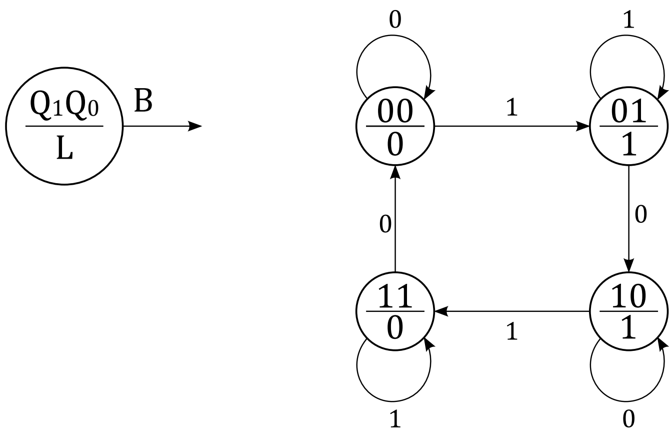
Zustandsmaschinen

Übungen Digitales Design

Lösung vs. Hinweise:
Nicht alle hier gegebenen Antworten sind vollständige Lösungen. Einige dienen lediglich als Hinweise, um Ihnen bei der eigenständigen Lösungsfindung zu helfen. In anderen Fällen wird nur ein Teil der Lösung präsentiert.

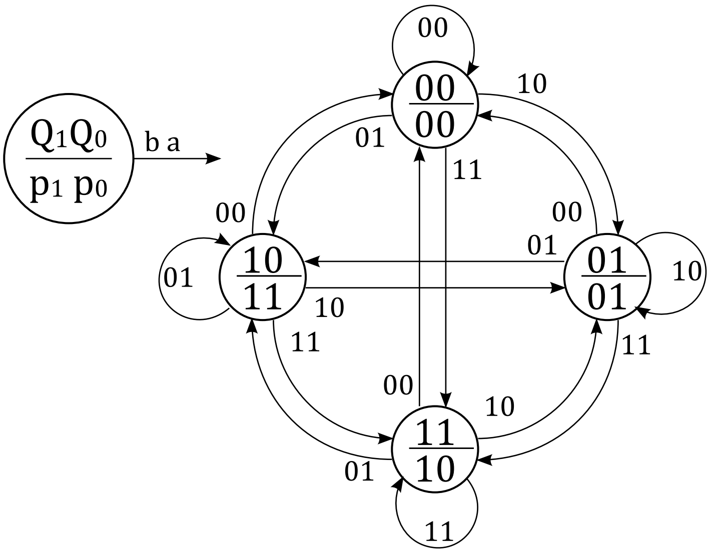
1 FSM - Moore-Maschinen

1.1 Graph einer Zustandsmaschine



fsm/moore-01

1.2 Graph einer Zustandsmaschine



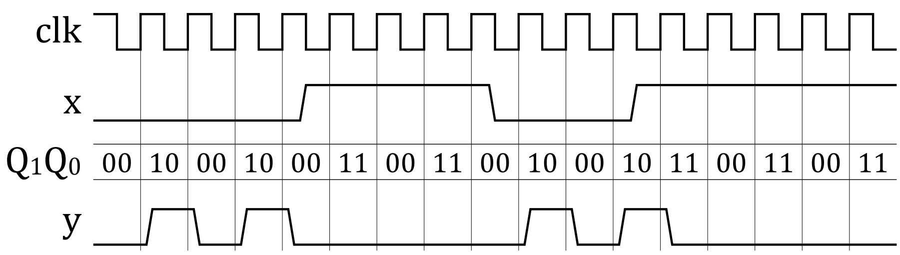
fsm/moore-02

1.3 Sequenz eines Zählers

$$\ldots \Rightarrow 0 \Rightarrow 1 \Rightarrow 3 \Rightarrow 2 \Rightarrow 6 \Rightarrow 7 \Rightarrow 5 \Rightarrow 4 \Rightarrow 0 \Rightarrow \ldots \qquad (1)$$

