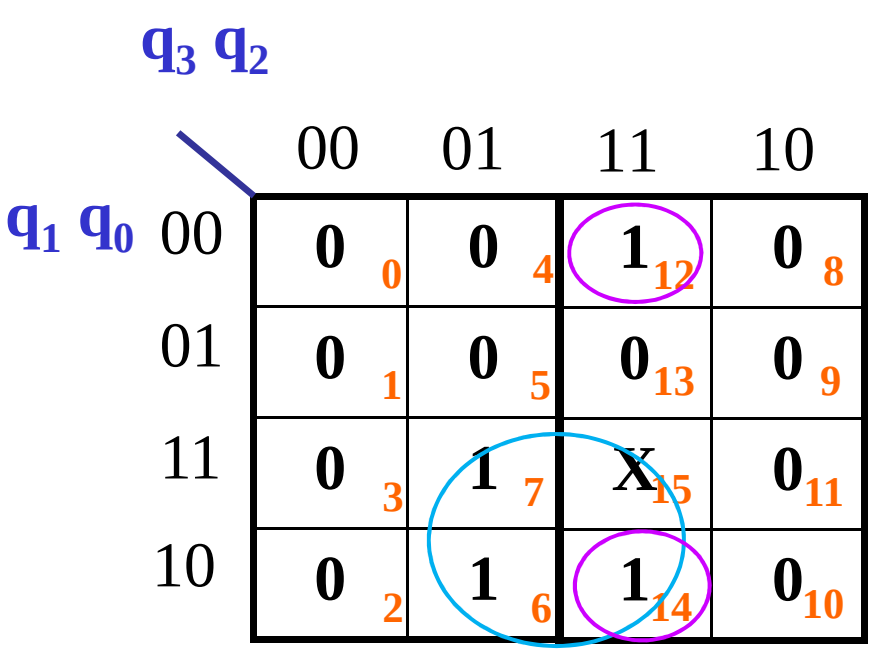
$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	0 0	1 4	1 12	0 8
01	0 1	1 5	1 13	0 9
11	1 3	1 7	X 15	1 11
10	0 2	0 6	0 14	0 10

X2

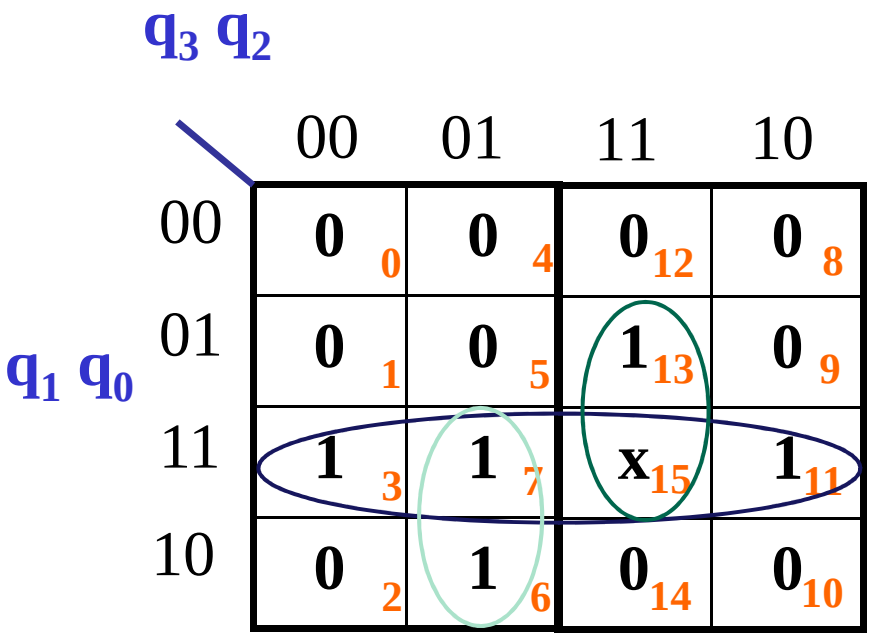
$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	0 0	1 4	1 12	0 8
01	0 1	1 5	1 13	0 9
11	1 3	1 7	X 15	1 11
10	0 2	1 6	0 14	0 10

