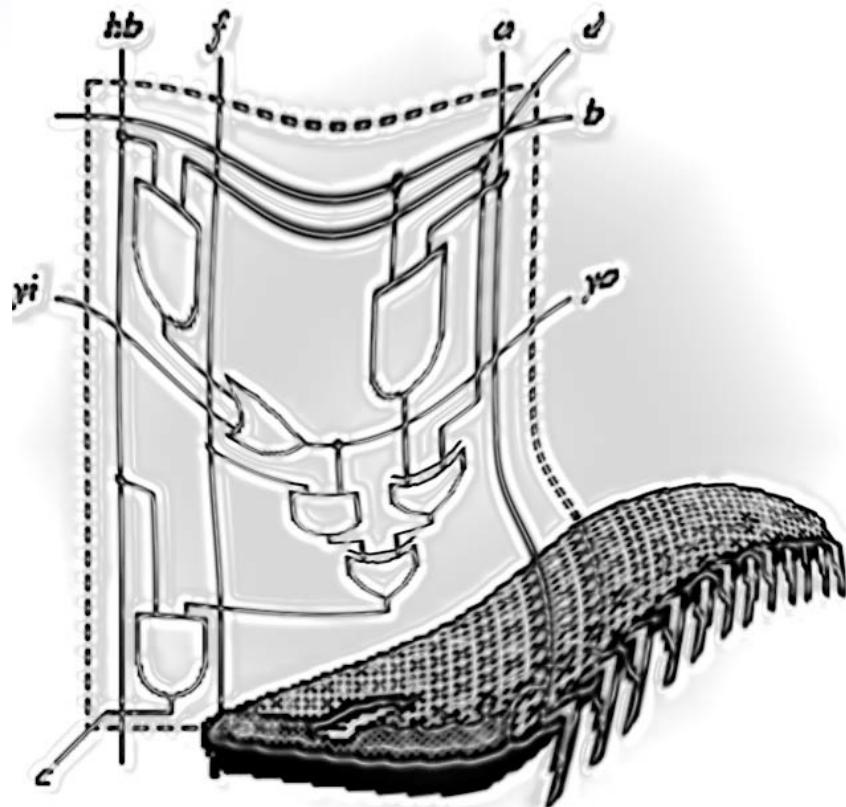


Technische Informatik I



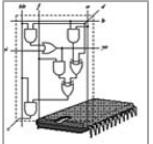
Kapitel 6

Schaltwerke

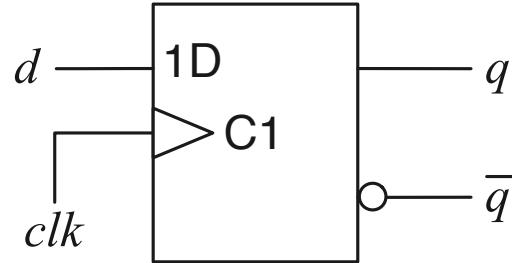
Prof. Dr. Dirk W. Hoffmann

Hochschule Karlsruhe ♦ University of Applied Sciences ♦ Fakultät für Informatik



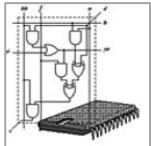


Das D-Flipflop

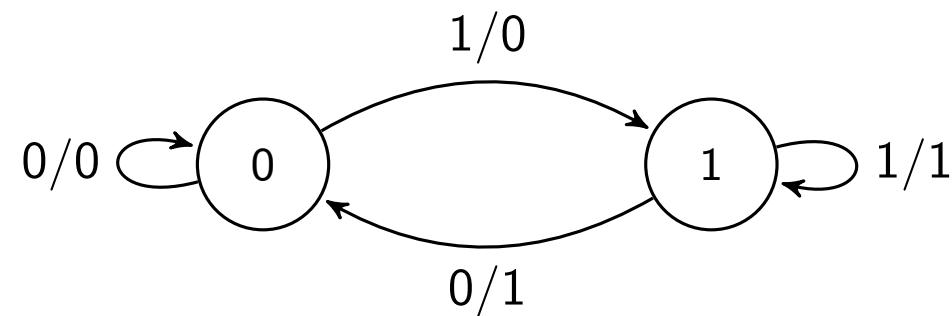
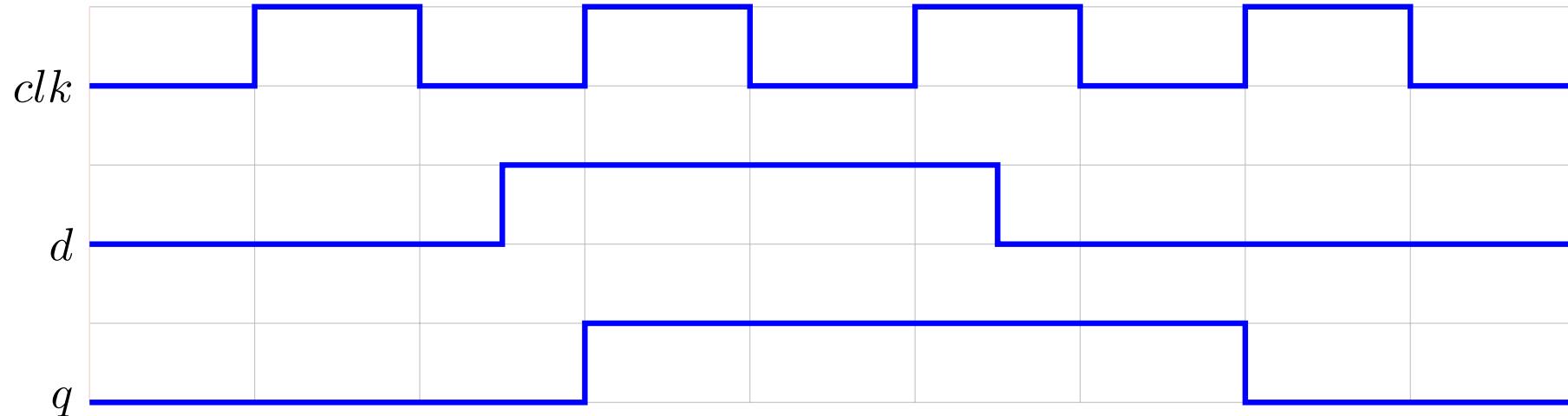
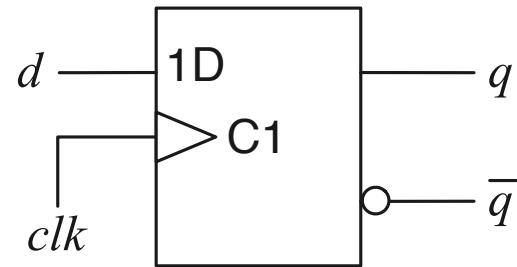


