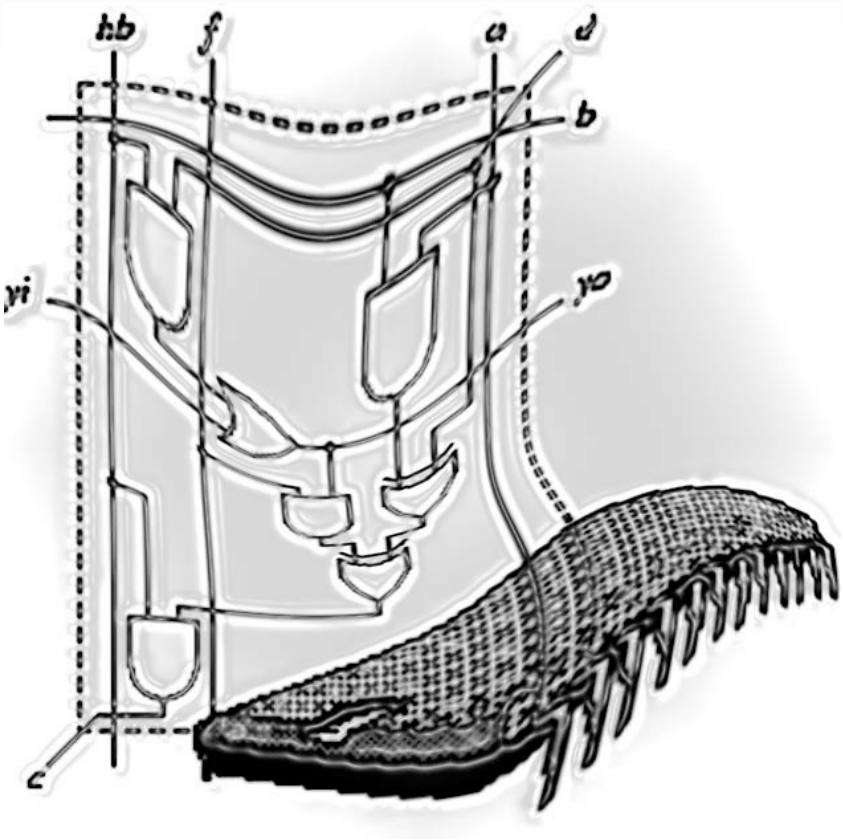
Technische Informatik I



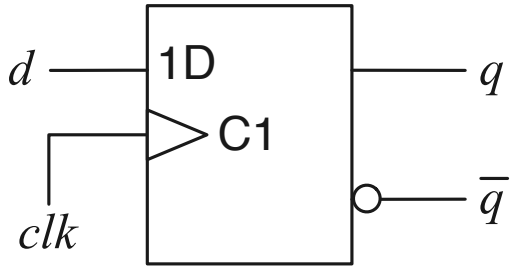
Kapitel 6

Schaltwerke

Prof. Dr. Dirk W. Hoffmann

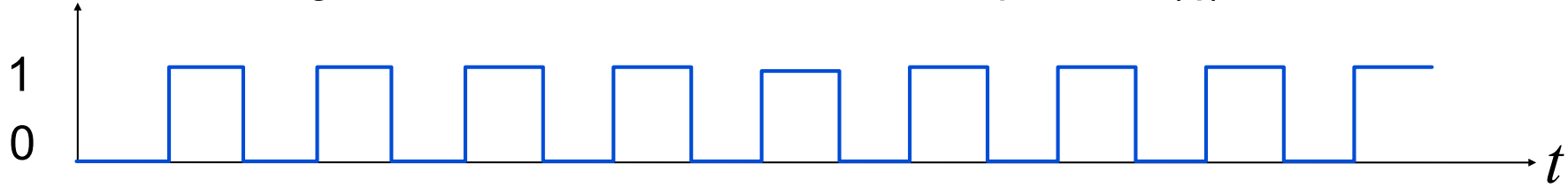
Hochschule Karlsruhe ◆ University of Applied Sciences ◆ Fakultät für Informatik

Das D-Flipflop



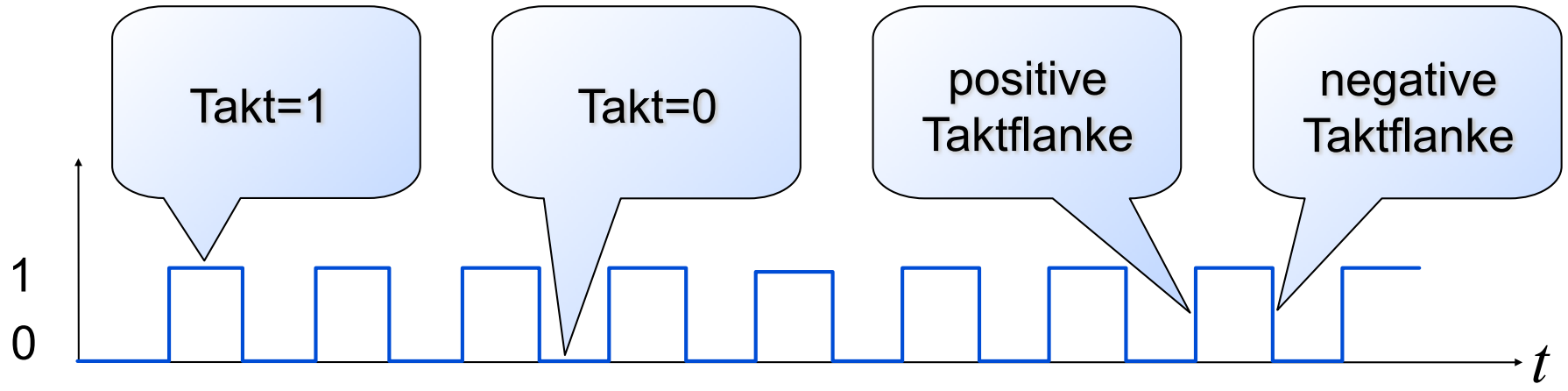
clk	*d*	*q‘*
0/1/↓	-	*q*
↑	0	0
↑	1	1

- Bei einer positiven Taktflanke (*clk*) …
  - … wird das Signal *d* in den internen Zustandsspeicher (*q*) übernommen