$$C_1 = X1(q_2 n q_1 + q_1 q_0) + X2(q_2 n q_1 + q_1 q_0 + n q_3 q_2)$$

X1

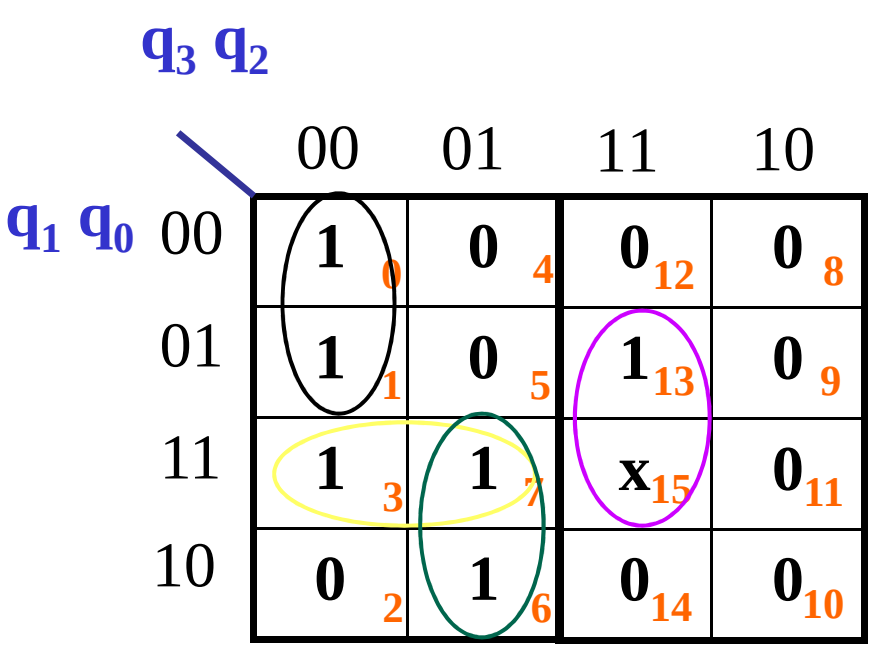


X2

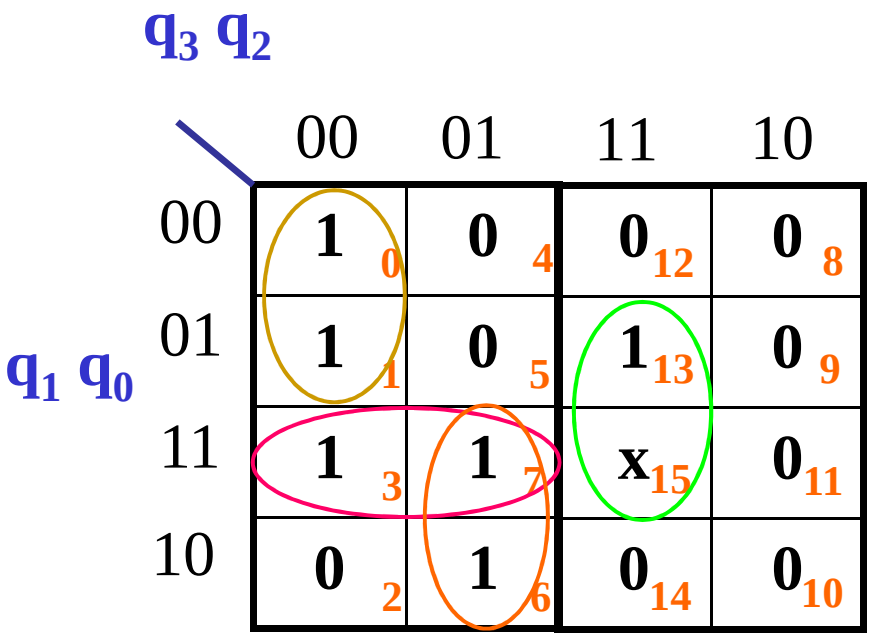


$$C_2 = X1(q_2q_1 + q_3q_2nq_0) + X2 (nq_3q_2q_1 + q_3q_2q_0 + q_1q_0)$$

X1



X2



$$C_3 = X1(nq_3nq_2nq_1+q_3q_2q_0+nq_3q_2q_1+nq_3q_1q_0) + X2 (nq_3nq_2nq_1+q_3q_2q_0+nq_3q_2q_1+nq_3q_1q_0)$$

