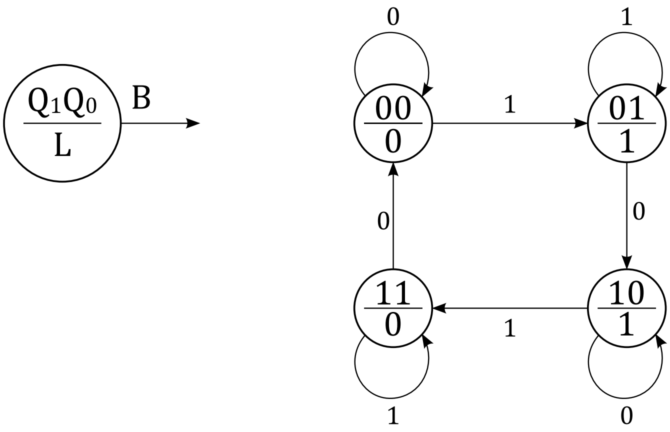
Machines d'états

Exercices Conception numérique

Solution vs. Hints:
Toutes les réponses fournies ici ne sont pas des solutions complètes. Certaines ne sont que des indices pour vous aider à trouver la solution vous-même. Dans d'autres cas, seule une partie de la solution est fournie.

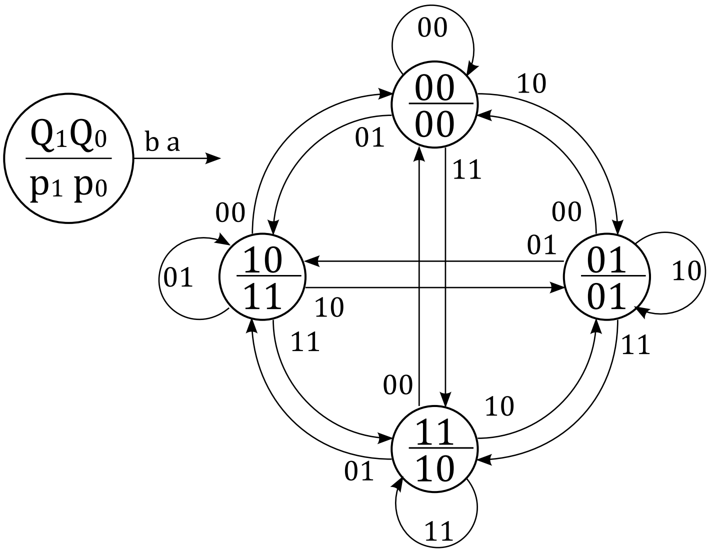
1 FSM - Machines de Moore

1.1 Graphe d'une machine d'états



fsm/moore-01

1.2 Graphe d'une machine d'états



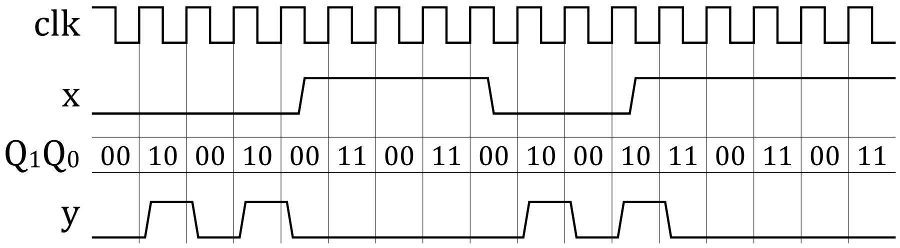
fsm/moore-02

1.3 Séquence d'un compteur

$$\ldots \Rightarrow 0 \Rightarrow 1 \Rightarrow 3 \Rightarrow 2 \Rightarrow 6 \Rightarrow 7 \Rightarrow 5 \Rightarrow 4 \Rightarrow 0 \Rightarrow \ldots \tag{1}$$