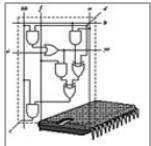
clk	d	q'
$0/1/\downarrow$	-	q
\uparrow	0	0
\uparrow	1	1

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

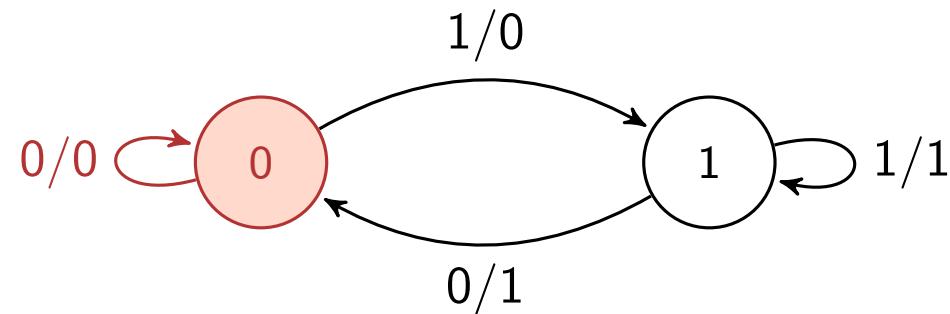
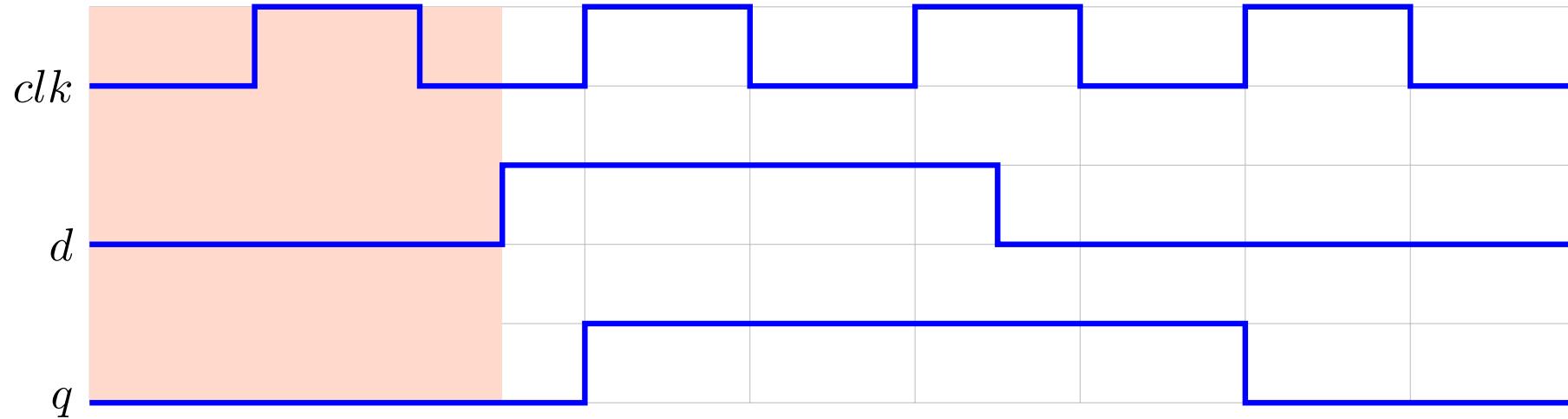
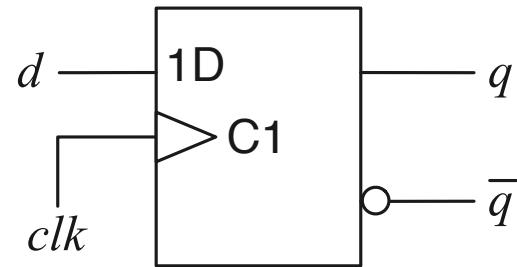


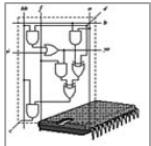
Das D-Flipflop



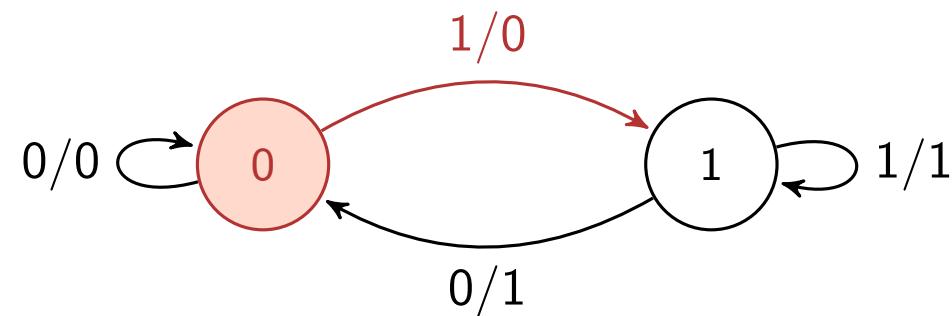
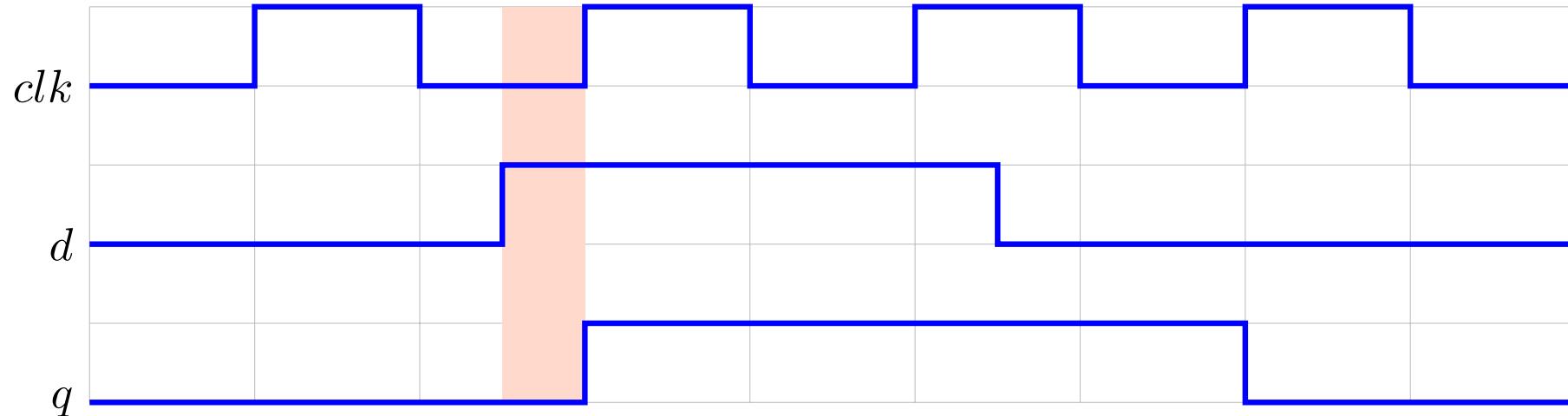
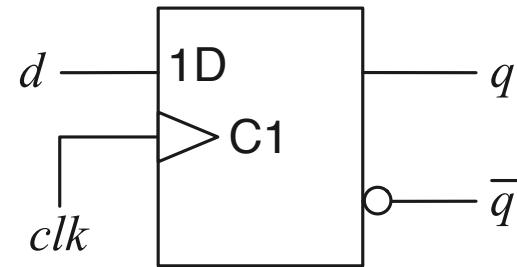


