



# Zustandsmaschinen

## Übungen Digitales Design

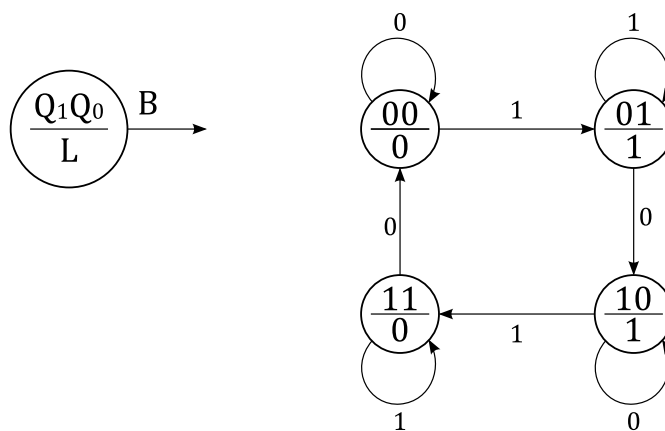


### Lösung vs. Hinweise:

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

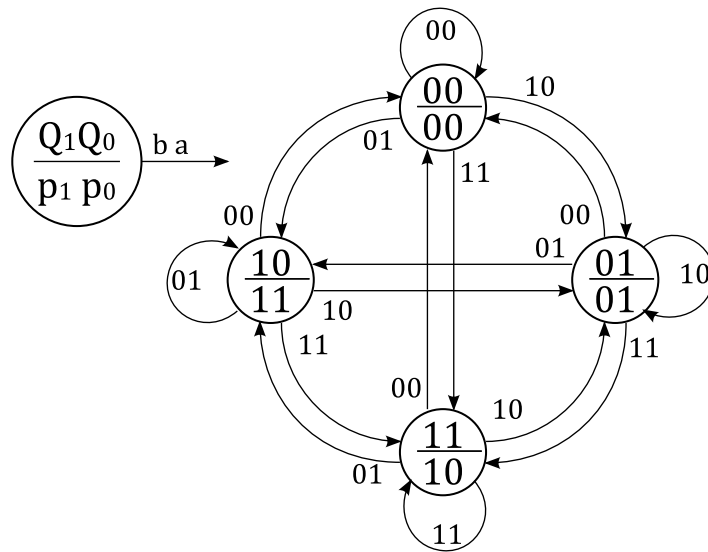
### 1.1 Graph einer Zustandsmaschine



*fsm/moore-01*



## 1.2 Graph einer Zustandsmaschine



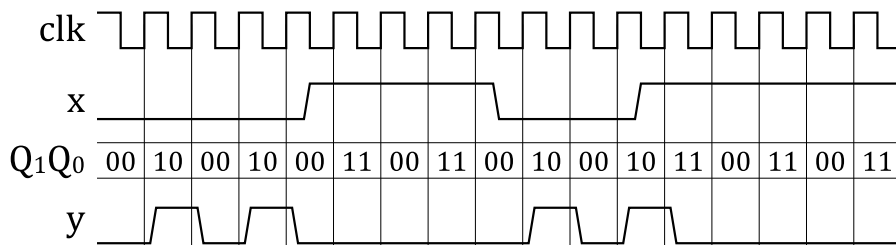
fsm/moore-02

## 1.3 Sequenz eines Zählers

...  $\Rightarrow 0 \Rightarrow 1 \Rightarrow 3 \Rightarrow 2 \Rightarrow 6 \Rightarrow 7 \Rightarrow 5 \Rightarrow 4 \Rightarrow 0 \Rightarrow \dots$  (1)