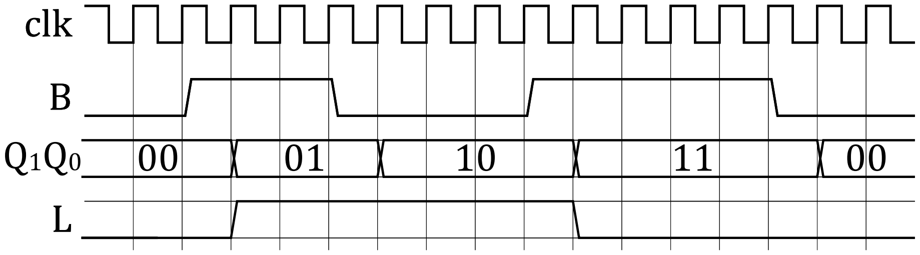
fsm/moore-03

1.4 Comportement temporel d'une machine d'états



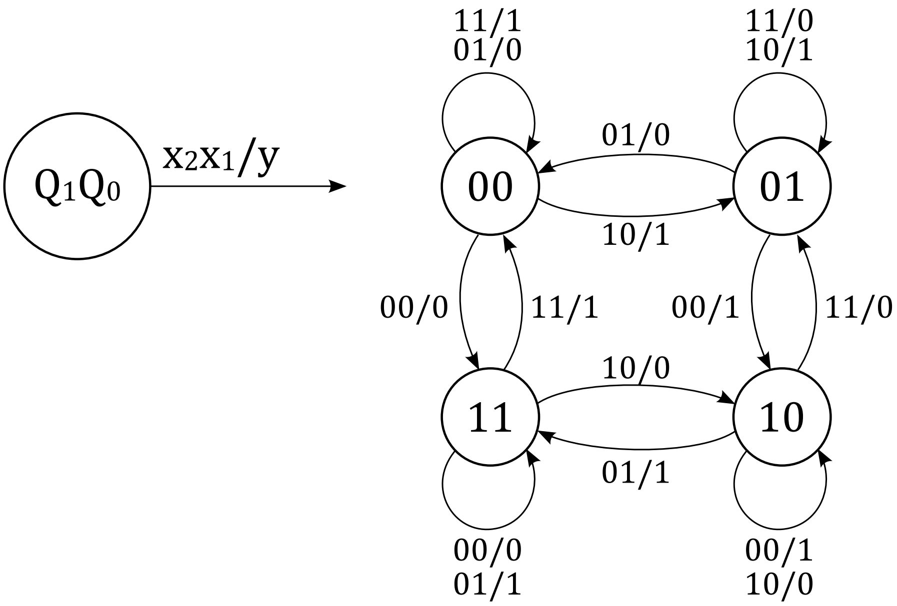
fsm/moore-04

1.5 Comportement temporel d'une machine d'états



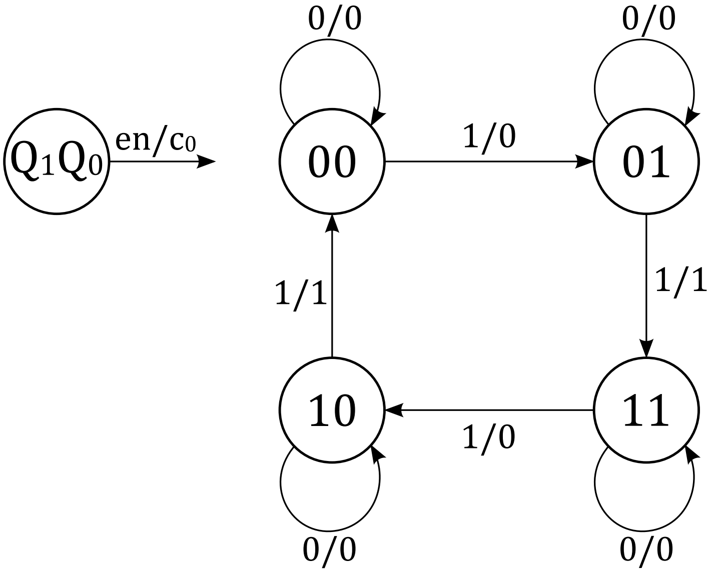
2 FSM - Machines de Mealy

2.1 Graphe d'une machine d'états



fsm/mealy-01

2.2 Graphe d'une machine d'états



fsm/mealy-02

2.3 Comportement temporel d'une machine d'états

2.3.1.1 Initial State

$x = 0 \Rightarrow Q = "00"$

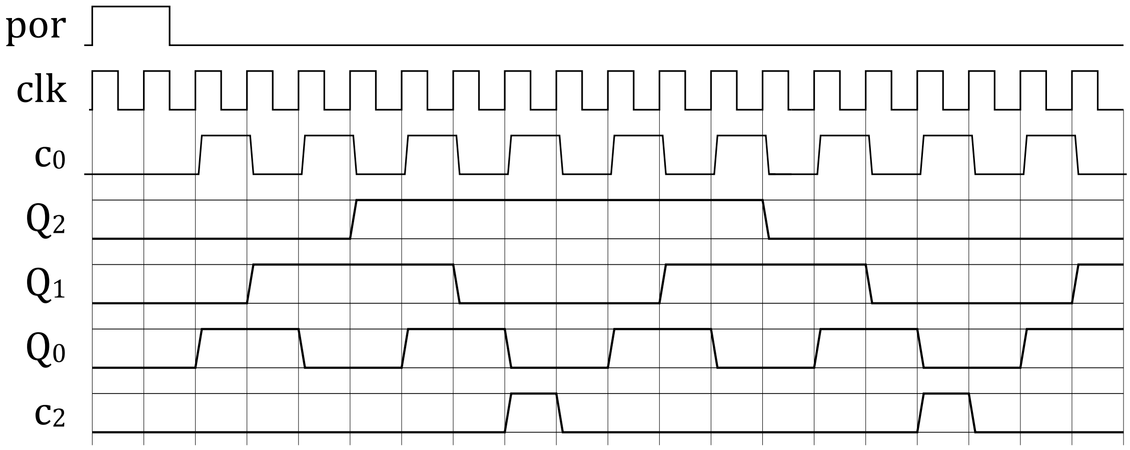
2.3.1.2 Outputs