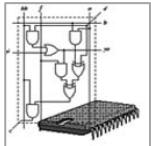
Das D-Flipflop



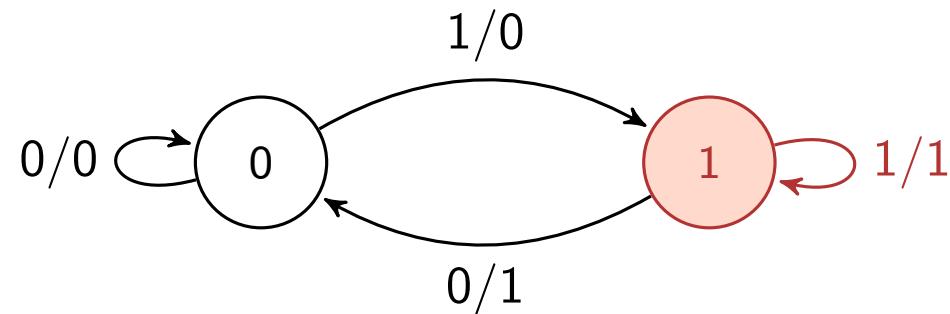
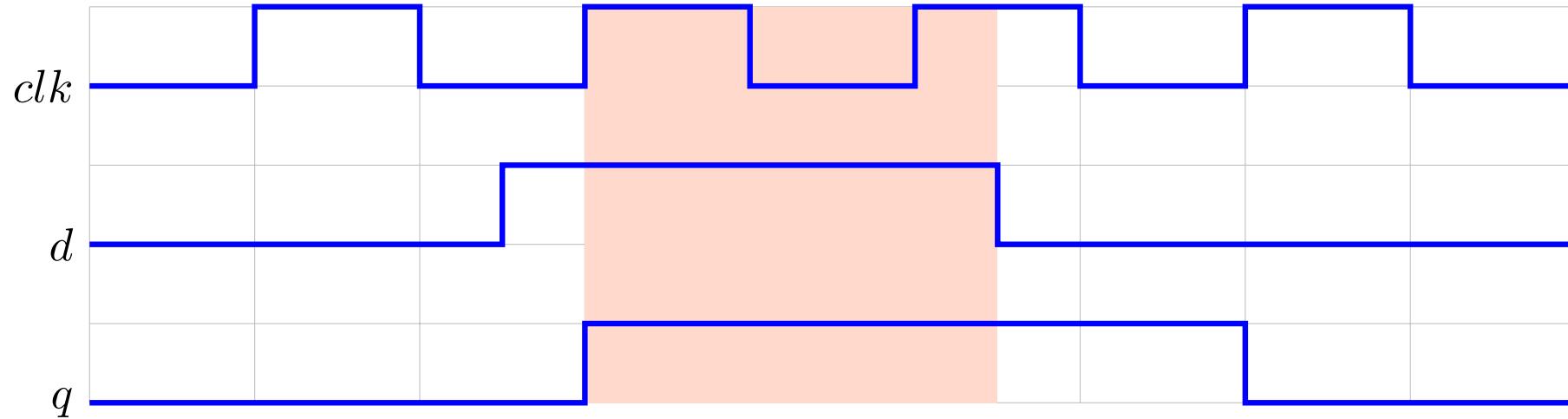
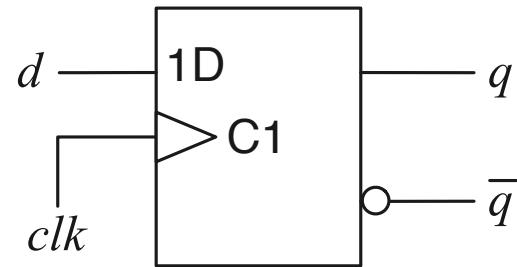