Diagrama de simulación

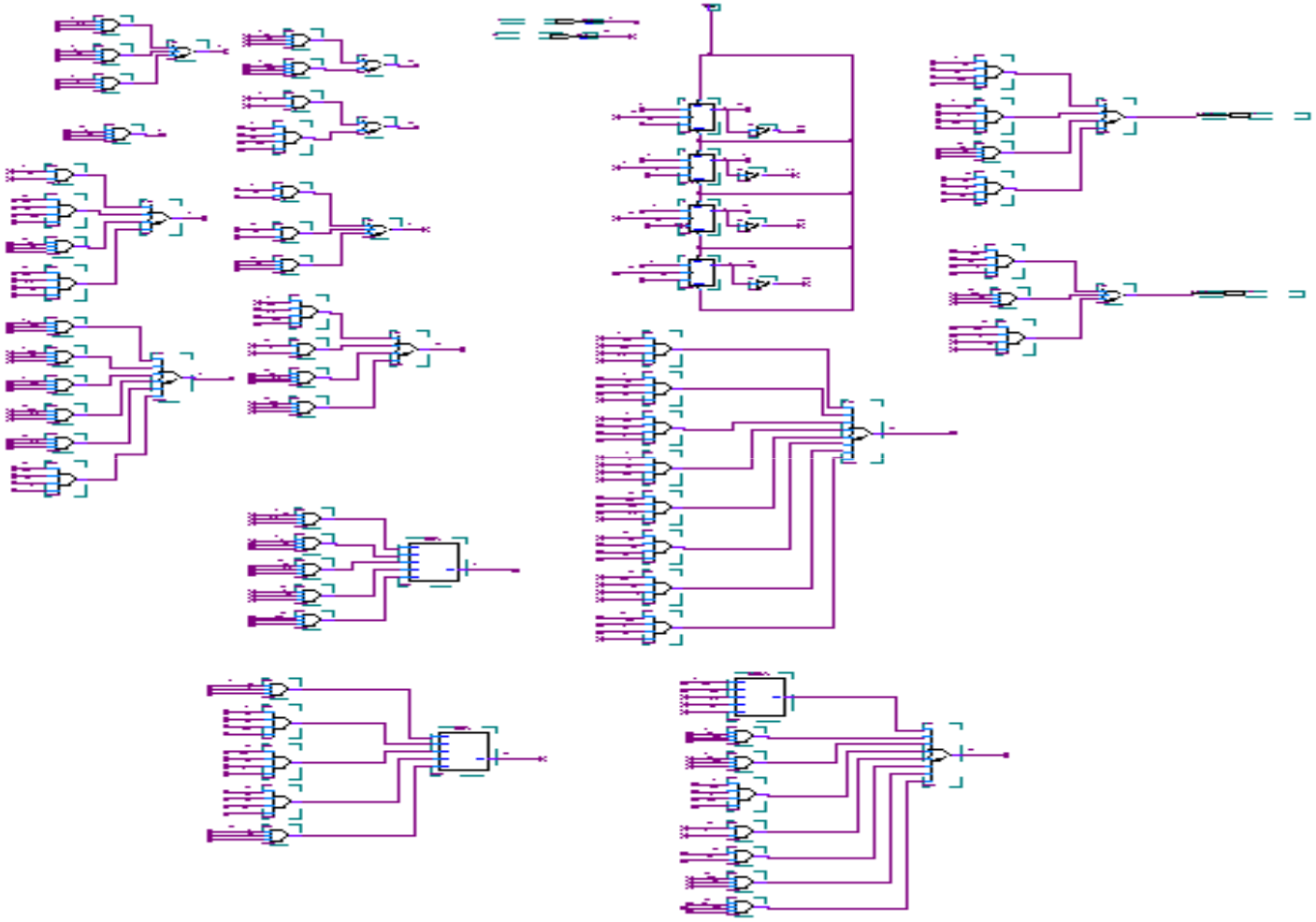


Diagrama de tiempo

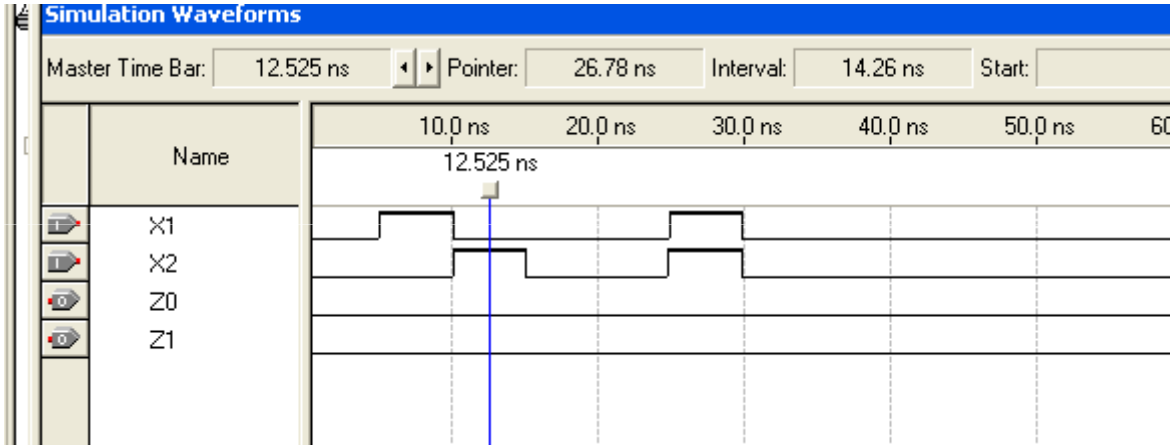


Tabla de Estados para el FF D

	X1	X2		
$q_3\ q_2\ q_1\ q_0$	$q_{3+}\ q_{2+}\ q_{1+}\ q_{0+}$ / $Z_1\ Z_0$	$q_{3+}\ q_{2+}\ q_{1+}\ q_{0+}$ / $Z_1\ Z_0$	$D_3\ D_2\ D_1\ D_0$	$D_3\ D_2\ D_1\ D_0$
0 0 0 0	1 0 0 0 / 0 0	0 0 0 1 / 0 0	1 x x x	1 x x x
0 0 0 1	1 0 0 0 / 0 0	0 0 1 0 / 0 0	1 x x 0	1 x x 0
0 0 1 0	0 0 1 1 / 0 0	0 0 1 0 / 0 0	x x x 1	x x x 1
0 0 1 1	1 0 0 1 / 0 0	0 1 0 0 / 0 1	1 x 0 x	1 1 0 0
0 1 0 0	0 1 1 1 / 0 1	0 1 1 0 / 0 1	x x 1 1	x x 1 1
0 1 0 1	0 1 1 1 / 0 1	0 1 0 1 / 0 1	x x 1 x	x x 1 x