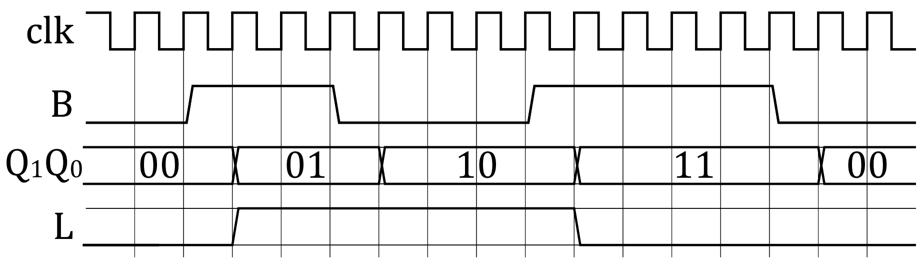
fsm/moore-03

1.4 Zeitliches Verhalten einer Zustandsmaschine



fsm/moore-04

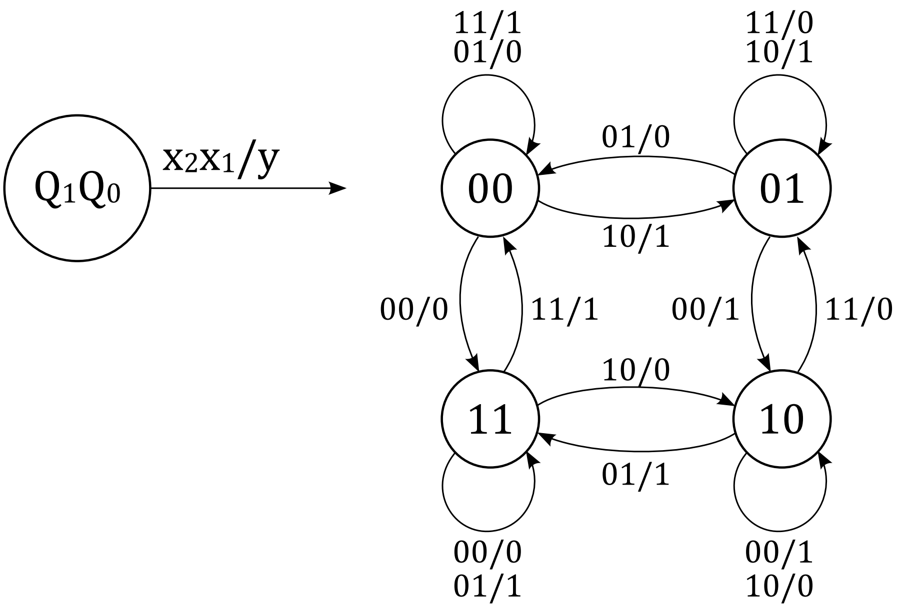
1.5 Zeitliches Verhalten einer Zustandsmaschine