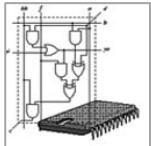
Das D-Flipflop



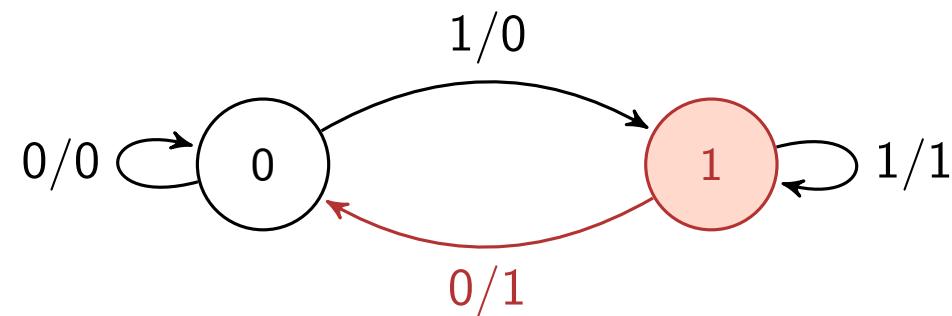
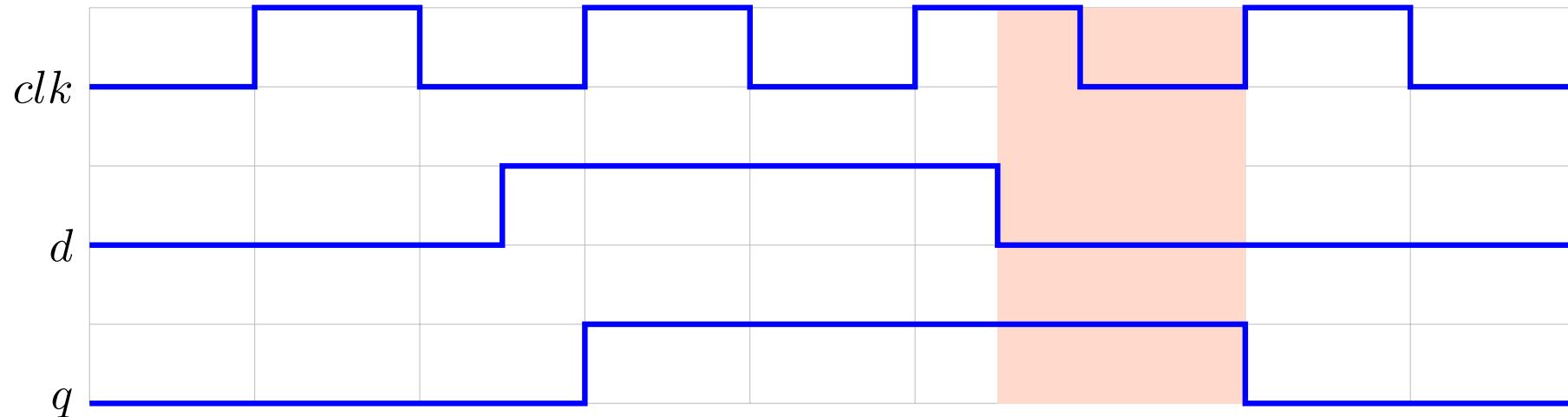
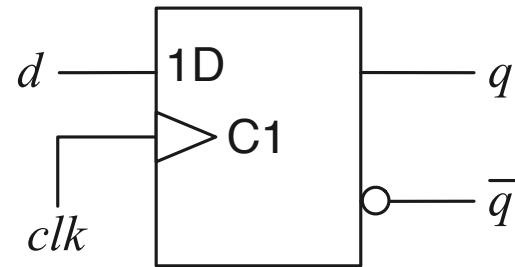


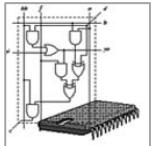
Das D-Flipflop



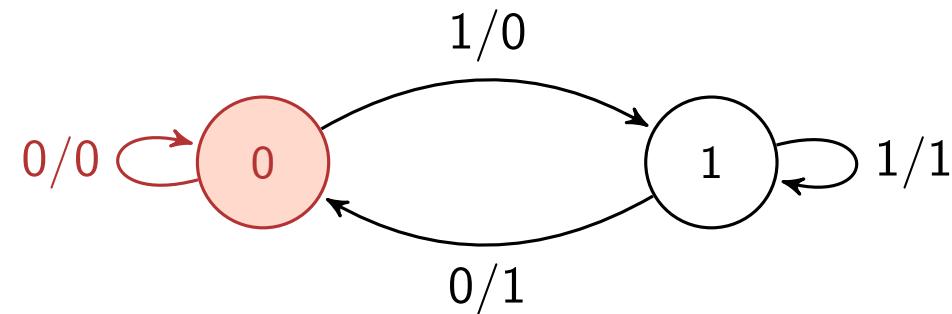
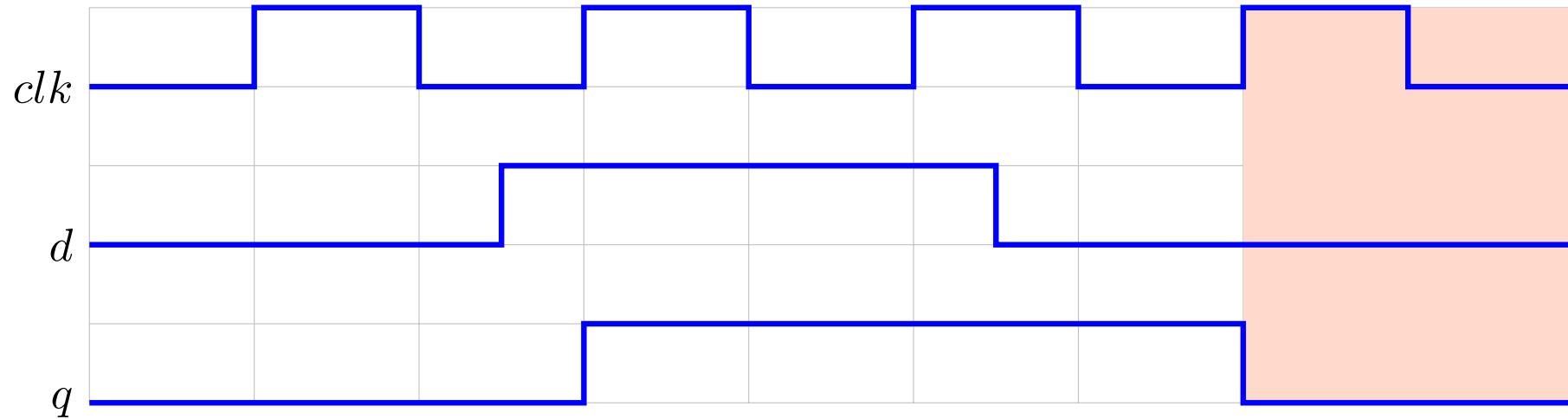
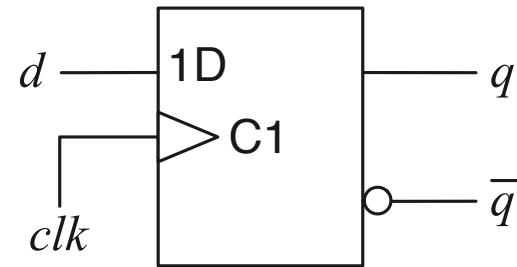