$$\begin{aligned} y_1 = 1 \Rightarrow & \begin{cases} Q = "10" \ \& \ x = 1 \\ Q = "11" \ \& \ x = 1 \mid x = 0 \end{cases} \\ y_0 = 1 \Rightarrow & \begin{cases} Q = "01" \ \& \ x = 1 \\ Q = "11" \\ Q = "10" \ \& \ x = 0 \end{cases} \end{aligned} \tag{2}$$

fsm/mealy-03

2.4 Compteur itératif

Mealy-Machine since c_2 depends on c_0 & Q_0 & Q_1.



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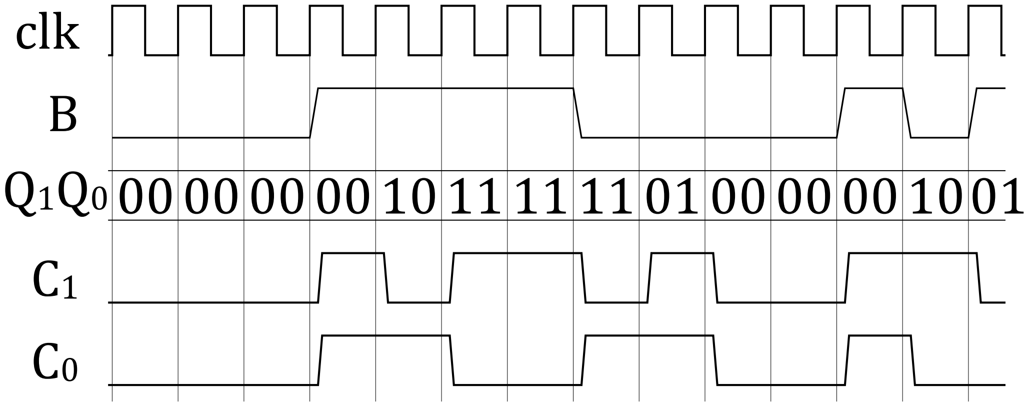
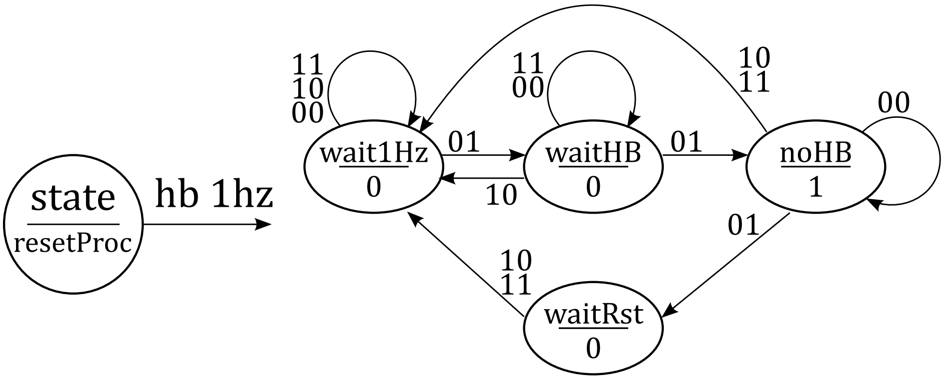
2.5 Comportement temporel d'une machine d'états