fsm/moore-05

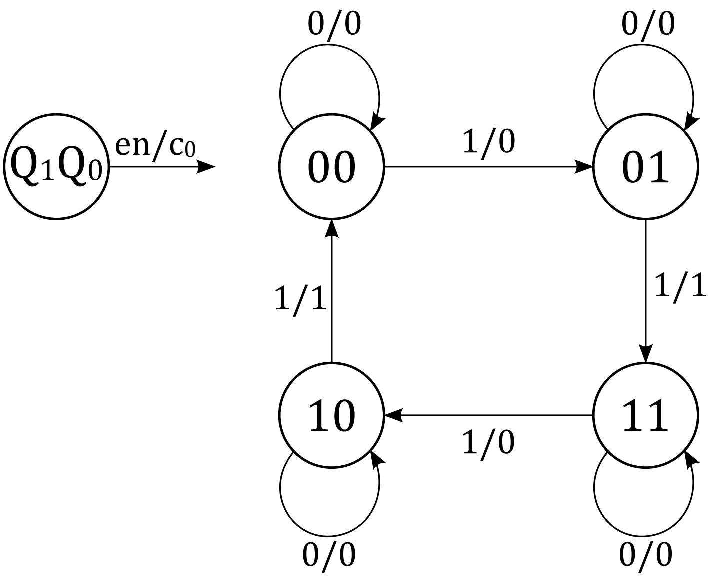
2 FSM - Mealy-Maschinen

2.1 Graph einer Zustandsmaschine



fsm/mealy-01

2.2 Graph einer Zustandsmaschine



fsm/mealy-02

2.3 Zeitliches Verhalten einer Zustandsmaschine

2.3.0.1 Initial State

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

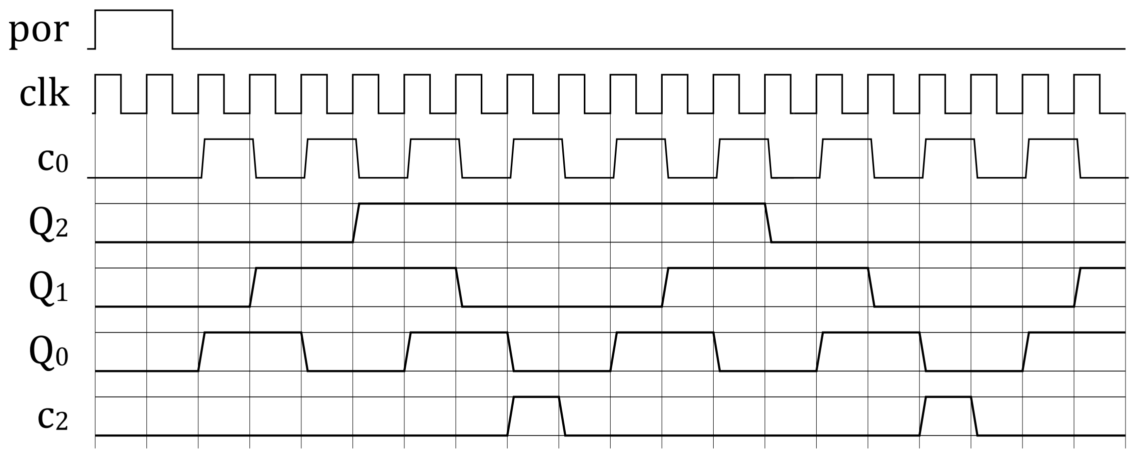
2.3.0.2 Outputs

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

fsm/mealy-03

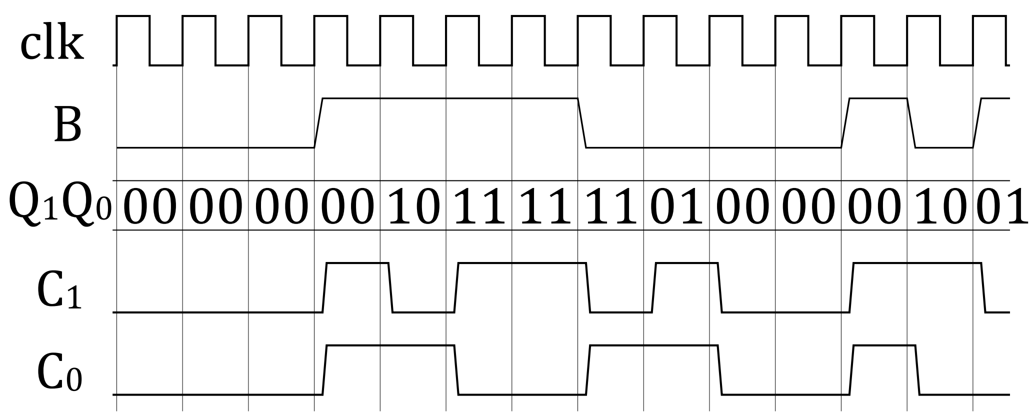
2.4 Iterativzähler

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



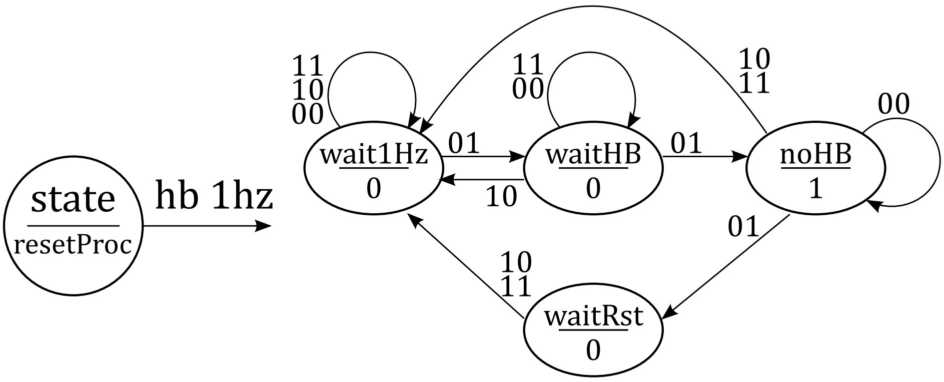
fsm/mealy-04