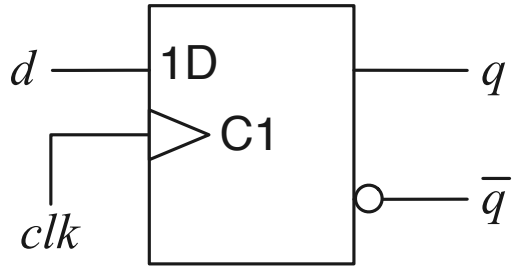


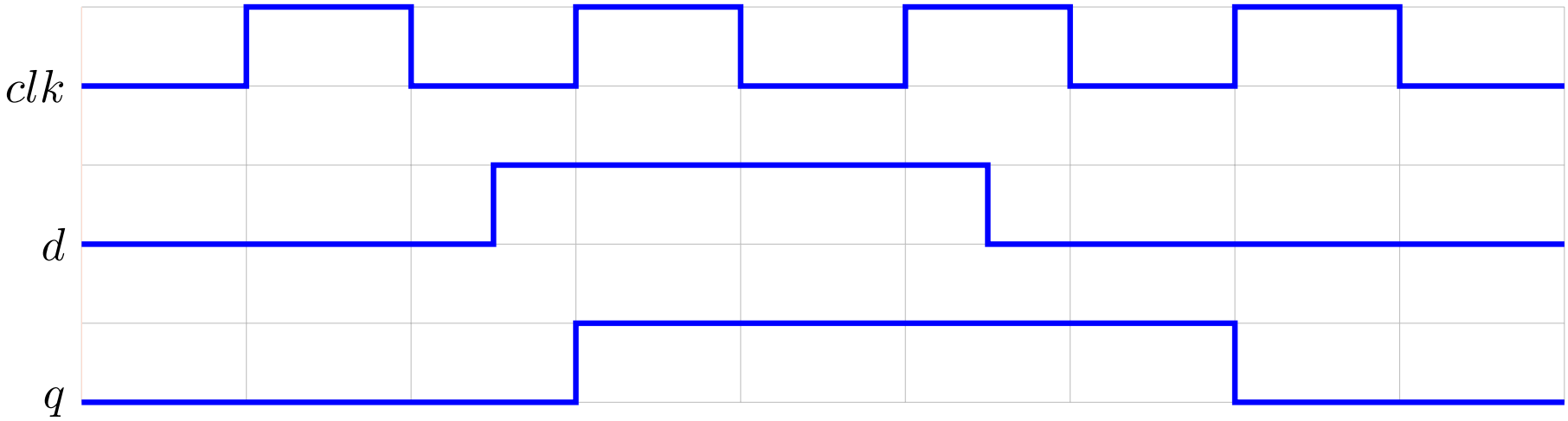
Takt

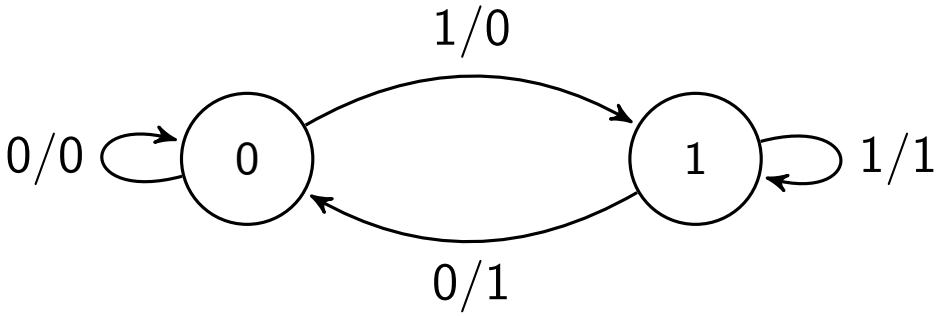
- Interner Zustand eines Schaltelements
  - Schaltelemente sind zu jedem Zeitpunkt im Zustand 0 oder im Zustand 1
  - Zustandsänderungen werden über den Takt gesteuert
- Pegelsteuerung
  - Zustandsänderung während eine 1 auf der Taktleitung anliegt
- Flankensteuerung
  - Zustandsänderung bei einer positiven bzw. einer negativen Taktflanke



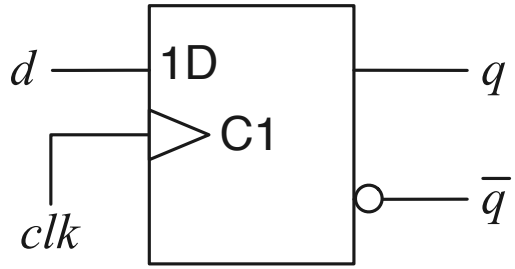
Das D-Flipflop

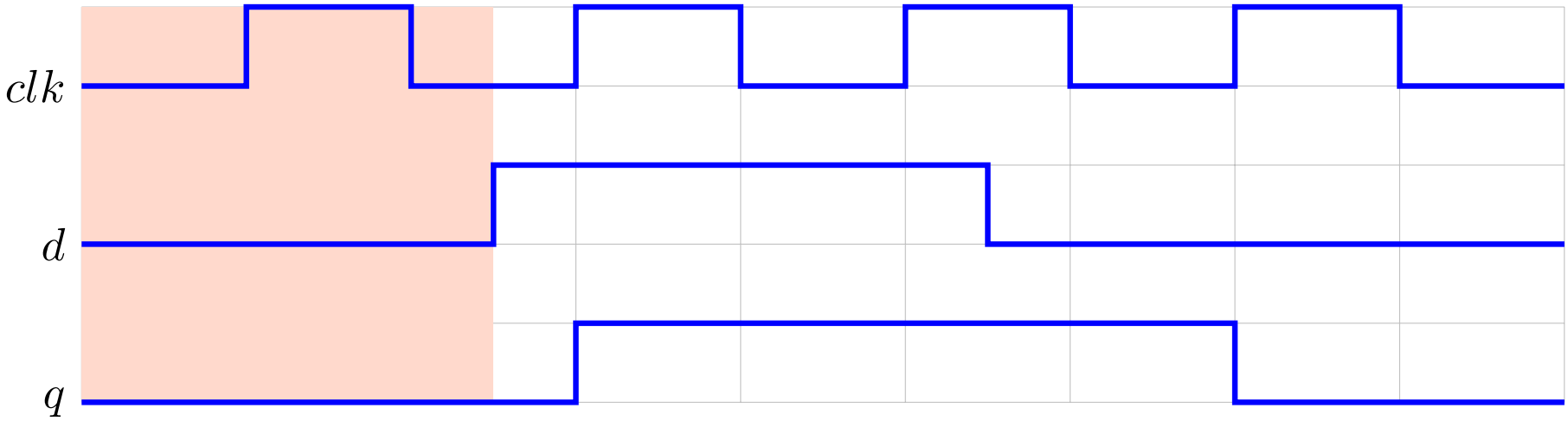


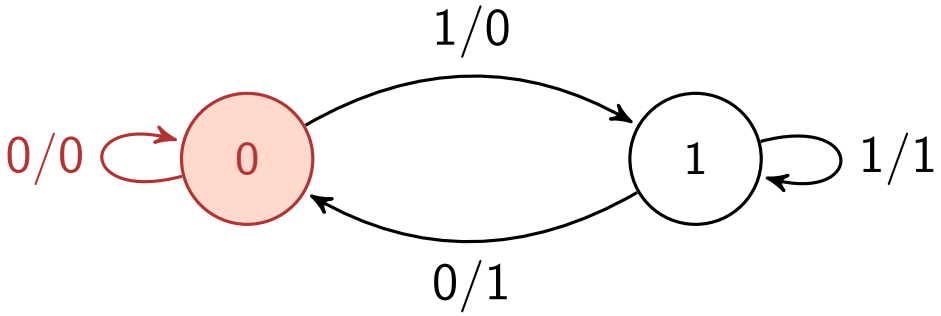




Das D-Flipflop







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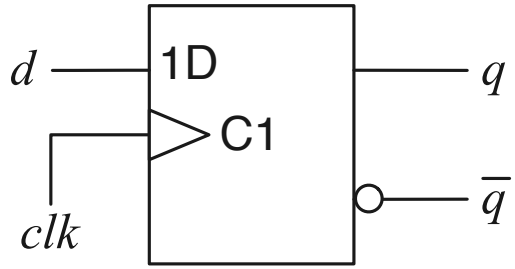
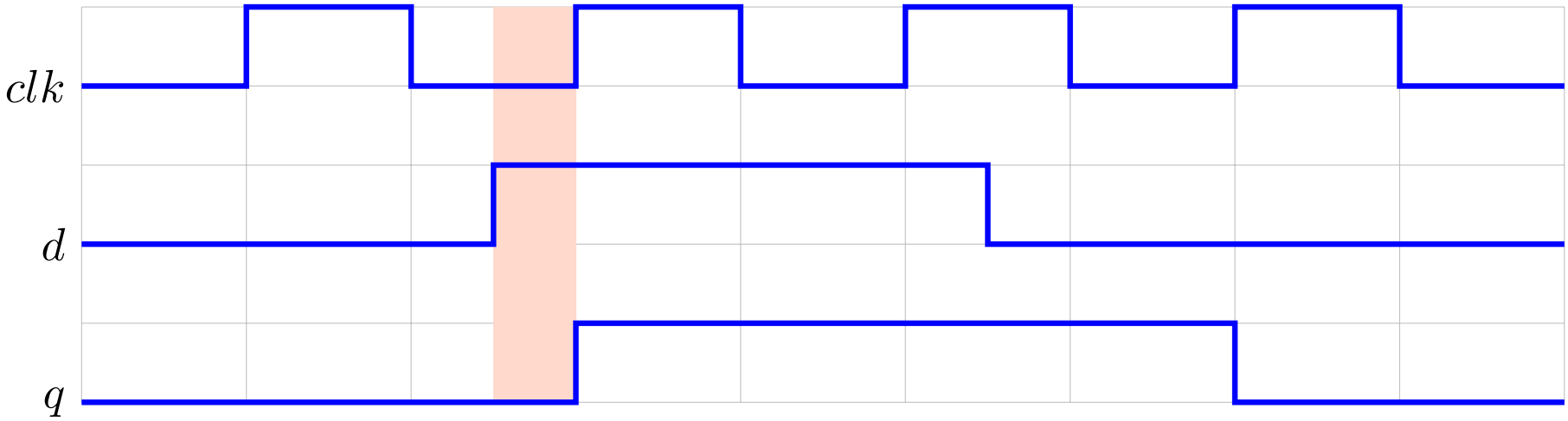
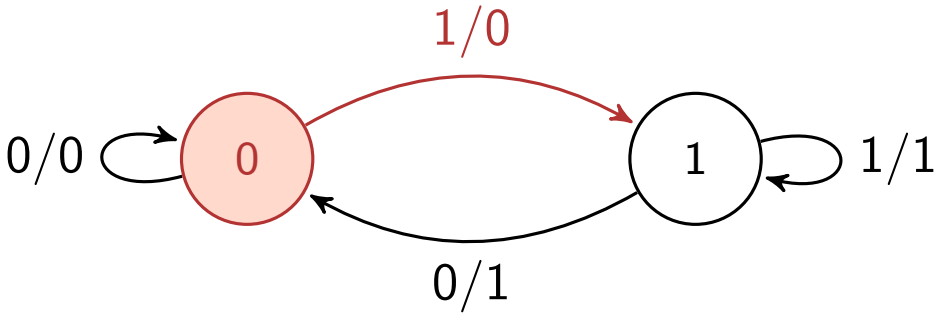
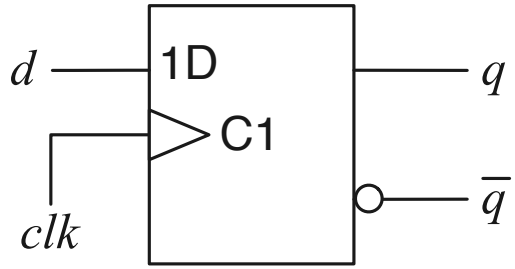
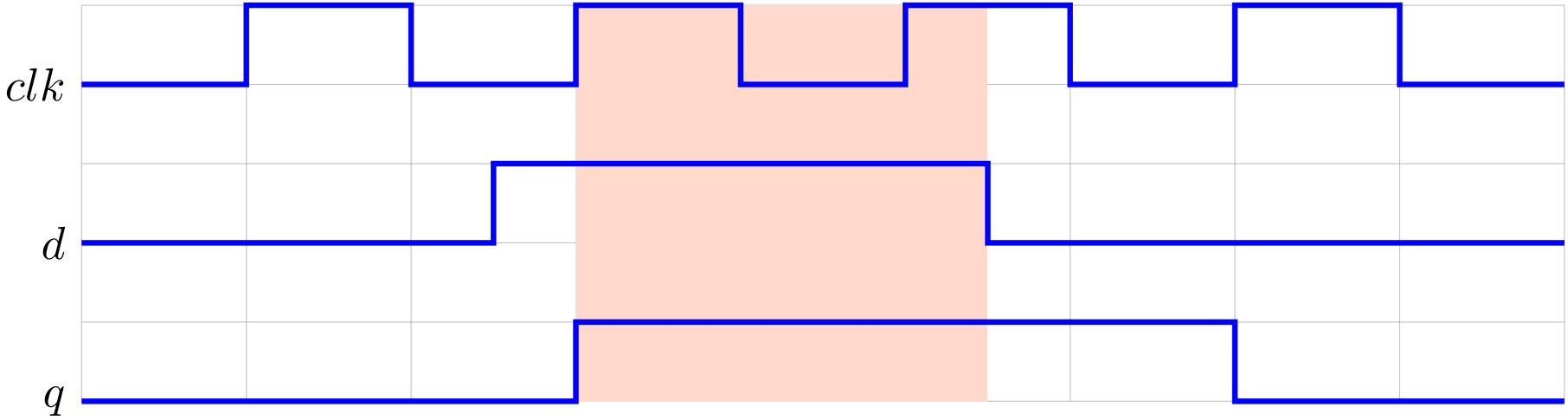