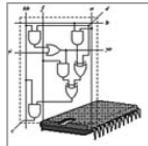
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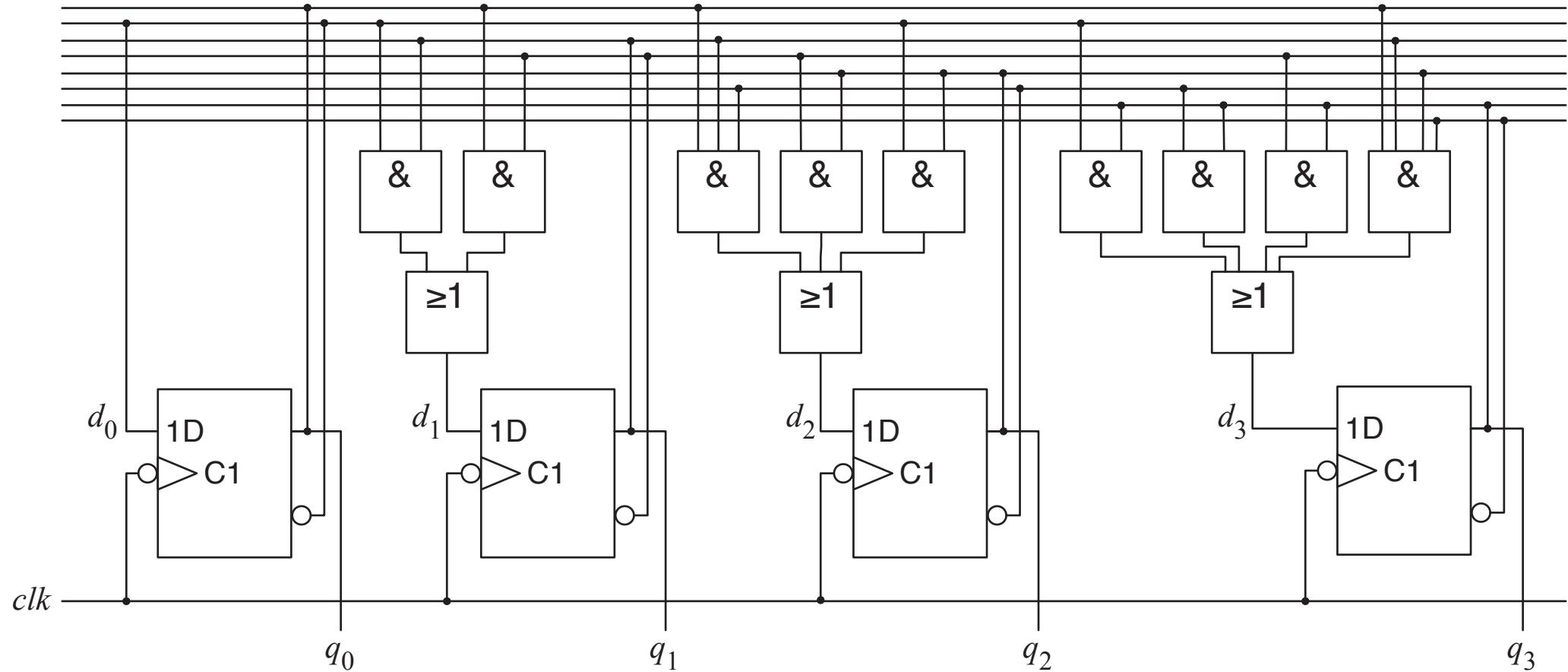


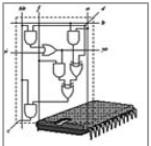
Das D-Flipflop



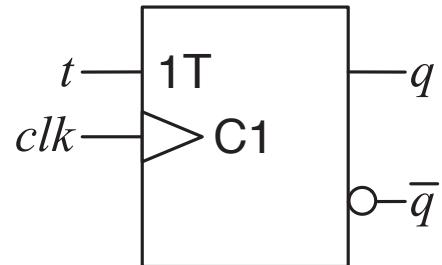


Was verbirgt sich hinter dieser Schaltung?



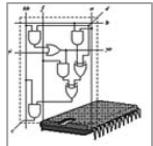


Das T-Flipflop

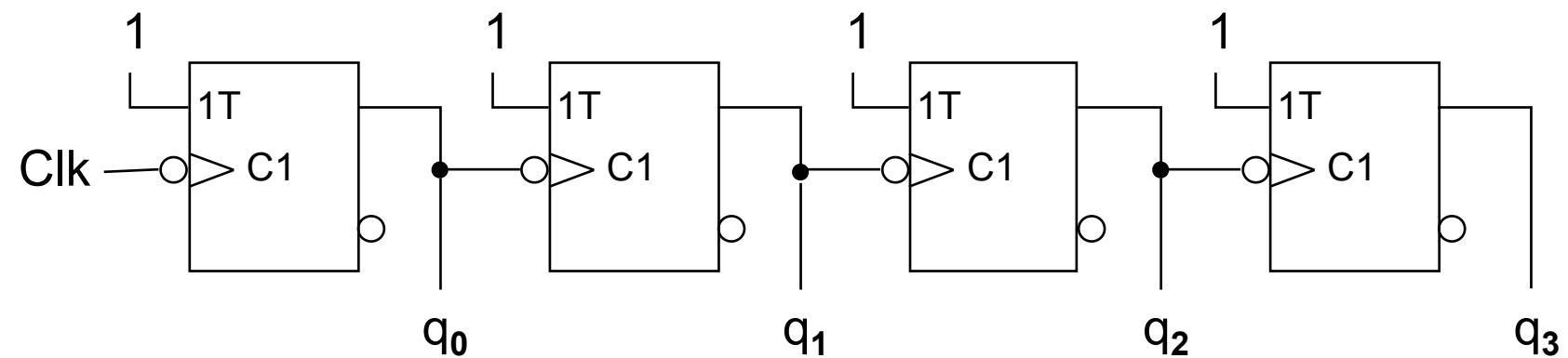


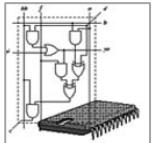
clk	t	q'
0/1/ \downarrow	-	q
\uparrow	0	q
\uparrow	1	$\neg q$

- 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?