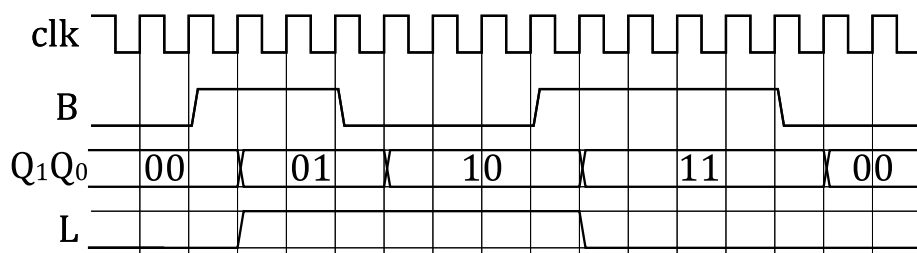
fsm/moore-03

## 1.4 Zeitliches Verhalten einer Zustandsmaschine



fsm/moore-04

## 1.5 Zeitliches Verhalten einer Zustandsmaschine



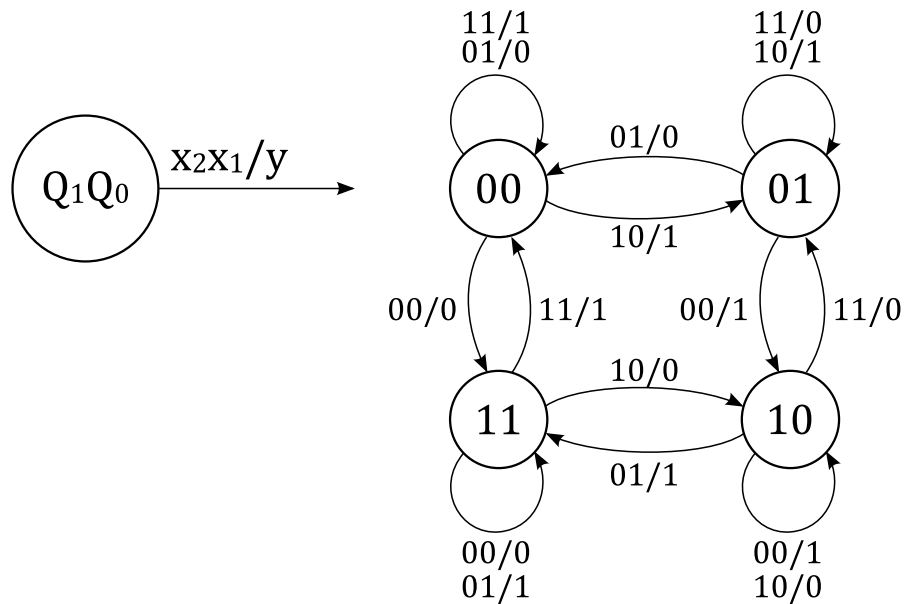


*fsm/moore-05*



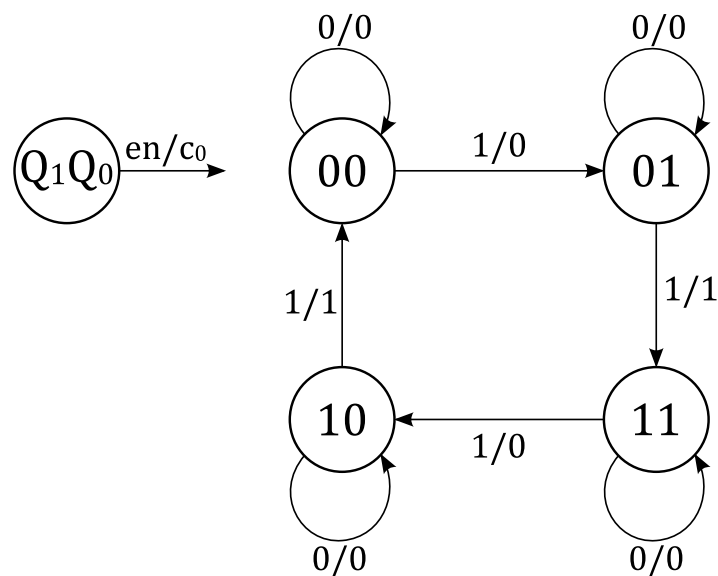
## 2 | FSM - Mealy-Maschinen

### 2.1 Graph einer Zustandsmaschine



*fsm/mealy-01*

### 2.2 Graph einer Zustandsmaschine



*fsm/mealy-02*