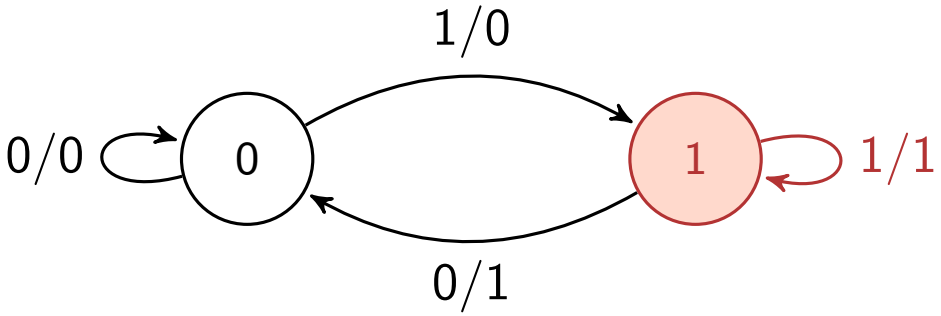




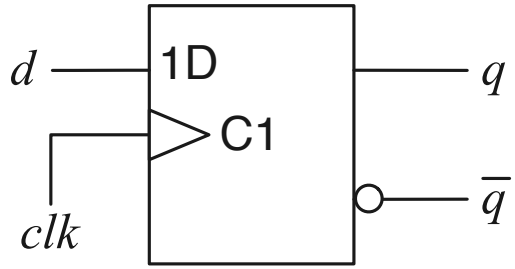
Das D-Flipflop

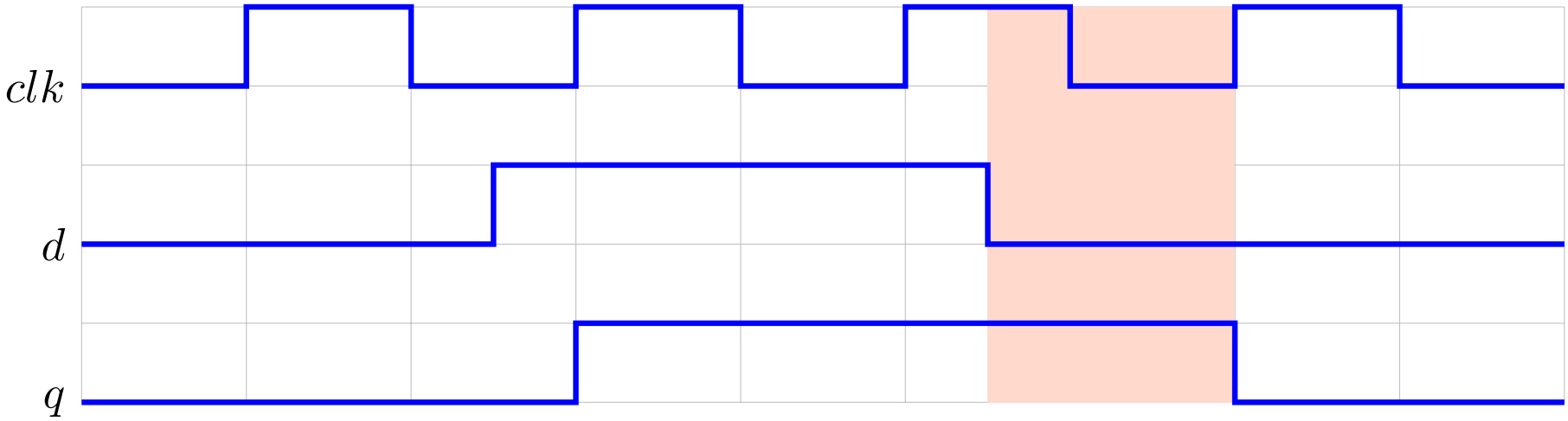


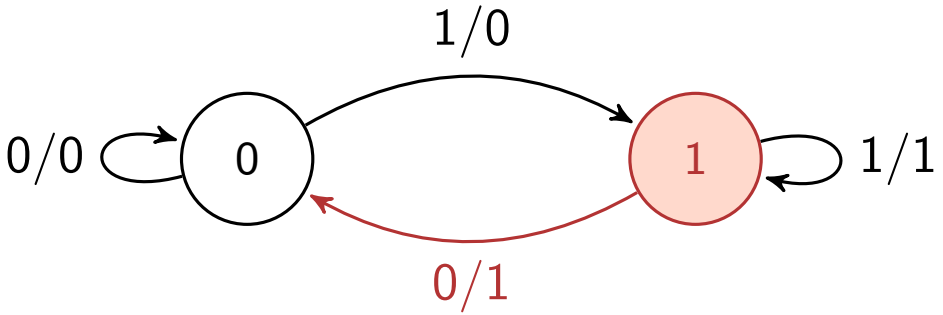




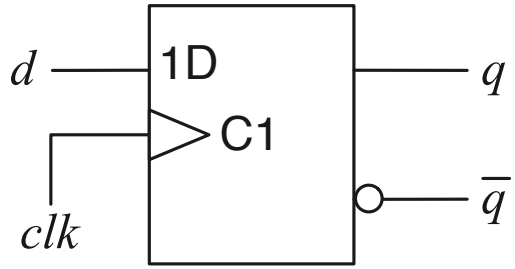
Das D-Flipflop

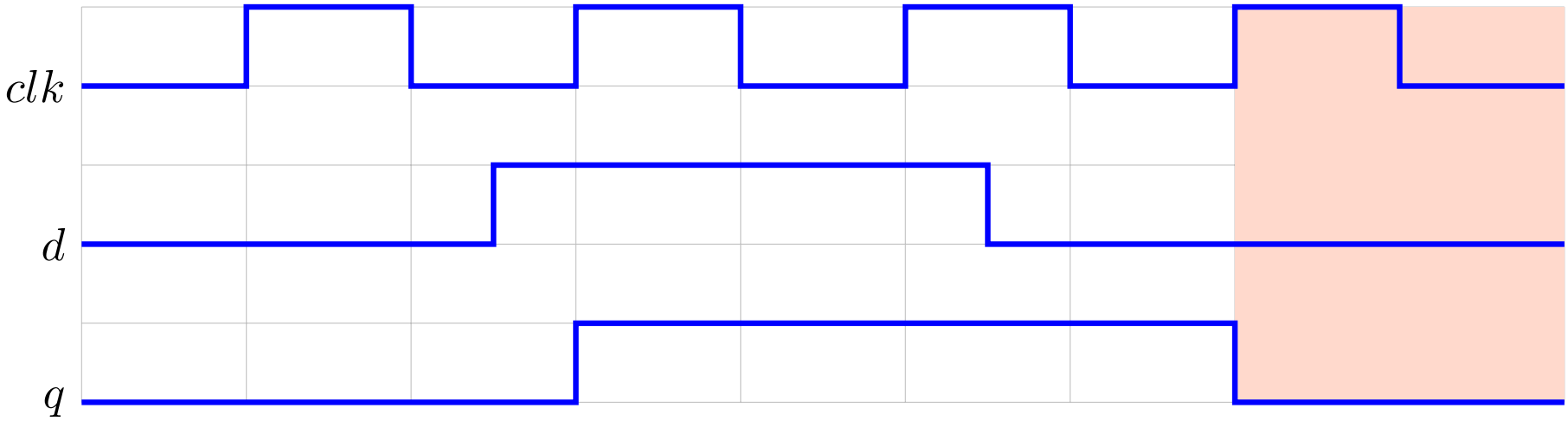


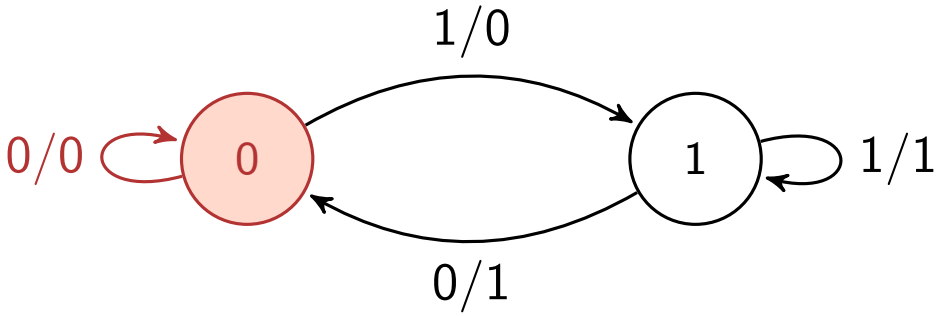




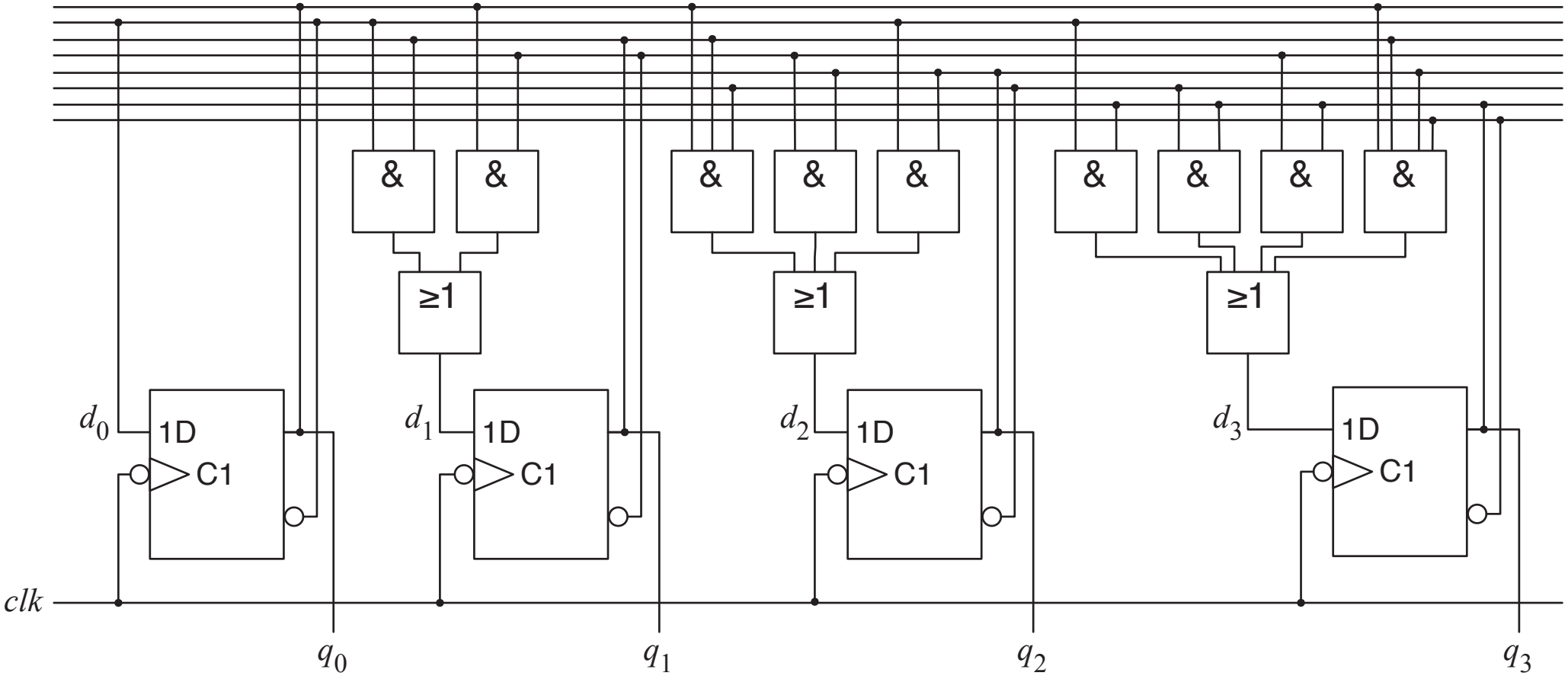