0 1 1 0	1 0 1 1 / 00*	0 1 0 1 / 0 1	1 0 x 1	1 0 0 1
0 1 1 1	1 0 0 1 / 0 0	0 1 0 0 / 0 1	1 0 0 x	1 0 0 0
1 0 0 0	1 0 0 1 / 0 0	0 0 0 1 / 0 0	x x x 1	x x x 1
1 0 0 1	1 0 0 1 / 0 0	1 0 1 0 / 0 0	x x x x	x x x 0
1 0 1 0	1 0 1 1 / 1 0	0 0 1 0 / 0 0	x x x 1	x x x 1
1 0 1 1	1 0 0 1 / 0 0	1 1 0 0 / 1 0	x x 0 x	x 1 0 0
1 1 0 0	1 0 1 1 / 1 0	1 1 0 1 / 1 0	x 0 1 1	x 0 1 1
1 1 0 1	0 1 1 1 / 00*	1 1 1 0 / 1 0	0 x 1 x	0 x 1 0
1 1 1 0	1 0 1 1 / 1 0	1 1 1 0 / 1 0	x 0 x 1	x 0 x 1
1 1 1 1	x x x x / x x	x x x x / x x	x x x x	x x x x

Mapas de K

X1

$q_3\ q_2$

$q_1\ q_0$	00	01	11	10
00	1 0	x 4	x_{12}	X_8
01	1 1	x 5	0_{13}	X_9
11	1 3	1 7	X_{15}	X_{11}
10	x 2	1 6	X_{14}	X_{10}