## 2.3 Zeitliches Verhalten einer Zustandsmaschine

### 2.3.1.1 Initial State

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

### 2.3.1.2 Outputs

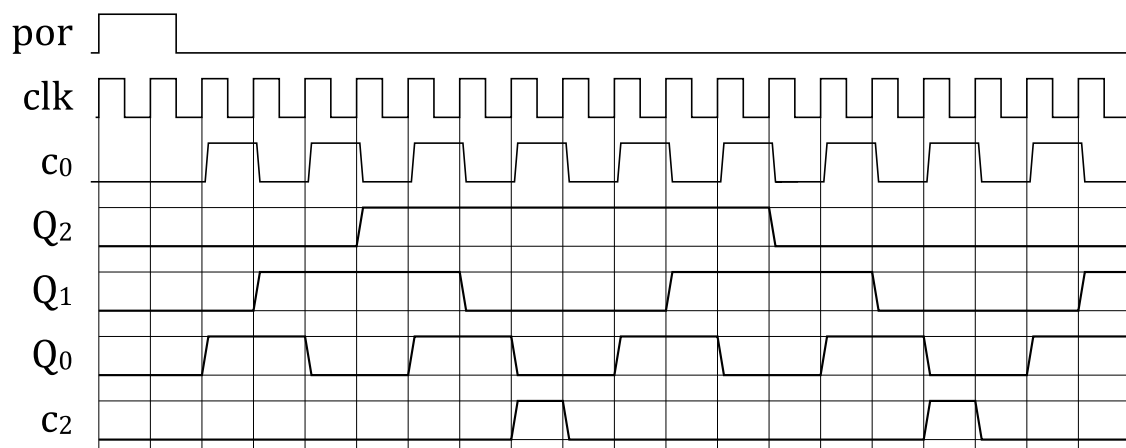
$$y_1 = 1 \Rightarrow \begin{cases} Q = "10" \ \& \ x = 1 \\ Q = "11" \ \& \ x = 1 \mid x = 0 \end{cases} \quad (2)$$

$$y_0 = 1 \Rightarrow \begin{cases} Q = "01" \ \& \ x = 1 \\ Q = "11" \\ Q = "10" \ \& \ x = 0 \end{cases}$$

*fsm/mealy-03*

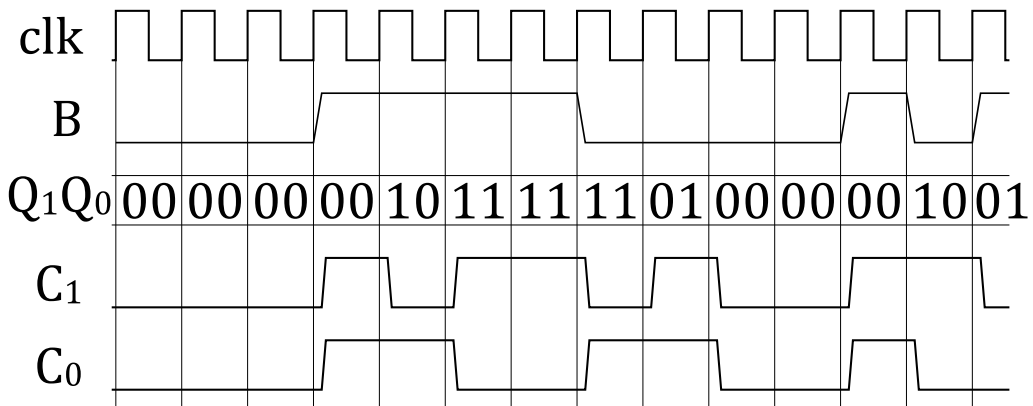
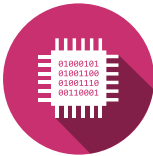
## 2.4 Iterativzähler