Das D-Flipflop



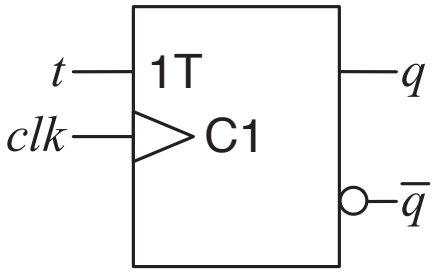




Was verbirgt sich hinter dieser Schaltung?



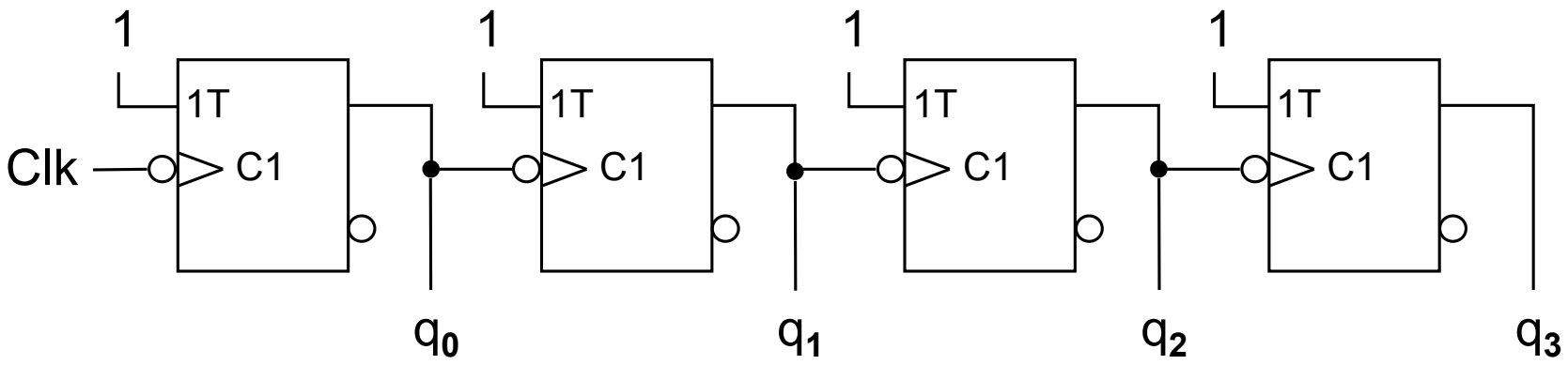
Das T-Flipflop



clk	*t*	*q‘*
0/1/↓	-	*q*
↑	0	*q*
↑	1	¬*q*

- Bei einer positiven Taktflanke (*clk*) …
  - … wird bei *t* = 0 der Zustand *q* beibehalten.
  - … wird bei *t* = 1 der Zustand *q* invertiert.