2.5 Zeitliches Verhalten einer Zustandsmaschine



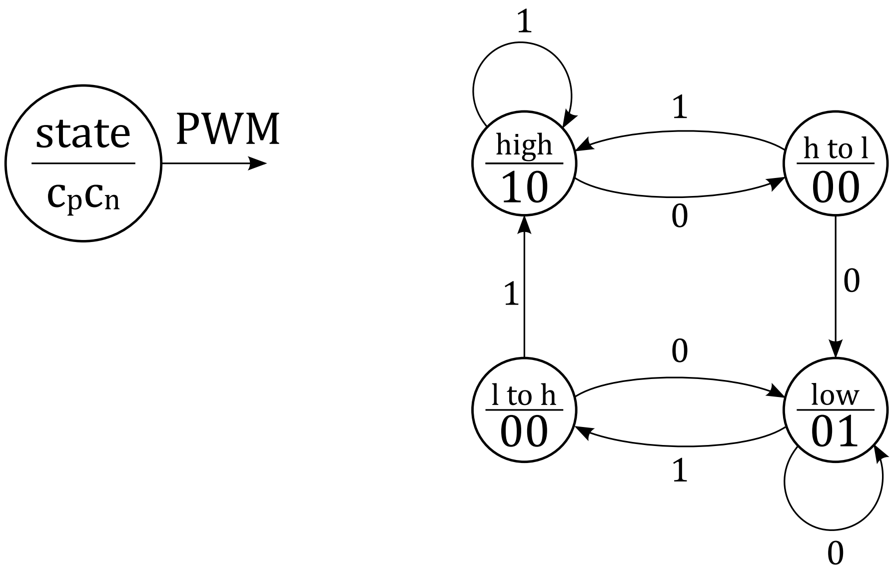
3 FSM - Erstellen eines Zustandsgraphen

3.1 Betriebsüberwachung



fsm/fsm-01

3.2 Generator von nicht überlappenden Steuersignalen



fsm/fsm-02

3.3 Steuerung eines Snackautomates

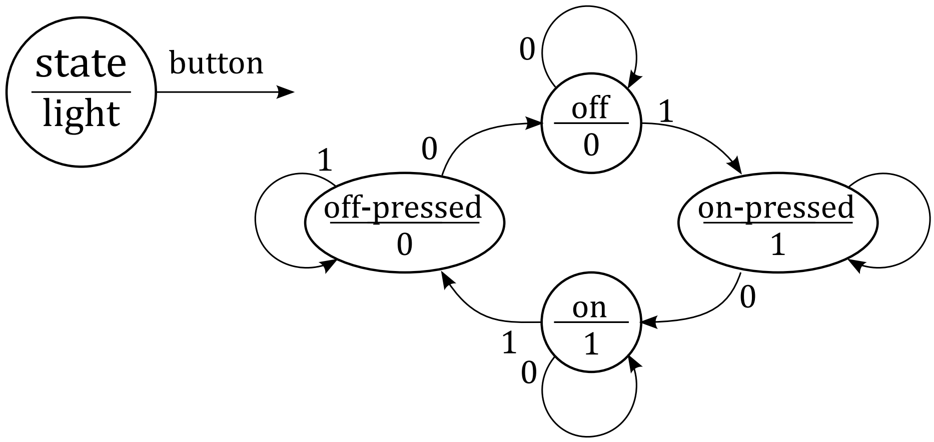
FSM-Type = Moore. There is no realtime action needed

$c_1 c_2$ = "11" ⇒ impossible

fsm/fsm-03

3.4 Steuerung der Beleuchtung

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

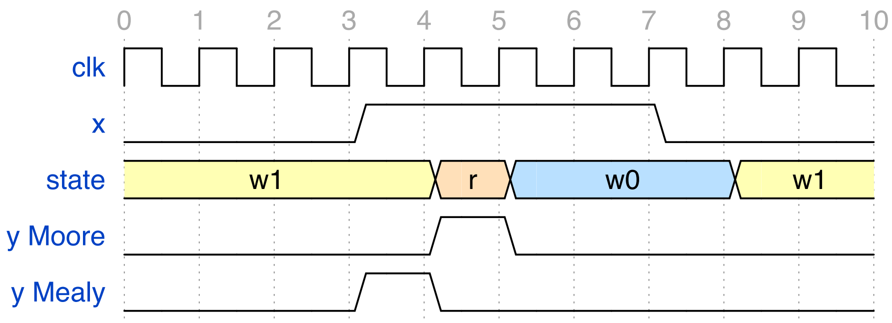


fsm/fsm-04

3.5 Detektierung einer aufsteigenden Flanke

FSM Type = Moore and Mealy possible.