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



*fsm/mealy-04*

## 2.5 Zeitliches Verhalten einer Zustandsmaschine

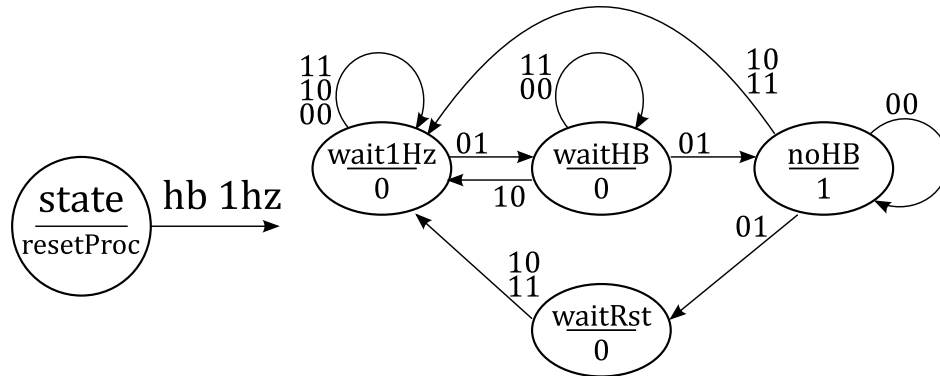


fsm/mealy-05



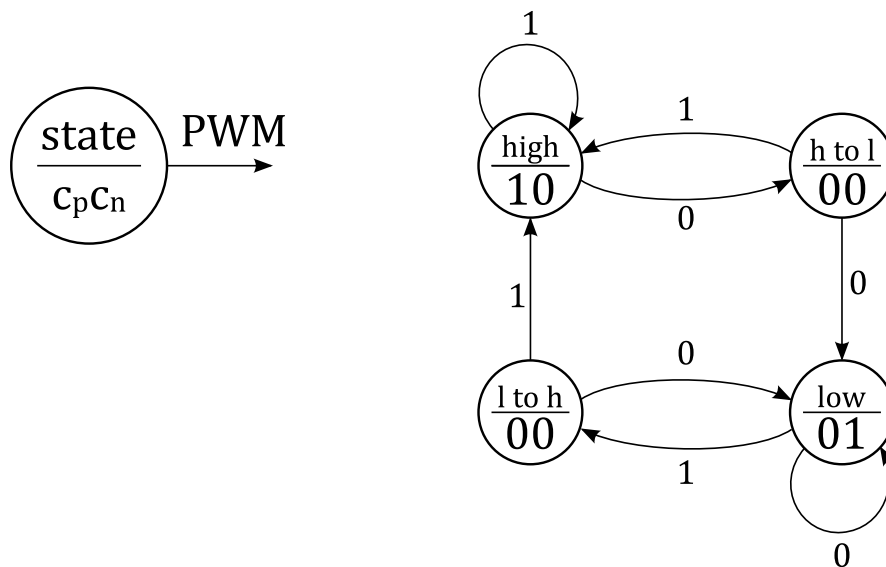
### 3 | FSM - Erstellen eines Zustandsgraphen

#### 3.1 Betriebsüberwachung



fsm/fsm-01

#### 3.2 Generator von nicht überlappenden Steuersignalen



fsm/fsm-02

#### 3.3 Steuerung eines Snackautomates

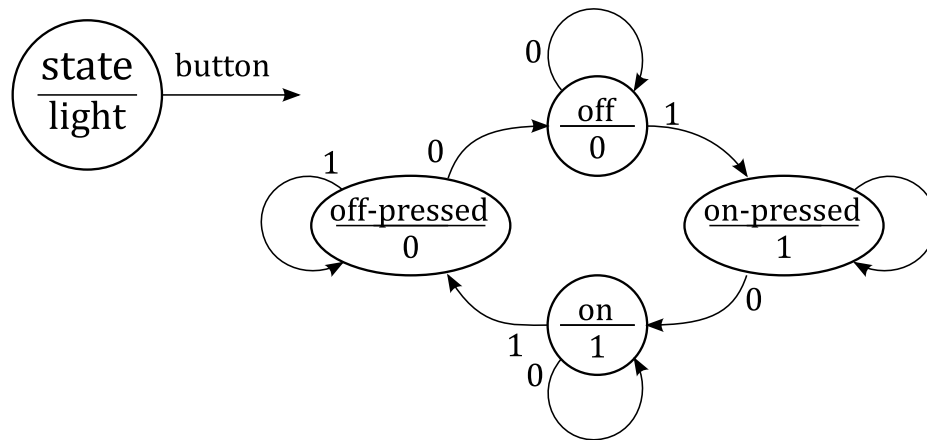
FSM-Type = Moore. There is no realtime action needed  
 $c_1 c_2 = "11" \Rightarrow$  impossible