Was verbirgt sich hinter dieser Schaltung?



- Bei einer positiven Taktflanke (*clk*) …
  - … wird bei $t = 0$ der Zustand q beibehalten.
  - … wird bei $t = 1$ der Zustand q invertiert.

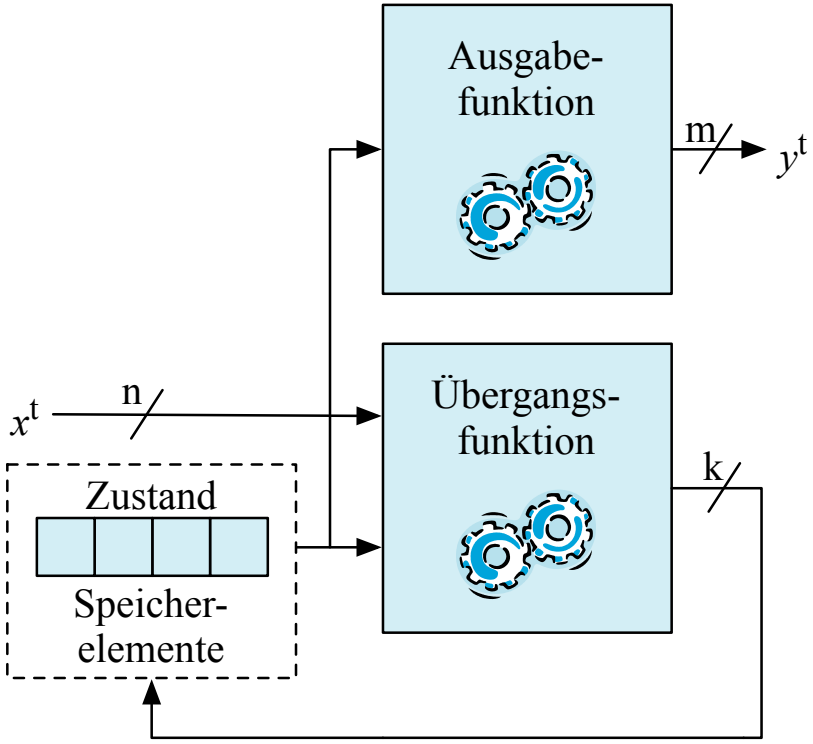
Analyse

- Synchroner Zähler
  - ⊕ Schnelle Implementierung durch zweistufiges Netz
  - ⊕ Alle Flipflops schalten zur gleichen Zeit
  - ⊖ Hohe Hardware-Kosten
    - Anzahl Gatter steigt quadratisch mit der Anzahl Bits an
- Asynchroner Zähler
  - ⊕ Geringe Hardware-Kosten
    - Anzahl Gatter steigt linear mit der Bitbreite an
  - ⊖ Laufzeit steigt linear mit der Bitbreite an
  - ⊖ Flipflops schalten zu unterschiedlichen Zeiten

Schaltwerke – Allgemeines Schema

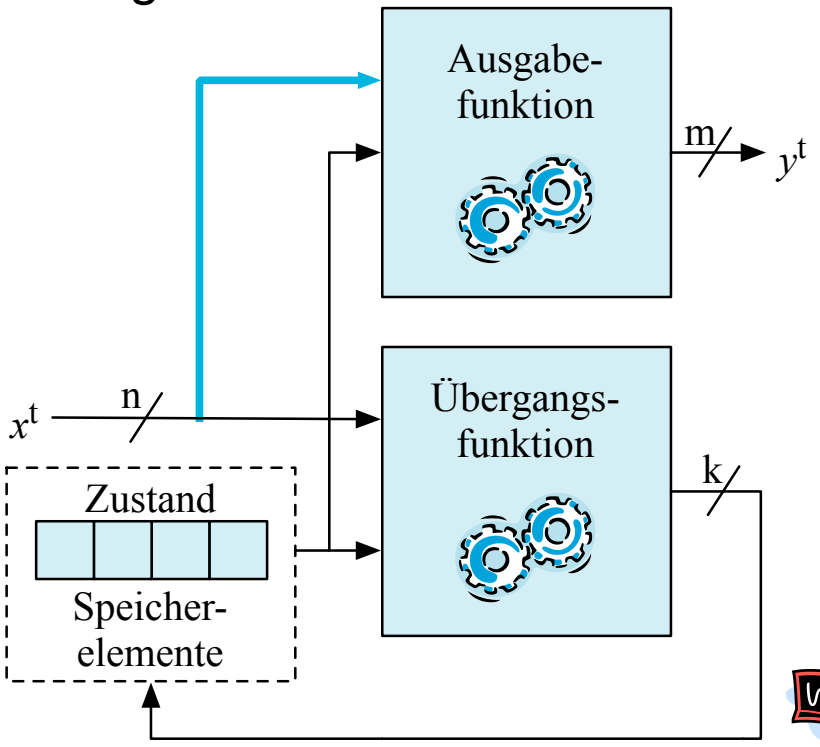
Moore-Automat

- Zustandsautomat
  - Ausgabe hängt ausschließlich vom aktuellen Zustand ab



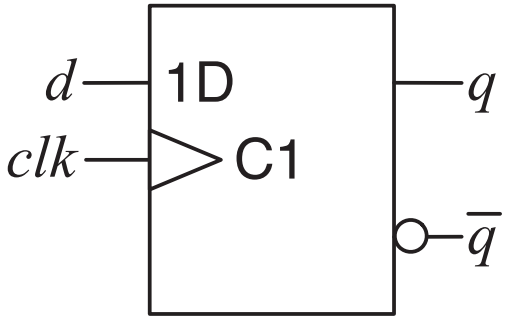
Mealy-Automat

- Übergangsautomat
  - Ausgabe hängt vom aktuellen Zustand und der aktuellen Eingabe ab

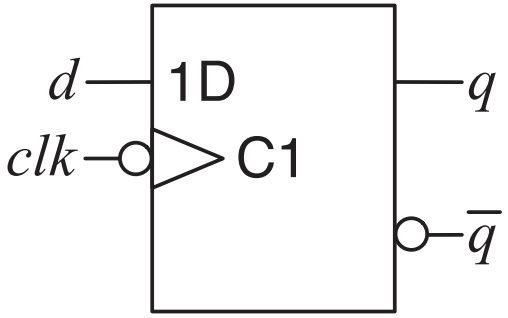


Verschiedene Varianten des D-Elements

- Flipflops

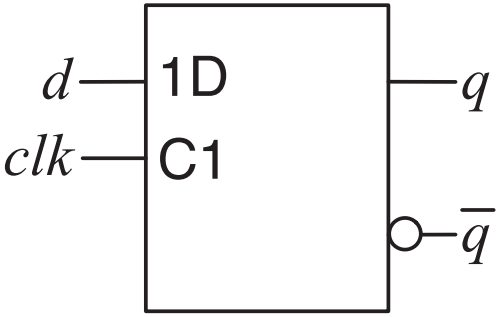


Schaltet bei einer positiven Taktflanke

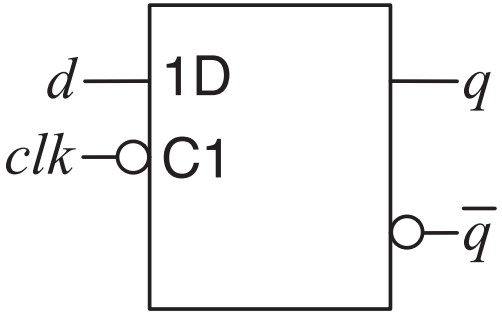


Schaltet bei einer negativen Taktflanke

- Latches



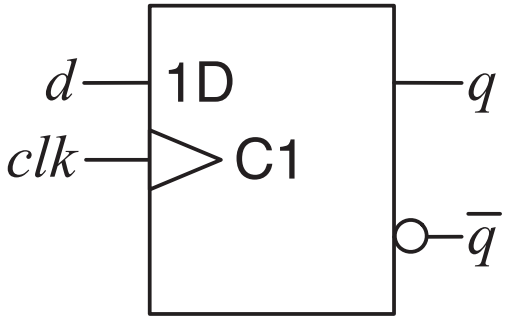
Schaltet während der positiven Taktphase