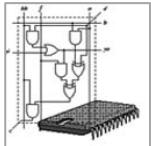
■ Synchroner Zähler

- ① Schnelle Implementierung durch zweistufiges Netz
- ① Alle Flipflops schalten zur gleichen Zeit
- ④ Hohe Hardware-Kosten

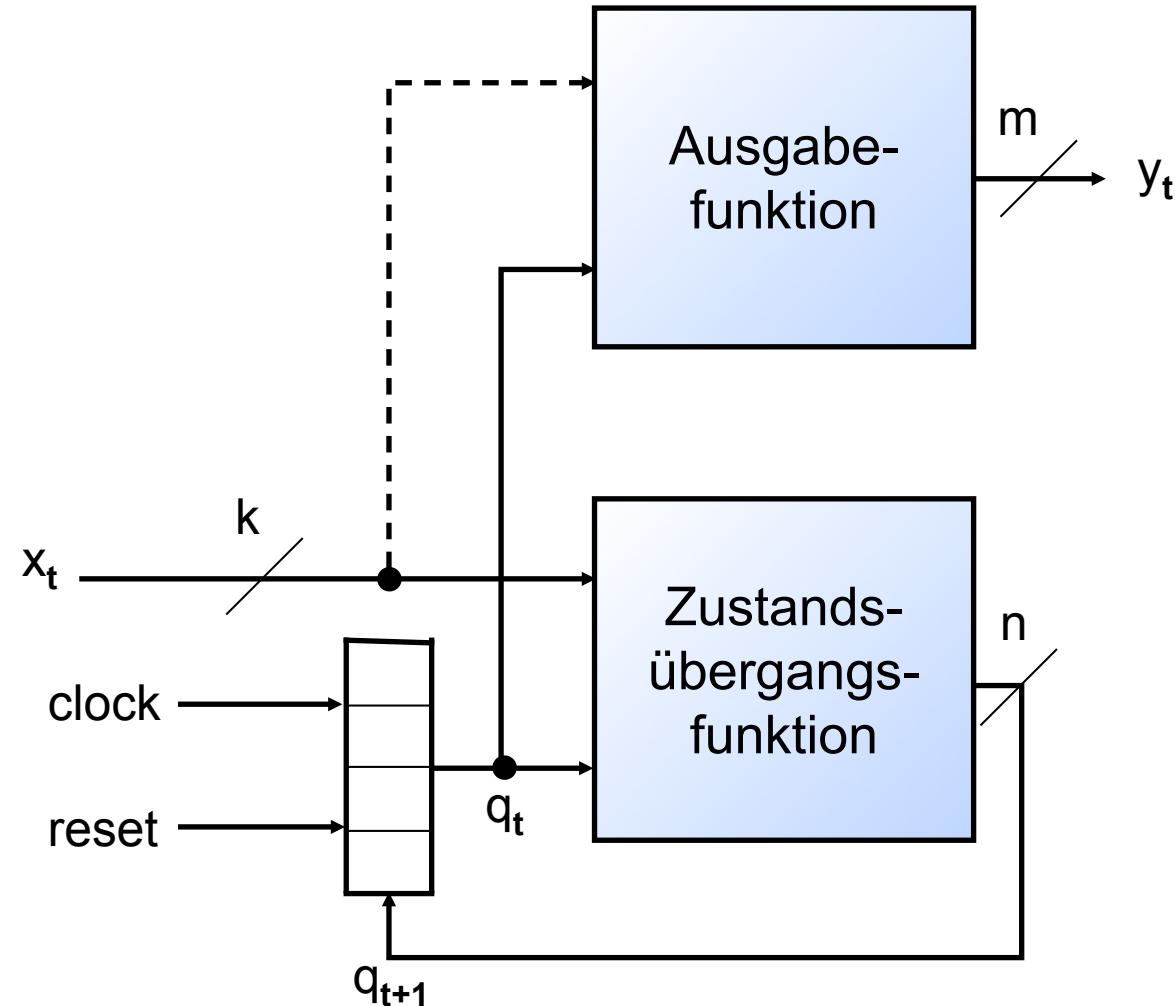
Anzahl Gatter steigt quadratisch mit der Anzahl Bits an

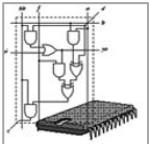
■ Asynchroner Zähler

- ① Geringe Hardware-Kosten
Anzahl Gatter steigt linear mit der Bitbreite an
- ④ Laufzeit steigt linear mit der Bitbreite an
- ④ Flipflops schalten zu unterschiedlichen Zeiten



Schaltwerke – Allgemeines Schema

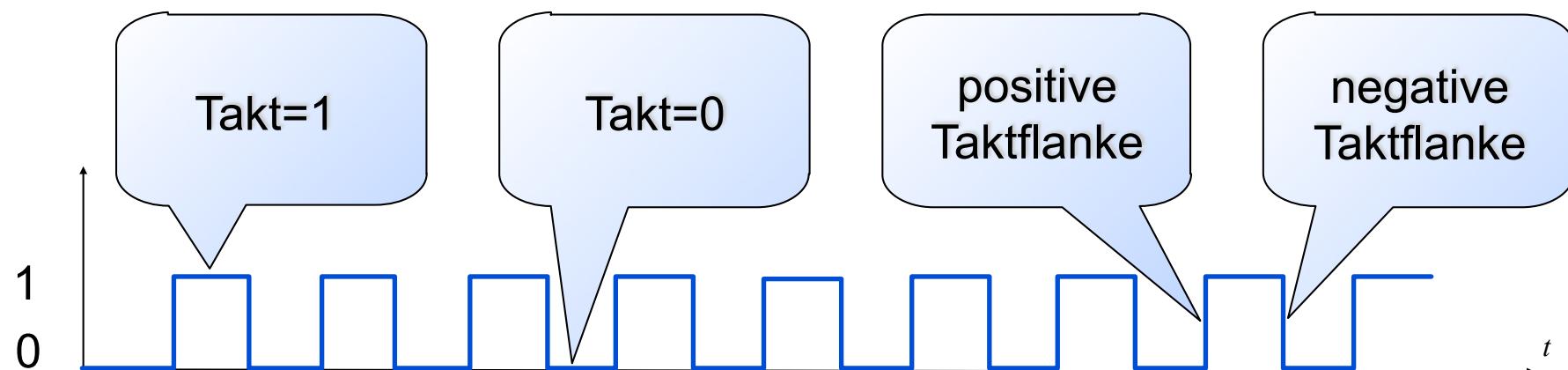


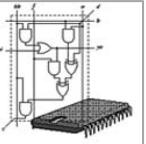


Takt



- Interner Zustand eines Schaltwerks
 - Schaltwerke sind zu jedem Zeitpunkt in einem bestimmten Zustand
 - Zustand ist durch den aktuellen Inhalt aller Speicherelemente definiert
 - Zustandsänderungen werden über den Takt gesteuert
- Pegelsteuerung
 - Zustandsänderung während eine 1 auf der Takteleitung anliegt
- Flankensteuerung
 - Zustandsänderung bei positiver und/oder negativer Taktflanke