X2

$q_3\ q_2$

$q_1\ q_0$	00	01	11	10
00	1 0	x 4	X_{12}	X_8
01	1 1	X 5	0_{13}	X_9
11	1 3	1 7	X_{15}	X_{11}
10	x 2	1 6	x_{14}	x_{10}

$$d_3 = X1\ (\ nq_3\ ) + X2\ (\ nq_1\ )$$

X1

$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	X 0	x 4	0 12	X 8
01	X 1	X 5	x 13	X 9
11	X 3	0 7	X 15	X 11
10	x 2	0 6	0 14	x 10

X2

$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	X 0	X 4	0 12	X 8
01	X 1	X 5	X 13	1 9
11	1 3	0 7	x 15	X 11
10	x 2	0 6	0 14	x 10

$d_2 = X2 (q_2)$

X1

$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	X 0	1 4	1 12	X 8
01	X 1	1 5	1 13	X 9
11	0 3	0 7	X 15	0 11
10	X 2	1 6	x 14	X 10

X2

$q_1 q_0$ \ $q_3 q_2$	00	01	11	10
00	X 0	1 4	1 12	X 8
01	x 1	1 5	1 13	X 9
11	0 3	0 7	X 15	0 11
10	X 2	0 6	x 14	x 10

$$d_1 = X1(nq_1) + X2 (nq_1)$$

X1

$q_3\ q_2$

$q_1\ q_0$	00	01	11	10
00	x 0	1 4	1 12	1 8
01	0 1	x 5	x 13	X 9
11	x 3	x 7	X 15	X 11
10	1 2	1 6	1 14	1 10