fsm/fsm-03



### 3.4 Steuerung der Beleuchtung

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

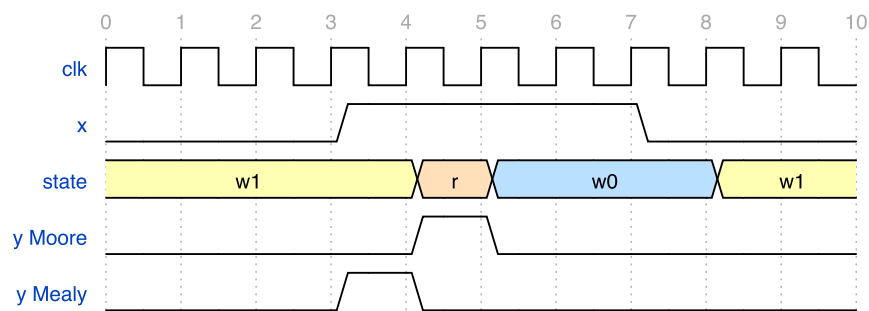


*fsm/fsm-04*

### 3.5 Detektierung einer aufsteigenden Flanke

FSM Type = Moore and Mealy possible.

#### 3.5.1.1 Timing Diagram

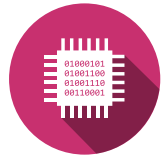


#### 3.5.1.2 Grap

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

*fsm/fsm-05*

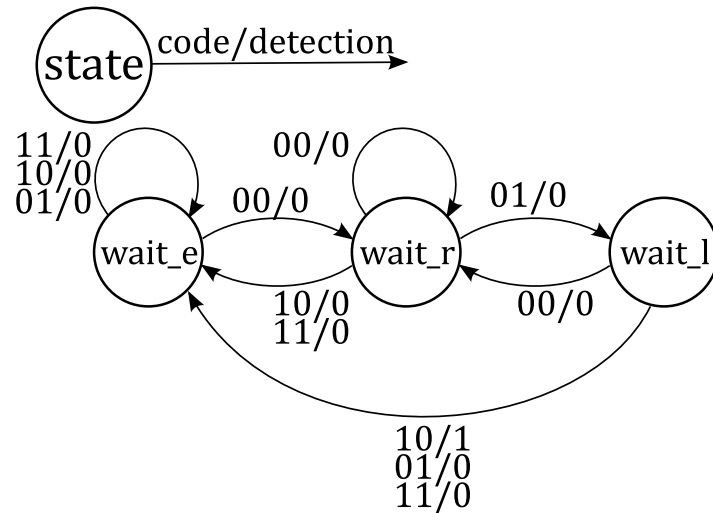




### 3.6 Erkennung von Zeichenketten

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

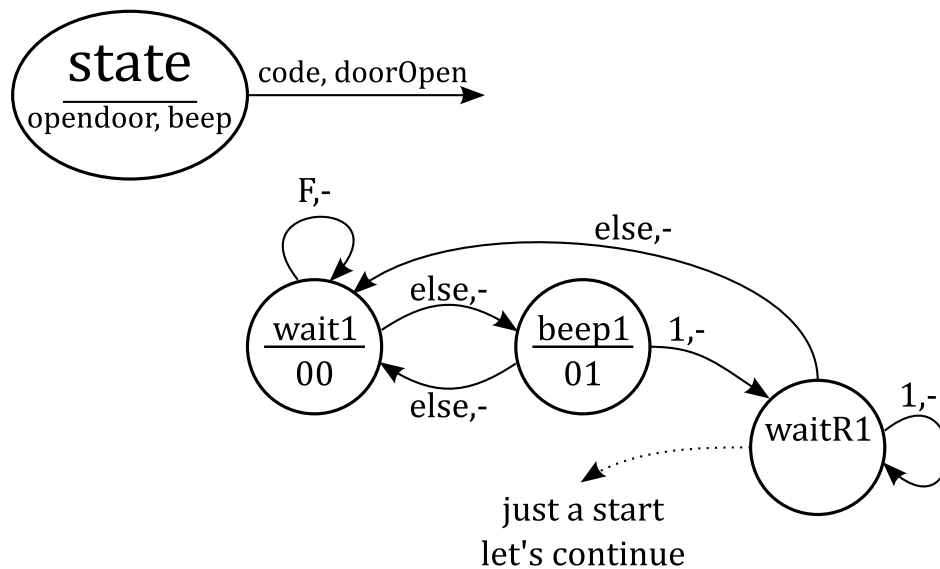
#### 3.6.1.1 Graph



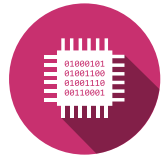
fsm/fsm-06

### 3.7 Elektronisches Schloss

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



fsm/fsm-07



## 4 | FSM - Graphenvereinfachung

### 4.1 Graphenvereinfachung

#### 4.1.1.1 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*

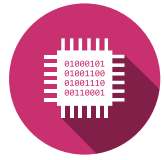
### 4.2 Graphenvereinfachung

#### 4.2.1.1 Truth Table

state \ $x_1x_2$	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

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

*fsm/coding-02*

### 5.3 Logikschaltung

One-Hot Encoding Scheme was used.