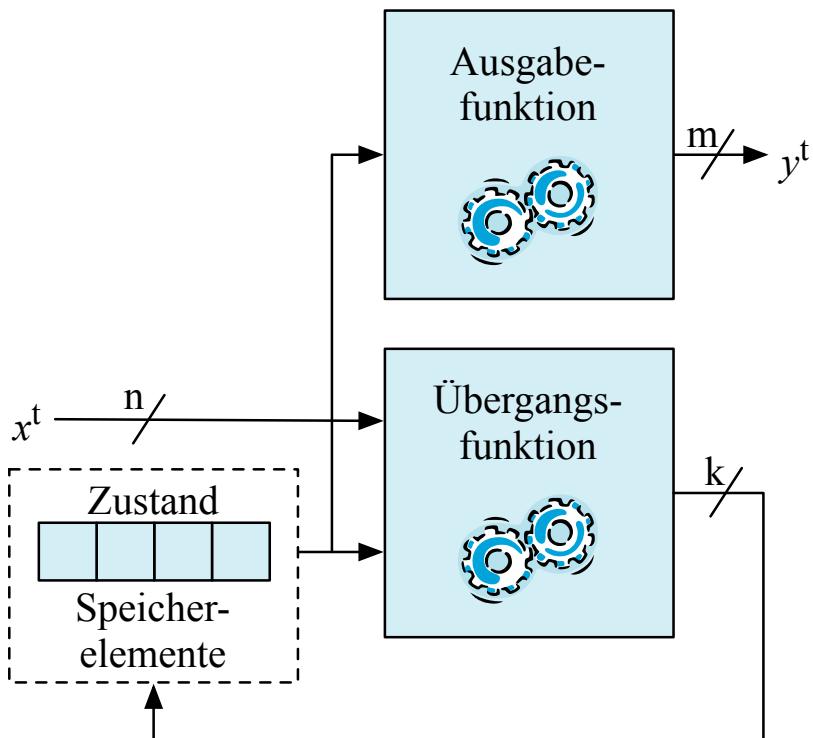




Moore- und Mealy-Automaten

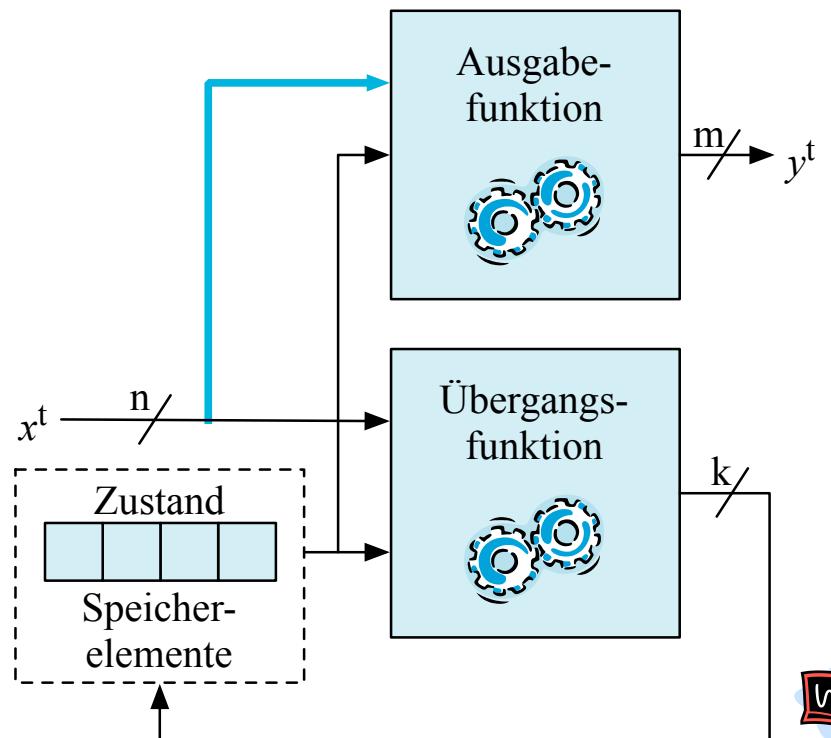
Moore-Automat

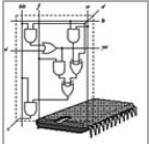
- Zustandsautomat
 - Ausgabe hängt ausschließlich vom aktuellen Zustand ab