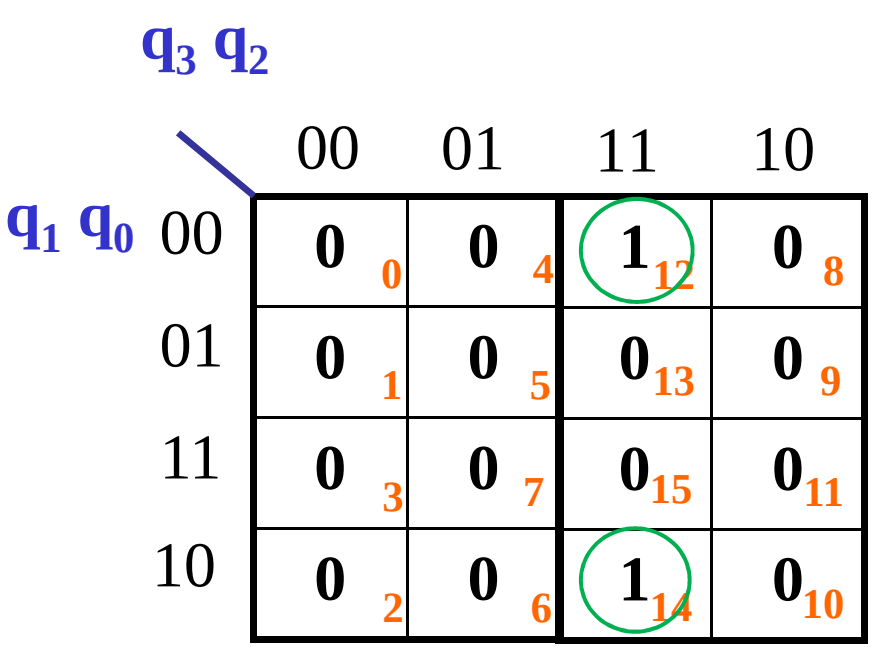
X2

$q_3\ q_2$

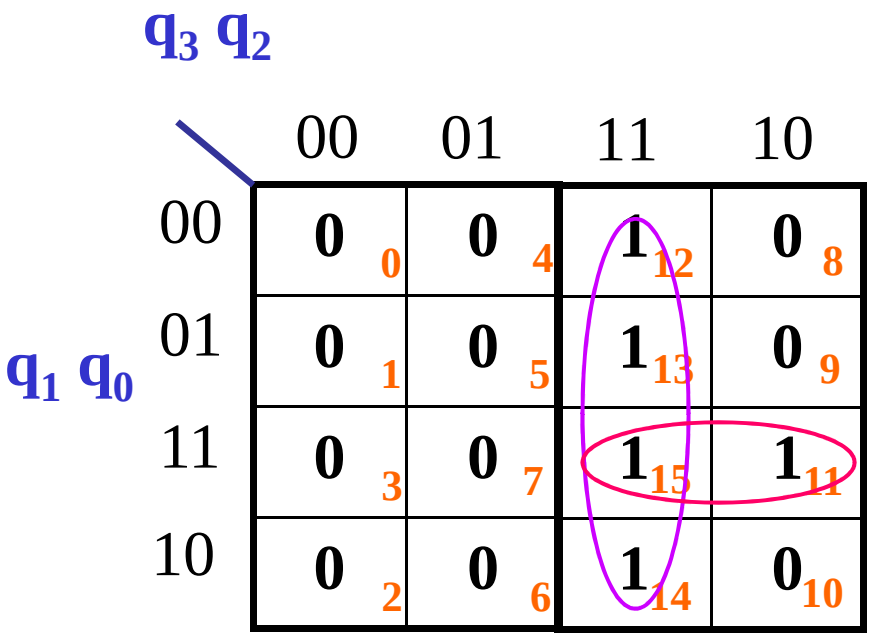
$q_1\ q_0$	00	01	11	10
00	x 0	1 4	1 12	1 8
01	0 1	X 5	0 13	0 9
11	0 3	0 7	X 15	0 11
10	1 2	1 6	1 14	1 10