3.5.0.1 Timing Diagram



3.5.0.2 Grap

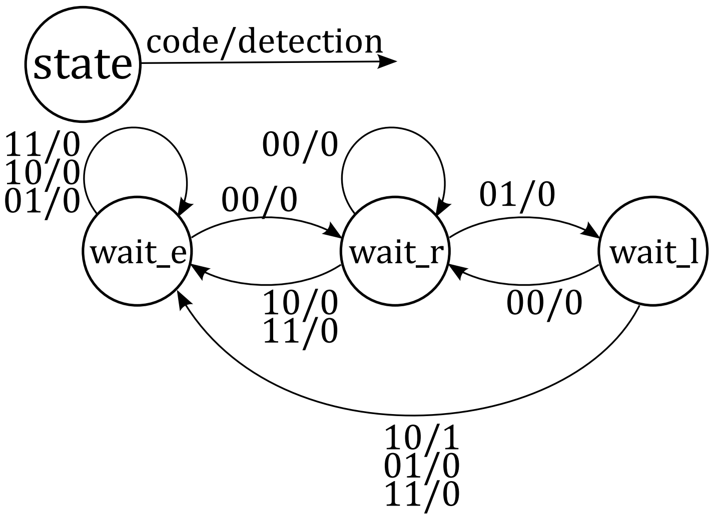
Moore FSM can be done with 3 states. Mealy FSM can be done with 2 states.

fsm/fsm-05

3.6 Erkennung von Zeichenketten

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

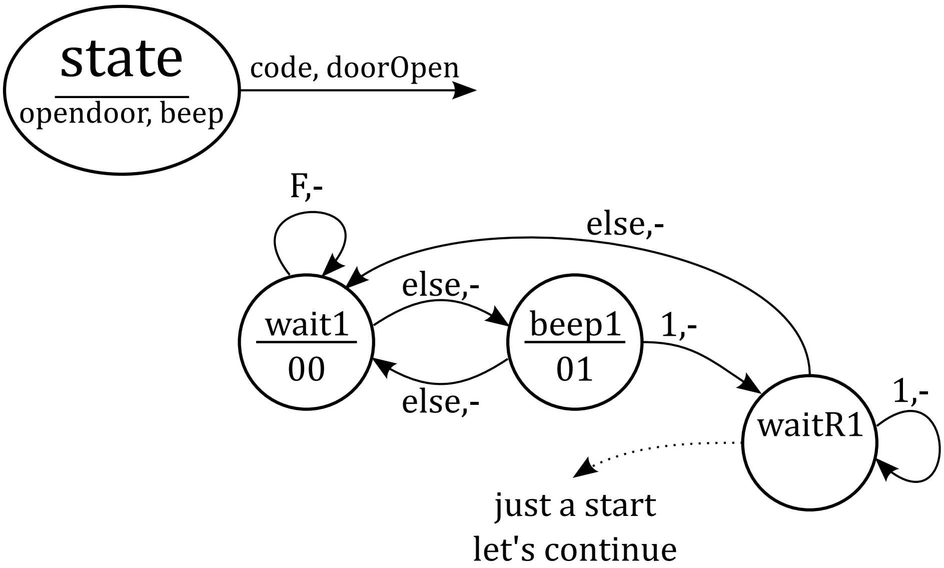
3.6.0.1 Graph



fsm/fsm-06

3.7 Elektronisches Schloss

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



fsm/fsm-07

4 | FSM - Graphenvereinfachung

4.1 Graphenvereinfachung

4.1.0.1 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 Graphenvereinfachung

4.2.0.1 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 - Zustandskodierung

5.1 Logikschaltung

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

fsm/coding-01

5.2 Logikschaltung

$$
\begin{aligned}
Q_1^+ &= x(Q_1 + Q_0) \\
Q_0^+ &= xQ_1 + x\overline{Q_0} \\
y_1 &= Q_1Q_0 + xQ_1 \\
y_0 &= \overline{x}Q_1 + xQ_0
\end{aligned}
\tag{4}
$$

fsm/coding-02

5.3 Logikschaltung

One-Hot Encoding Scheme was used.