fsm/mealy-05

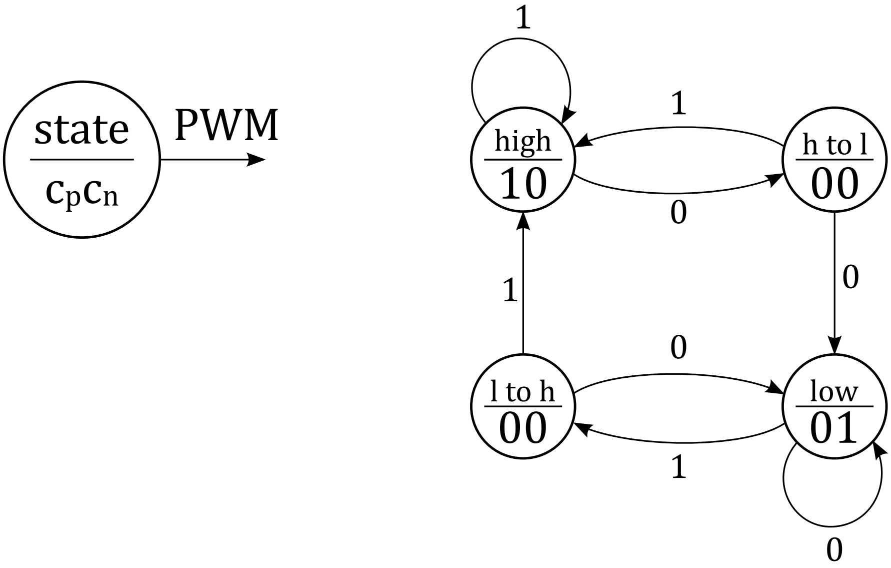
3 FSM - Établissement du graphe des états

3.1 Superviseur de fonctionnement



fsm/fsm-01

3.2 Générateur de commandes non-recouvrantes



fsm/fsm-02

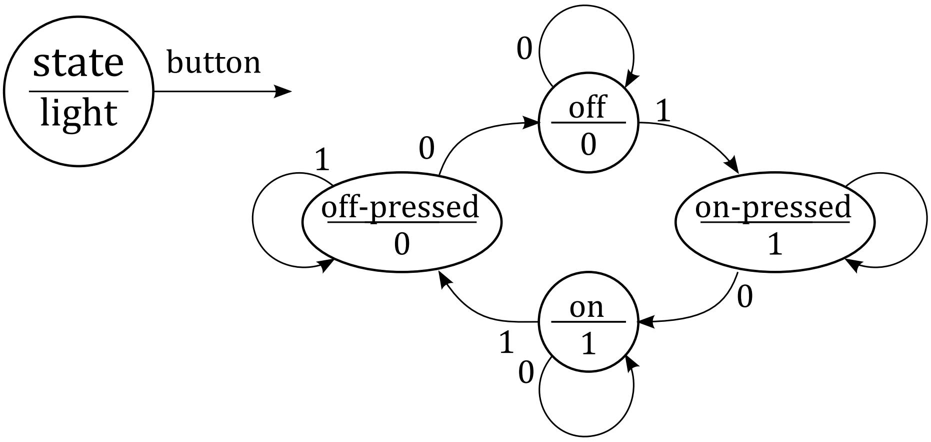
3.3 Commande de distributeur automatique

FSM-Type = Moore. There is no realtime action needed
$c_1 c_2 =$ "11" ⇨ impossible

fsm/fsm-03

3.4 Commande de lumières

FSM Type = Moore. There is no realtime action needed.