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

*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.

#### 5.4.1.1 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

$Q_2$	$Q_1$	$Q_0$
0	1	1
0	1	0
1	1	0
1	0	0

$Q_2$	$Q_1$	$Q_0$
1	0	0
1	0	1
1	1	0
1	1	1

#### 5.4.1.3 Equations

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

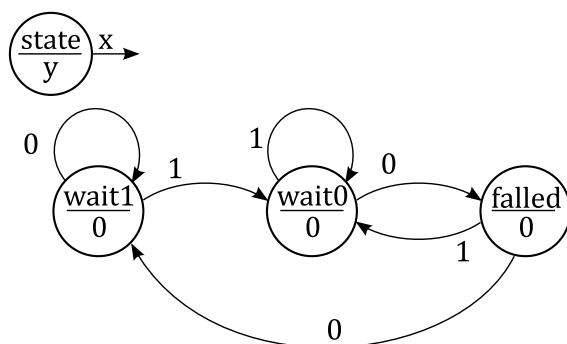
#### 5.4.1.2 Karnaugh Table

$Q_2$	$Q_1$	$Q_0$
0	1	1
0	1	0
1	1	0
1	0	0

$Q_2$	$Q_1$	$Q_0$
0	0	0
0	0	1
1	0	0
1	0	1

fsm/coding-04

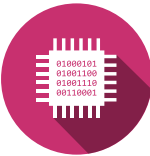
## 5.5 Detektierung einer fallenden Flanke



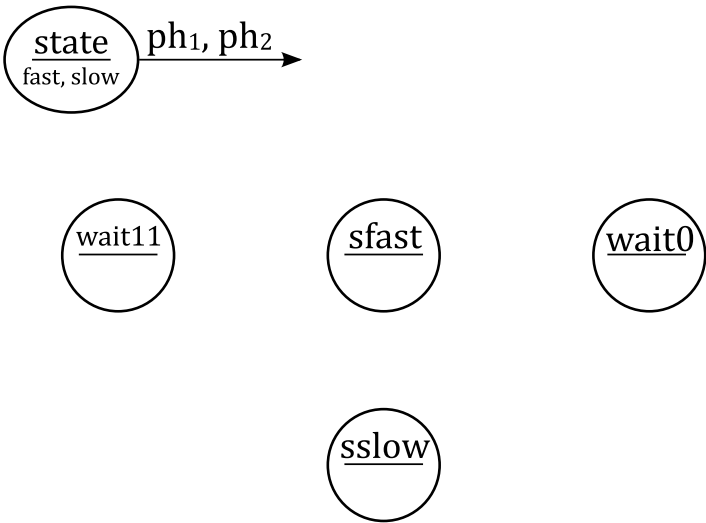
state	Q Encoding
wait1	10
wait0	00
failed	11

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

fsm/coding-05



5.6 Phasendetektor



5.6.1.1 State encoding (One-Hot)

state	Q Encoding
wait11	0001
sfast	0010
sslow	0100
wait0	1000

5.6.1.2 Equations

$D_0 = ph_1 ph_2$   
 $D_1 = (Q_0 + Q_1) \overline{ph_1} ph_2$   
 $D_2 = (Q_0 + Q_2) ph_1 \overline{ph_2}$   
 $D_3 = \overline{ph_1} \overline{ph_2} + (Q_1) ph_1 \overline{ph_2} + (Q_2) \overline{ph_1} ph_2 + Q_3^{(7)} (ph_1 \oplus ph_2)$   
 $fast = Q_1$   
 $slow = Q_2$

fsm/coding-06