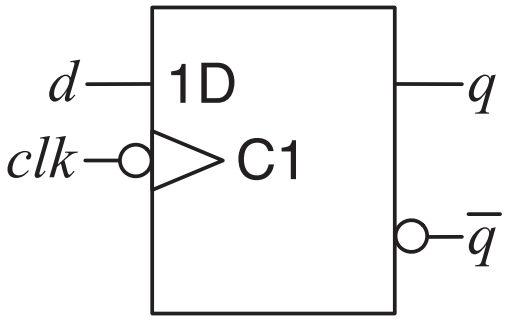


Schaltet während der negativen Taktphase

Verschiedene Varianten des D-Elements

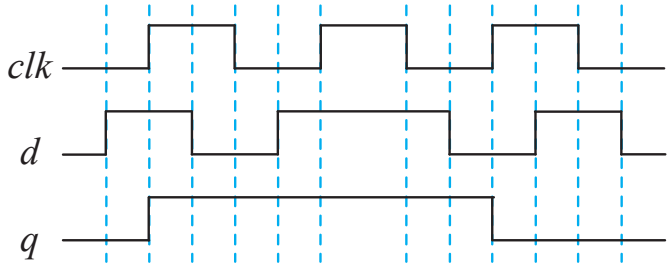
- Flipflops

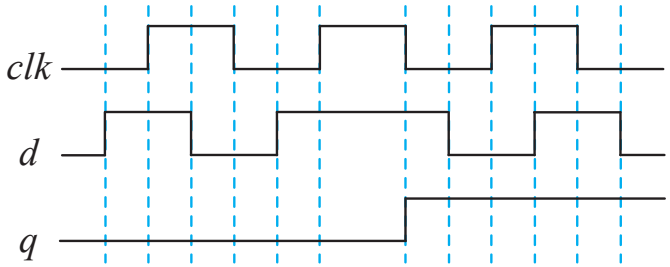




clk	d	q^{t+1}
0/1/↓	-	q^t
↑	0	0
↑	1	1

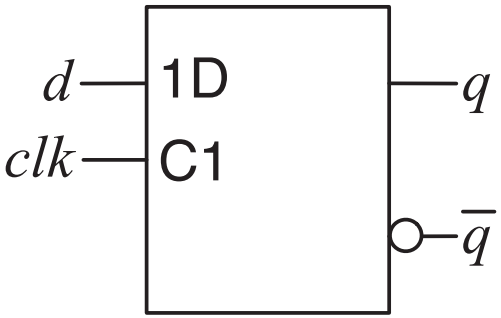
clk	d	q^{t+1}
0/1/↑	-	q^t
↓	0	0
↓	1	1





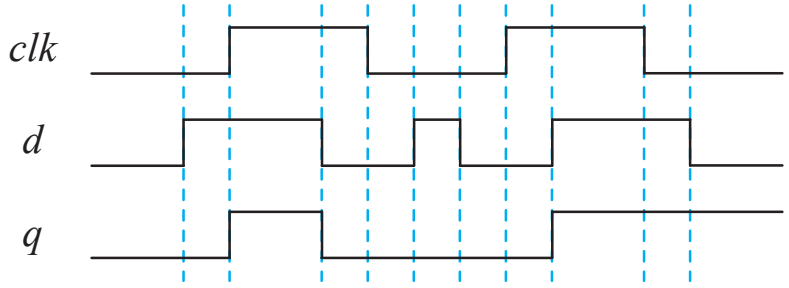
Verschiedene Varianten des D-Elements

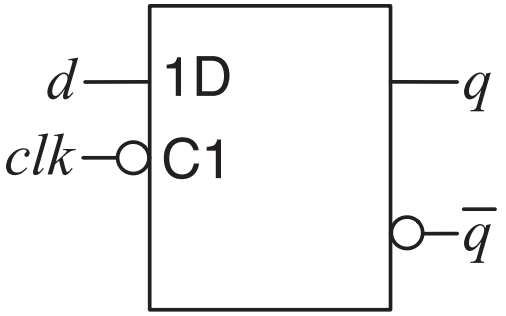
- Latches



Schaltet während der positiven Taktphase

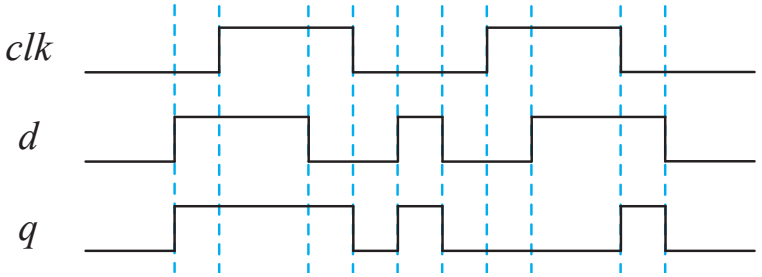
clk	d	q^{t+1}
0	-	q^t
1	0	0
1	1	1





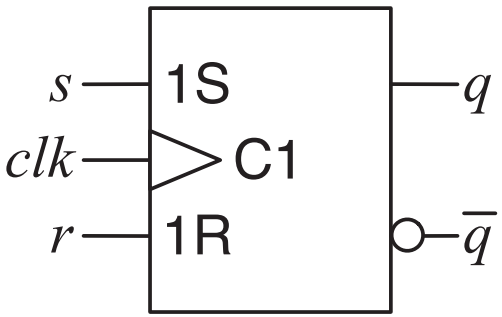
Schaltet während der negativen Taktphase

clk	d	q^{t+1}
0	0	0
0	1	1
1	-	q^t

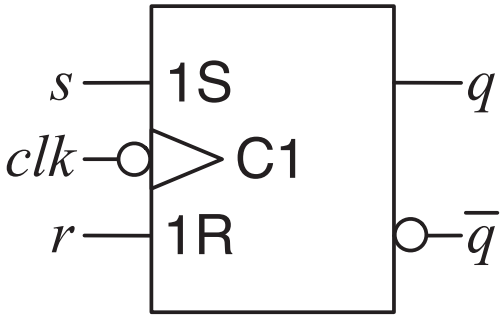


Verschiedene Varianten des RS-Elements

- Flipflops

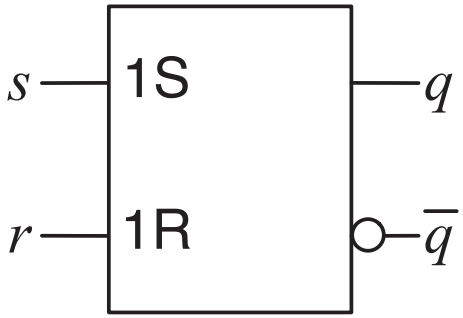


Schaltet bei einer positiven Taktflanke

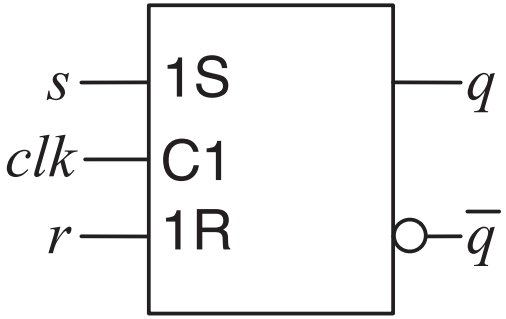


Schaltet bei einer negativen Taktflanke

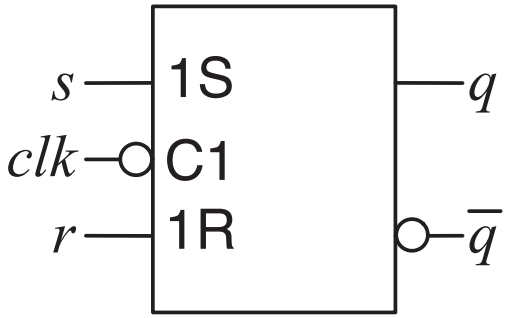
- Latches



Schaltet zu einem beliebigen Zeitpunkt



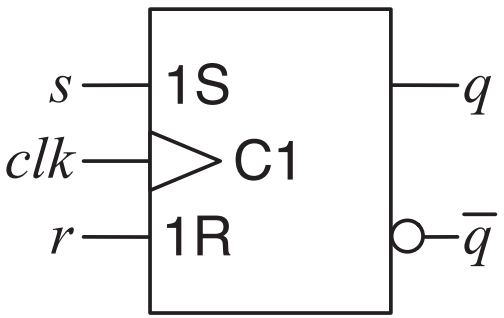
Schaltet während der positiven Taktphase