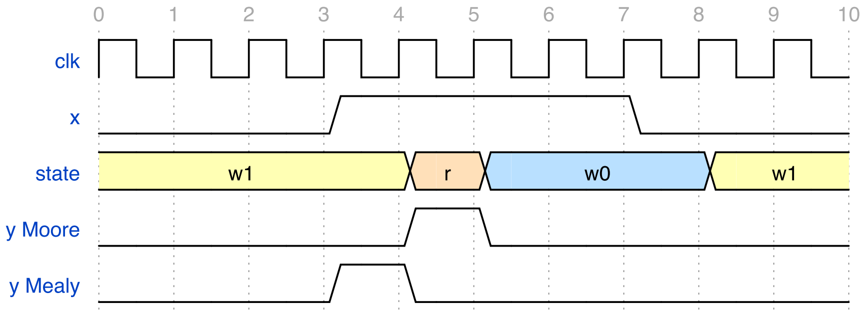


fsm/fsm-04

3.5 Détecteur de flanc montant

FSM Type = Moore and Mealy possible.

3.5.1.1 Timing Diagram



3.5.1.2 Grap

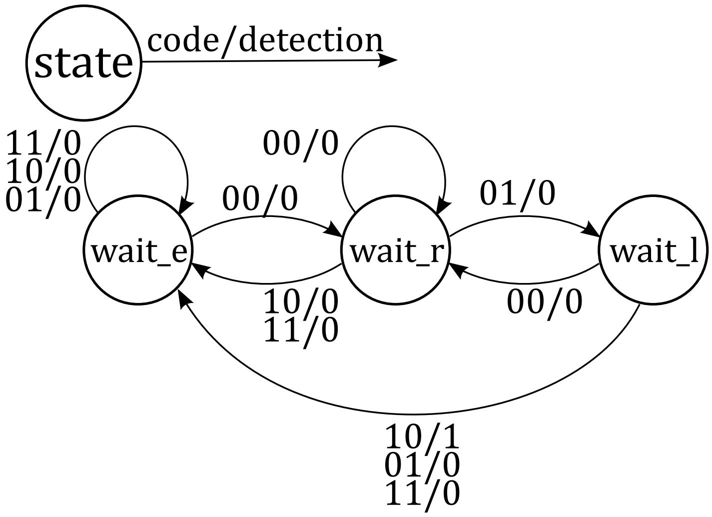
Moore FSM can be done with 3 states. Mealy FSM can be done with 2 states.

fsm/fsm-05

3.6 Détection de chaîne de caractères

FSM-Type = Mealy since an immediate response is needed.

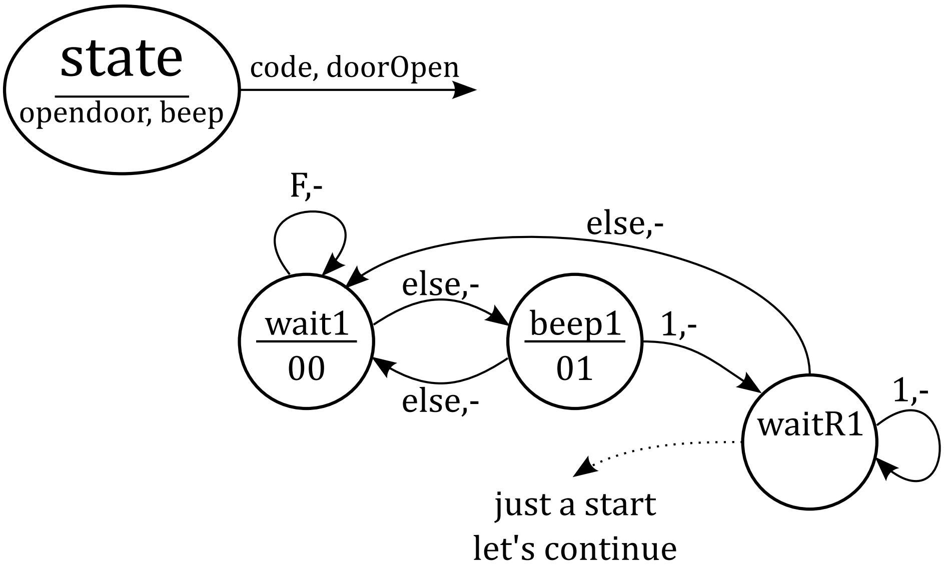
3.6.1.1 Graph



fsm/fsm-06

3.7 Serrure électronique

FSM-Type = Moore. The output signal is during one clock period.



fsm/fsm-07

4 FSM - Réduction de graphes

4.1 Réduction de graphe

4.1.1.1 Truth Table

state \ x	0	1
st0	st0,0	st1,0
st1	st3,0	st2,0
st2	st3,0	st4,1
st3	st0,0	st1,0
st4	st5,1	st7,1
st5	st6,1	st7,1
st6	st0,0	st7,1
st7	st5,1	st4,1