$$
\text{all arrows to a state}
\begin{cases}
D_0 = Q_0\overline{\text{step}} + Q_7\text{step cw} + Q_1\text{step }\overline{\text{cw}} \\
D_1 = Q_1\overline{\text{step}} + Q_0\text{step cw} + Q_2\text{step }\overline{\text{cw}} \\
D_2 = Q_2\overline{\text{step}} + Q_1\text{step cw} + Q_3\text{step }\overline{\text{cw}} \\
D_3 = Q_3\overline{\text{step}} + Q_2\text{step cw} + Q_4\text{step }\overline{\text{cw}} \\
D_4 = Q_4\overline{\text{step}} + Q_3\text{step cw} + Q_5\text{step }\overline{\text{cw}} \\
D_5 = Q_5\overline{\text{step}} + Q_4\text{step cw} + Q_6\text{step }\overline{\text{cw}} \\
D_6 = Q_6\overline{\text{step}} + Q_5\text{step cw} + Q_7\text{step }\overline{\text{cw}} \\
D_7 = Q_7\overline{\text{step}} + Q_6\text{step cw} + Q_0\text{step }\overline{\text{cw}}
\end{cases}
\tag{5}
$$

$$
\text{states were the output is set}
\begin{cases}
c_1 = Q_0 + Q_1 + Q_7 \\
c_2 = Q_1 + Q_2 + Q_3 \\
c_3 = Q_3 + Q_4 + Q_5 \\
c_4 = Q_5 + Q_6 + Q_7
\end{cases}
$$

fsm/coding-03

5.4 Logikschaltung

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.

5.4.0.1 Truth table

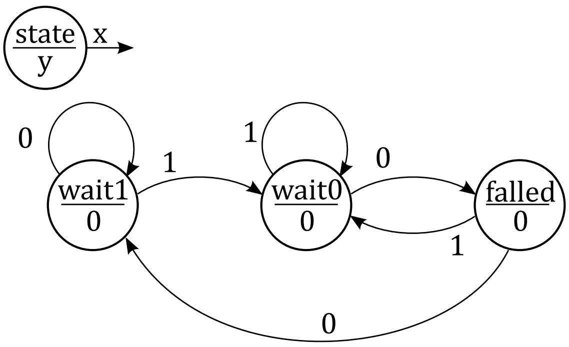
Q_2	Q_1	Q_0	Q_2^+	Q_1^+	Q_0^+	c_1
0	0	0	0	0	1	0
0	0	1	0	1	1	0
0	1	0	1	1	0	0
0	1	1	0	1	0	0
1	0	0	0	0	0	1
1	0	1	1	0	0	0
1	1	0	1	1	1	0
1	1	1	1	0	1	0

5.4.0.2 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 Detektierung einer fallenden Flanke

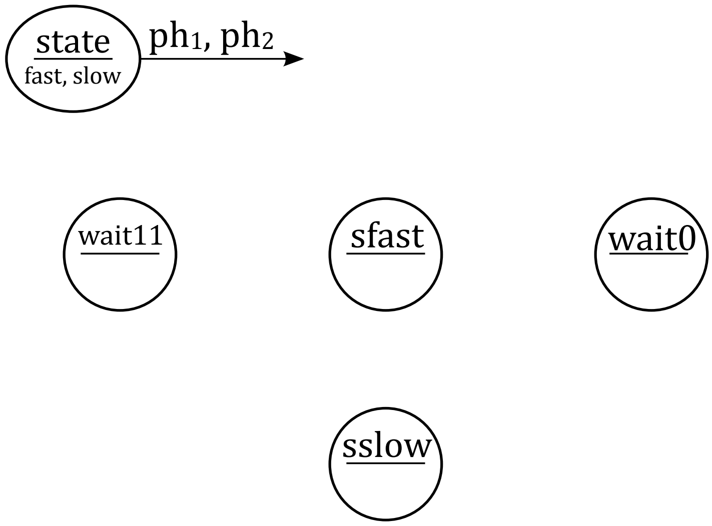


state	Q Encoding
wait1	10
wait0	00
falled	11

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

fsm/coding-05

5.6 Phasendetektor



5.6.0.1 State encoding (One-Hot)

state	Q Encoding
wait11	0001
sfast	0010
sslow	0100
wait0	1000

5.6.0.2 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