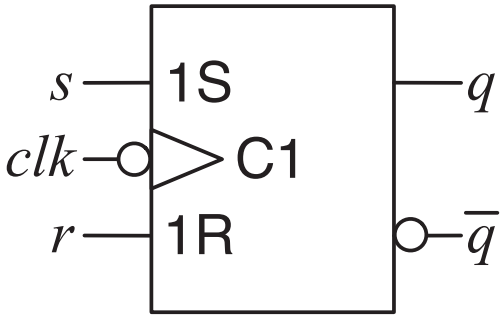


Schaltet während der negativen Taktphase

Verschiedene Varianten des RS-Elements

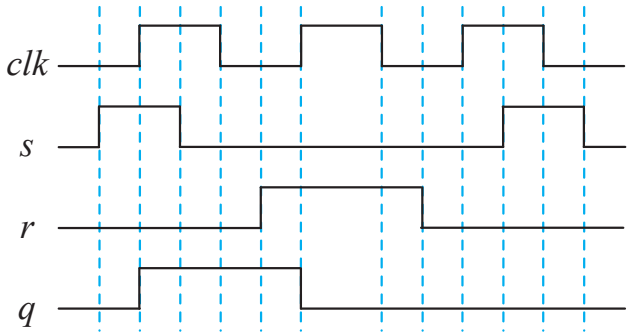
- Flipflops

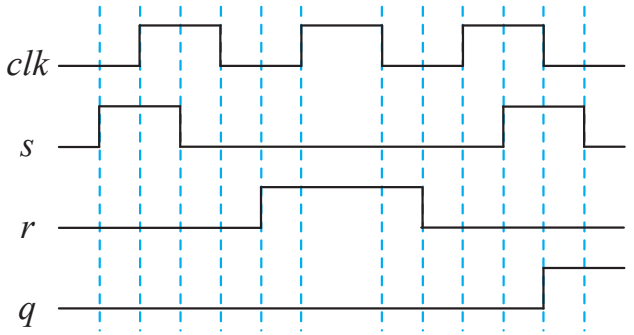




clk	s	r	q^{t+1}
0/1/↓	-	-	q^t
↑	0	0	q^t
↑	0	1	0
↑	1	0	1
↑	1	1	-

clk	s	r	q^{t+1}
0/1/↑	-	-	q^t
↓	0	0	q^t
↓	0	1	0
↓	1	0	1
↓	1	1	-

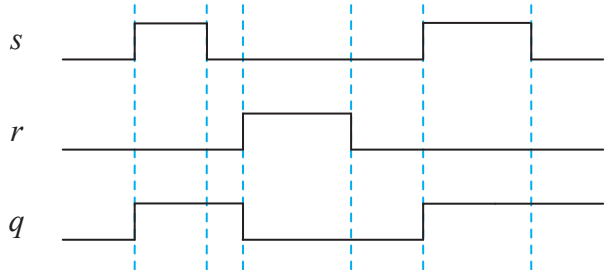




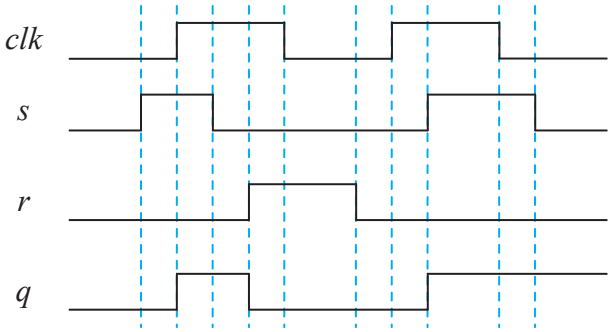
Verschiedene Varianten des RS-Elements

- Flipflops

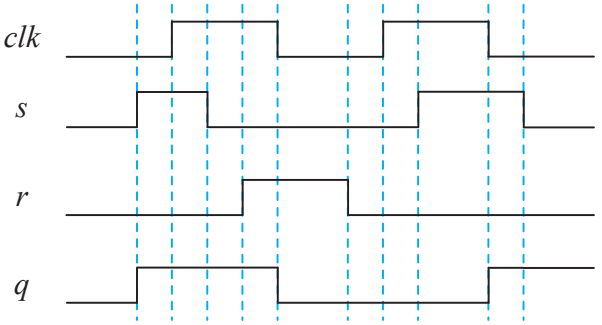
r	s	q^{t+1}
0	0	q^t
0	1	1
1	0	0
1	1	-



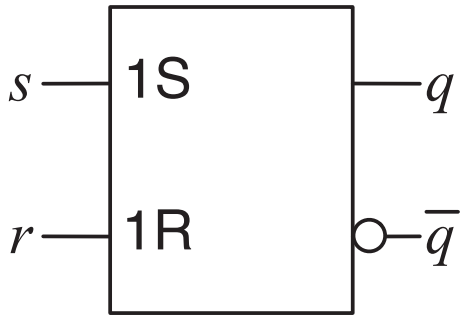
clk	r	s	q^{t+1}
0	-	-	q^t
1	0	0	q^t
1	0	1	1
1	1	0	0
1	1	1	-

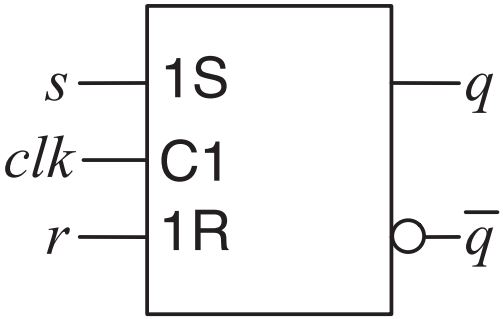


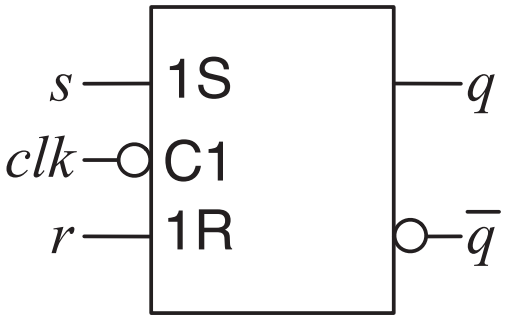
clk	r	s	q^{t+1}
0	0	0	q^t
0	0	1	1
0	1	0	0
0	1	1	-
1	-	-	q^t



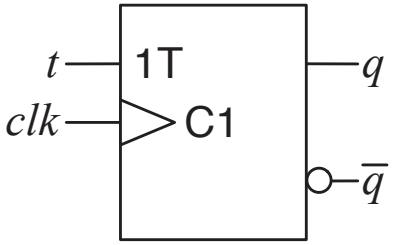
- Latches

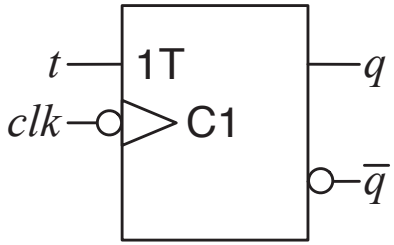






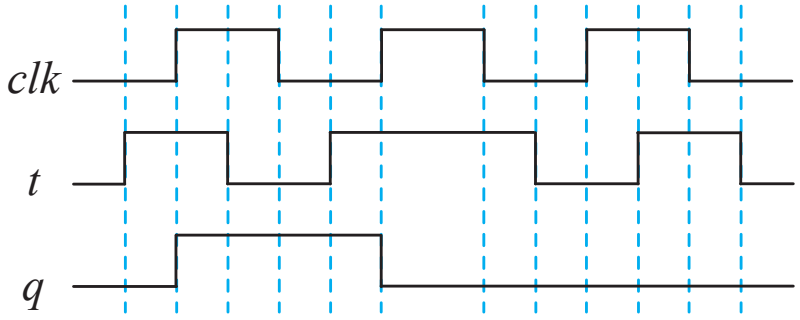
T-Flipflops

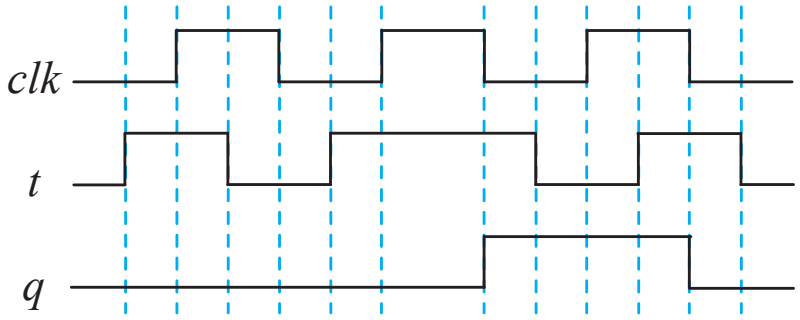




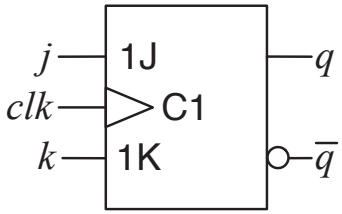
clk	t	q^{t+1}
0/1/↓	-	q^t
↑	0	q^t
↑	1	$\neg q^t$