The blue and green states can be combined to new states e.g. **`st03`** and **`st47`**. Draw also the new graph.

fsm/reduction-01

4.2 Réduction de graphe

4.2.1.1 Truth Table

state \ $x_1 x_2$	00	01	10	11
st0	st0,0	st2,0	st1,0	st0,0
st1	st1,0	st2,0	st1,0	st3,0
st2	st2,0	st2,0	st1,0	st3,0
st3	st5,1	st4,1	st3,0	st3,0
st4	st4,1	st4,1	st0,0	st3,0
st5	st5,1	st5,1	st0,0	st3,0

The blue and green states can be combined to new states e.g. **`st12`** and **`st45`**. Draw also the new graph.

fsm/reduction-02

5 FSM - Codage des états

5.1 Circuit logique

$$\begin{aligned}
Q_2^+ &= D_2 = \overline{x \oplus Q_2} \\
Q_1^+ &= D_1 = \overline{x}\ \overline{Q_2}\ \overline{Q_1}\ Q_0 + \overline{x}\ Q_2\ Q_1\ Q_0 + x\overline{Q_2}\ Q_1\ \overline{Q_0} + x\ Q_2\ \overline{Q_1}\ \overline{Q_0} \\
Q_0^+ &= D_0 = \overline{x}\ \overline{Q_2}\ \overline{Q_1}\ \overline{Q_0} + \overline{x}\ Q_2\ \overline{Q_1}\ Q_0 + x\ \overline{Q_2}\ \overline{Q_1}\ Q_0 + x\ Q_2\ Q_1\ \overline{Q_0} \\
y_1 &= Q_2 \\
y_2 &= Q_2\ \overline{Q_1}\ \overline{Q_0}
\end{aligned} \tag{3}$$

fsm/coding-01

5.2 Circuit logique

$$\begin{aligned}
Q_1^+ &= x(Q_1 + Q_0) \\
Q_0^+ &= xQ_1 + x\overline{Q_0} \\
y_1 &= Q_1 Q_0 + xQ_1 \\
y_0 &= \overline{x}Q_1 + xQ_0
\end{aligned} \tag{4}$$

fsm/coding-02

5.3 Circuit logique

One-Hot Encoding Scheme was used.

$$\begin{gathered}
\text{all arrows to a state} \begin{cases}
D_0 = Q_0\overline{\text{step}} + Q_7\text{step cw} + Q_1\text{step } \overline{\text{cw}} \\
D_1 = Q_1\overline{\text{step}} + Q_0\text{step cw} + Q_2\text{step } \overline{\text{cw}} \\
D_2 = Q_2\overline{\text{step}} + Q_1\text{step cw} + Q_3\text{step } \overline{\text{cw}} \\
D_3 = Q_3\overline{\text{step}} + Q_2\text{step cw} + Q_4\text{step } \overline{\text{cw}} \\
D_4 = Q_4\overline{\text{step}} + Q_3\text{step cw} + Q_5\text{step } \overline{\text{cw}} \\
D_5 = Q_5\overline{\text{step}} + Q_4\text{step cw} + Q_6\text{step } \overline{\text{cw}} \\
D_6 = Q_6\overline{\text{step}} + Q_5\text{step cw} + Q_7\text{step } \overline{\text{cw}} \\
D_7 = Q_7\overline{\text{step}} + Q_6\text{step cw} + Q_0\text{step } \overline{\text{cw}}
\end{cases} \\
\text{states were the output is set} \begin{cases}
c_1 = Q_0 + Q_1 + Q_7 \\
c_2 = Q_1 + Q_2 + Q_3 \\
c_3 = Q_3 + Q_4 + Q_5 \\
c_4 = Q_5 + Q_6 + Q_7
\end{cases}
\end{gathered} \tag{5}$$

fsm/coding-03

5.4 Circuit logique

Additional signal

The states Q_1 and Q_0 can distinguish 4 different clock periods. But the signal as 8 clockperiods repeating as a mirror.
⇨ An additional signal is needed, to differentiate.