$$d_0 = X1\ (\ nq_0\ ) + X2\ (\ nq_0\ )$$

X1



X2



$$Z_1 = X_1(q_3q_2nq_0 + q_3q_1nq_0) + X2\ (q_3q_2 + q_3q_1q_0)$$

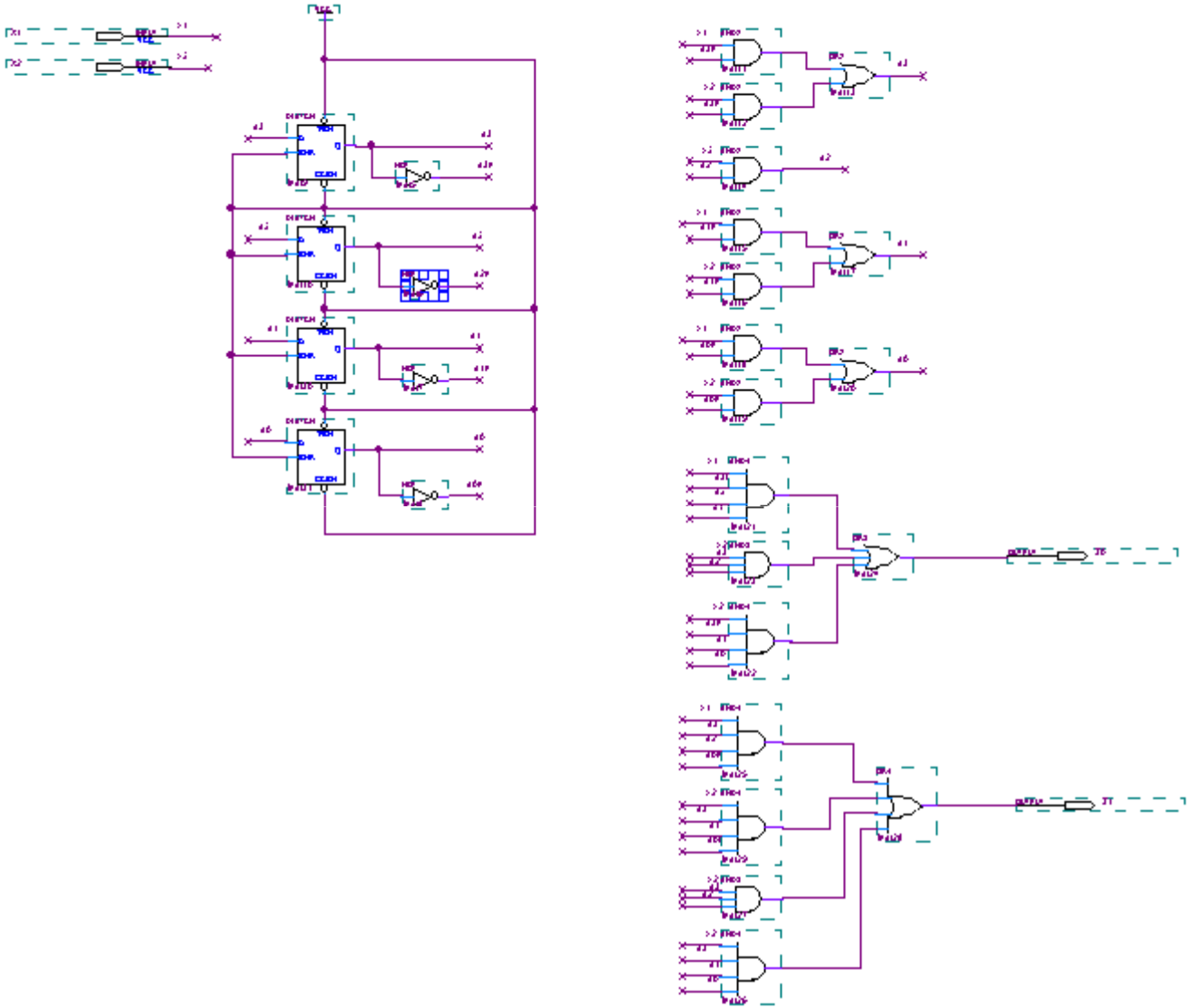
X1

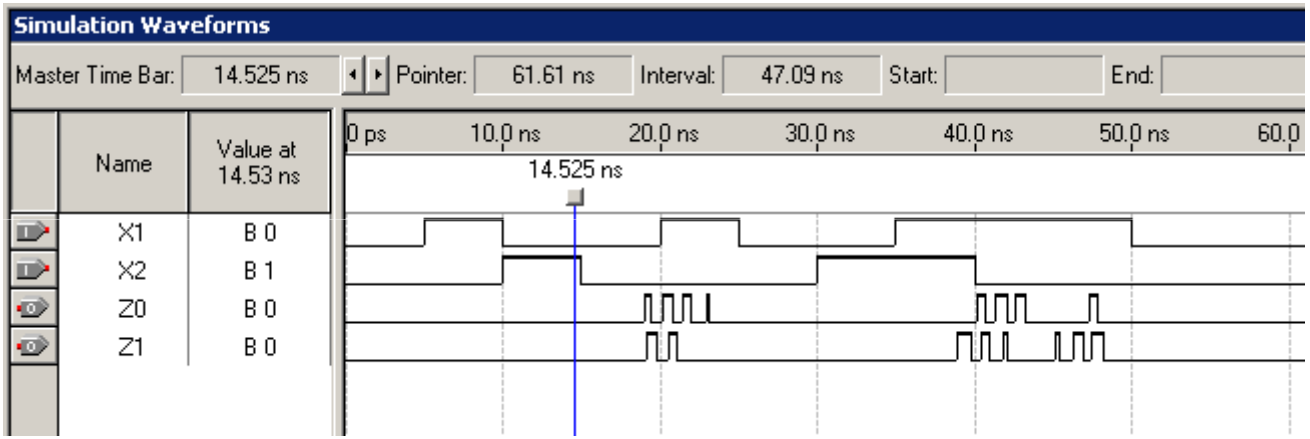
$q_3\,q_2$ / $q_1\,q_0$	00	01	11	10
00	0 (0)	1 (4)	0 (12)	0 (8)
01	0 (1)	1 (5)	0 (13)	0 (9)
11	0 (3)	0 (7)	x (15)	0 (11)
10	0 (2)	0 (6)	0 (14)	0 (10)

X2

$q_3\,q_2$ / $q_1\,q_0$	00	01	11	10
00	0 (0)	1 (4)	0 (12)	0 (8)
01	0 (1)	1 (5)	0 (13)	0 (9)
11	1 (3)	1 (7)	x (15)	0 (11)
10	0 (2)	1 (6)	0 (14)	0 (10)

$$Z_0 = X1(nq_3q_2q_1) + X2 (nq_3q_2 + nq_3q_1q_0)$$




Simulation Waveforms
Master Time Bar: 14.525 ns
Pointer: 61.61 ns
Interval: 47.09 ns
Start:
End:
Name
Value at 14.53 ns
0 ps
10.0 ns
20.0 ns
30.0 ns
40.0 ns
50.0 ns
60.0
14.525 ns
X1
B 0
X2
B 1
Z0
B 0
Z1
B 0