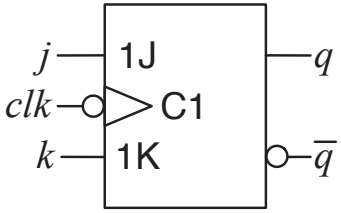
clk	t	q^{t+1}
0/1/↑	-	q^t
↓	0	q^t
↓	1	$\neg q^t$





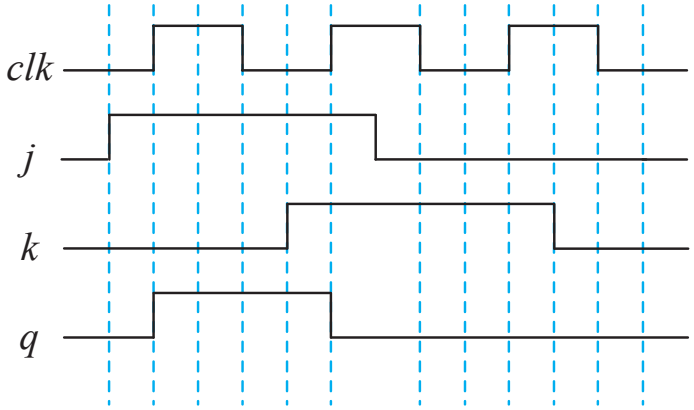
JK-Flipflops

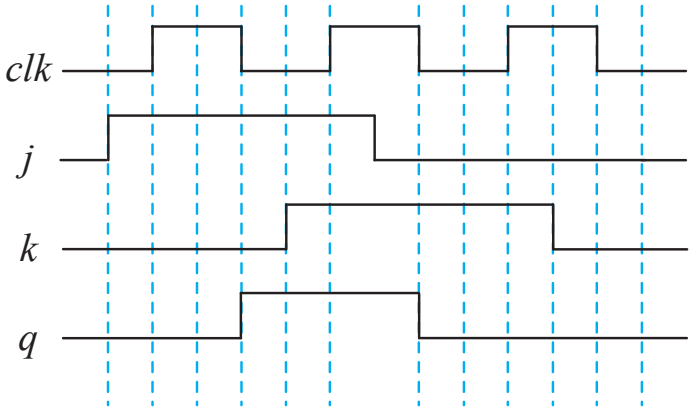




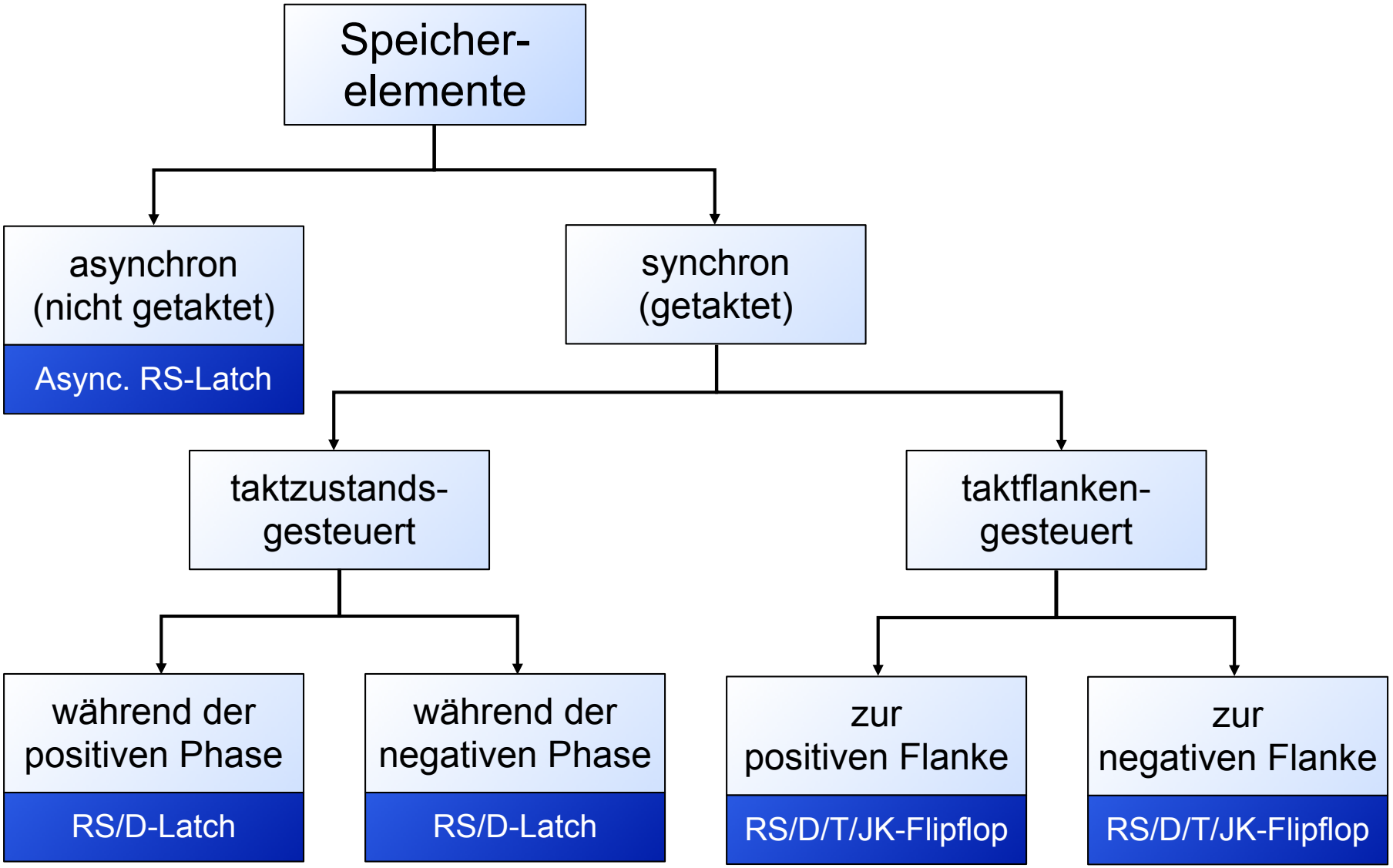
clk	j	k	q^{t+1}
0/1/↓	-	-	q^t
↑	0	0	q^t
↑	0	1	0
↑	1	0	1
↑	1	1	$\neg q^t$

clk	j	k	q^{t+1}
0/1/↑	-	-	q^t
↓	0	0	q^t
↓	0	1	0
↓	1	0	1
↓	1	1	$\neg q^t$

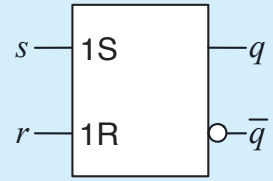
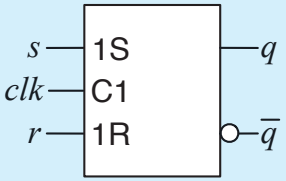
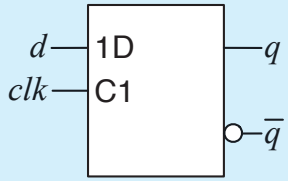
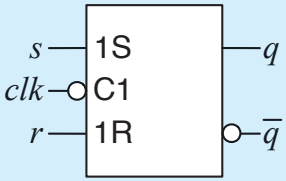
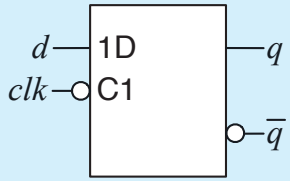
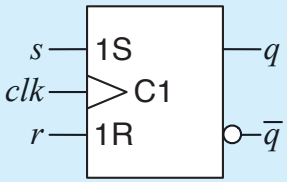
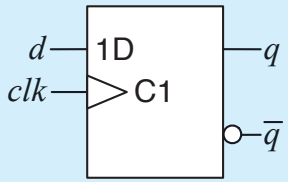
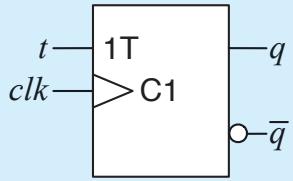
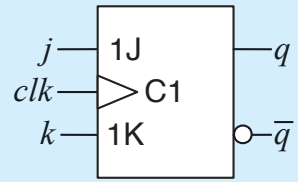




Zusammenfassung: Speicherelemente



Zusammenfassung: Schaltsymbole

	RS-Element	D-Element	T-Element	JK-Element
Asynchron				
Synchron, positiv taktzustandsgesteuert				
Synchron, negativ taktzustandsgesteuert				
Synchron, positiv taktflankengesteuert				
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