5.4.1.1 Truth table

Q_2	Q_1	Q_0	Q_2^+	Q_1^+	Q_0^+	c_1
0	0	0	0	0	1	0
0	0	1	0	1	1	0
0	1	0	1	1	0	0
0	1	1	0	1	0	0
1	0	0	0	0	0	1
1	0	1	1	0	0	0
1	1	0	1	1	1	0
1	1	1	1	0	1	0

5.4.1.2 Karnaugh Table

D_2

		Q_2		
	Q_1			
0	1	1	0	
0	0	1	1	Q_0

D_1

		Q_2		
	Q_1			
0	1	1	0	
1	1	0	0	Q_0

D_0

		Q_2		
	Q_1			
1	0	1	0	
1	0	1	0	Q_0

c_1

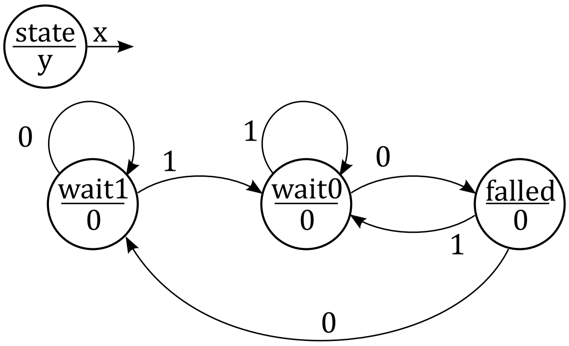
		Q_2		
	Q_1			
0	0	0	1	
0	0	0	0	Q_0

5.4.1.3 Equations

$$\begin{aligned} D_2 &= Q_0 Q_2 + \overline{Q_0} Q_1 \\ D_1 &= Q_0 \overline{Q_2} + \overline{Q_0} Q_1 \\ D_0 &= Q_1 \oplus \overline{Q_2} \\ c_1 &= Q_2 \ \overline{Q_1} \ \overline{Q_0} \end{aligned} \tag{6}$$

fsm/coding-04

5.5 Détecteur de flanc descendant

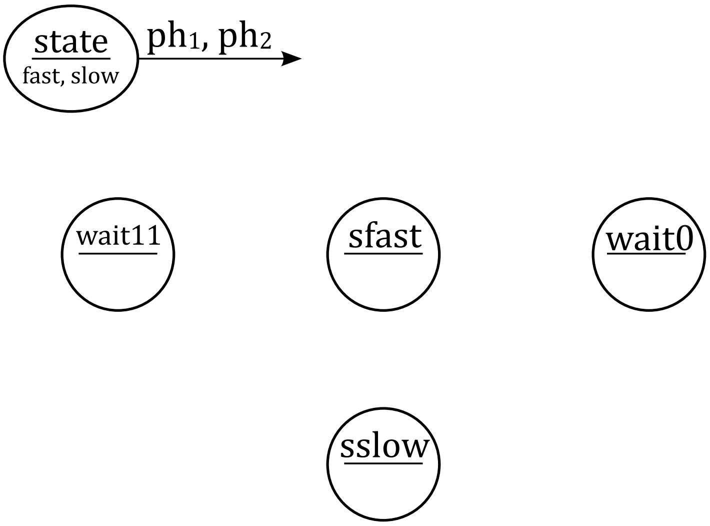


state	Q Encoding
wait1	10
wait0	00
falled	11

Next steps is to create the truth table and the Equations in order to draw the circuit.

fsm/coding-05

5.6 Détecteur de phase



5.6.1.1 State encoding (One-Hot)

state	Q Encoding
wait11	0001
sfast	0010
sslow	0100
wait0	1000

5.6.1.2 Equations

$$
\begin{aligned}
D_0 &= \mathrm{ph}_1 \mathrm{ph}_2 \\
D_1 &= (Q_0 + Q_1)\overline{\mathrm{ph}_1}\mathrm{ph}_2 \\
D_2 &= (Q_0 + Q_2)\mathrm{ph}_1\overline{\mathrm{ph}_2} \\
D_3 &= \overline{\mathrm{ph}_1}\ \overline{\mathrm{ph}_2} + (Q_1)\mathrm{ph}_1\overline{\mathrm{ph}_2} + (Q_2)\overline{\mathrm{ph}_1}\mathrm{ph}_2 + Q_3(\mathrm{ph}_1 \oplus \mathrm{ph}_2) \\
\mathrm{fast} &= Q_1 \\
\mathrm{slow} &= Q_2
\end{aligned}
\tag{7}
$$

fsm/coding-06