Mealy-Automat

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

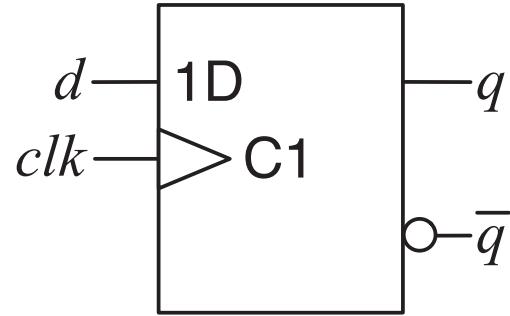




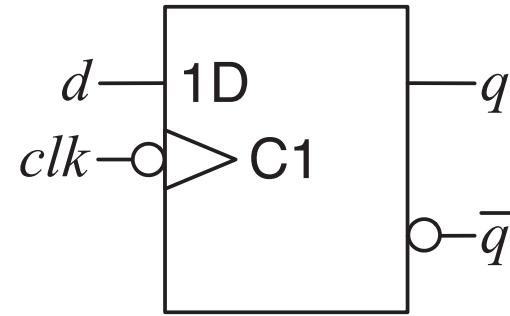
Verschiedene Varianten des D-Elements



- **Flipflops**

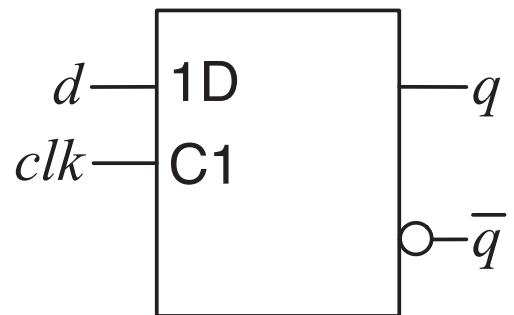


Schaltet bei einer
positiven Taktflanke

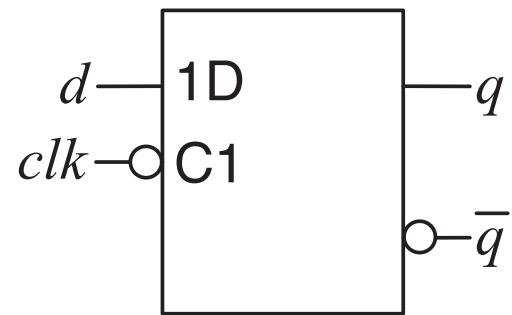


Schaltet bei einer
negativen Taktflanke

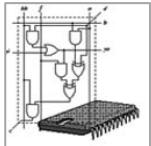
- **Latches**



Schaltet während der
positiven Taktphase

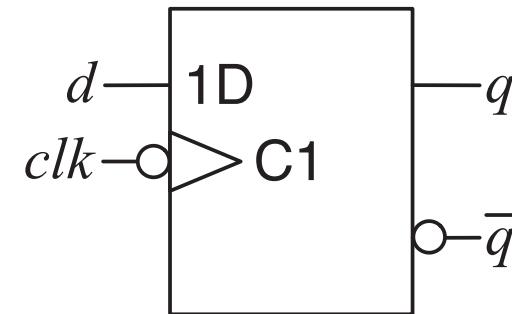
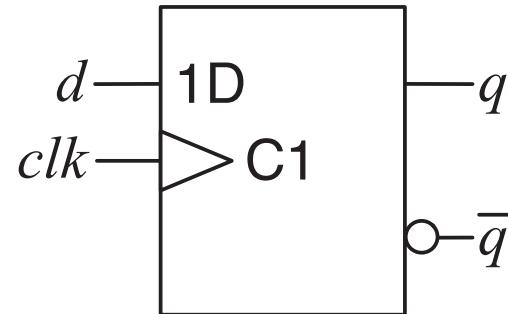


Schaltet während der
negativen Taktphase



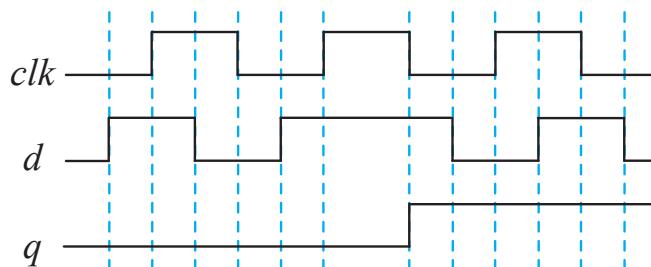
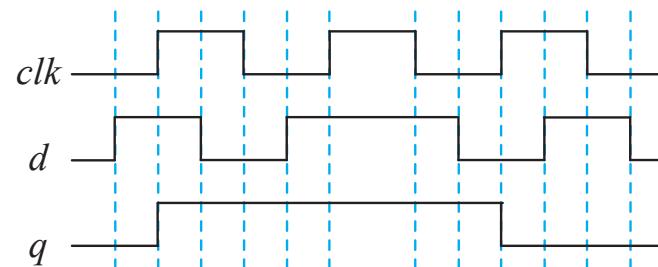
Verschiedene Varianten des D-Elements

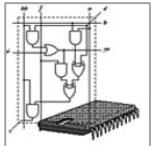
- Flipflops



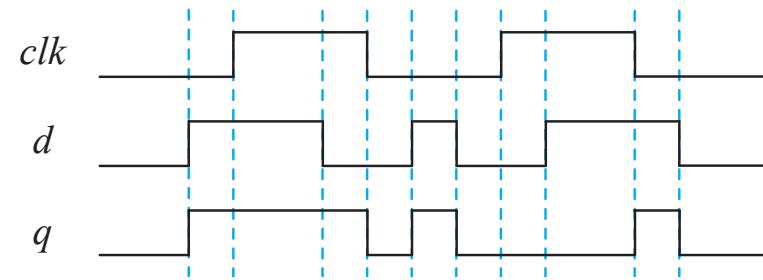
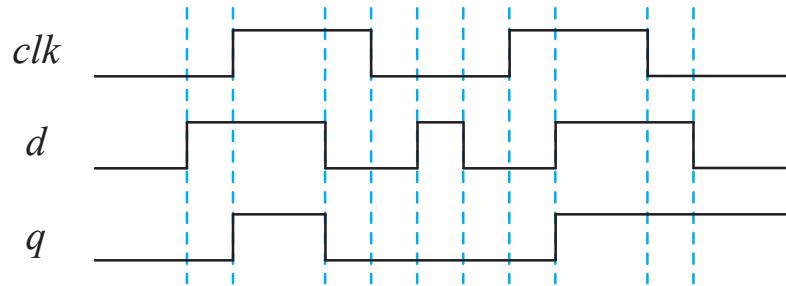
clk	d	q^{t+1}
0/1/ \downarrow	-	q^t
\uparrow	0	0
\uparrow	1	1

clk	d	q^{t+1}
0/1/ \uparrow	-	q^t
\downarrow	0	0
\downarrow	1	1





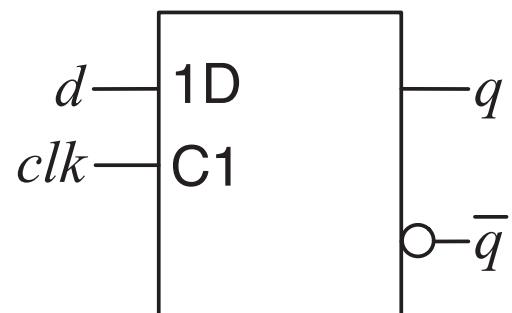
Verschiedene Varianten des D-Elements



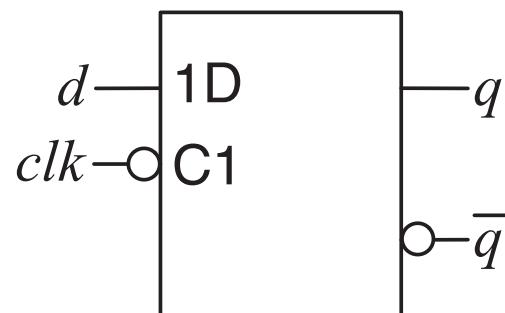
clk	d	q^{t+1}
0	-	q^t
1	0	0
1	1	1

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

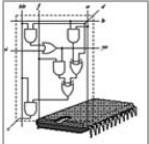
Latches



Schaltet während der positiven Taktphase



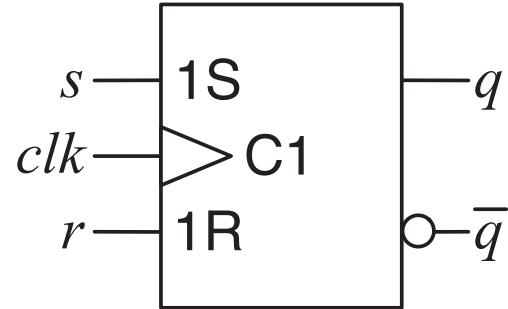
Schaltet während der negativen Taktphase



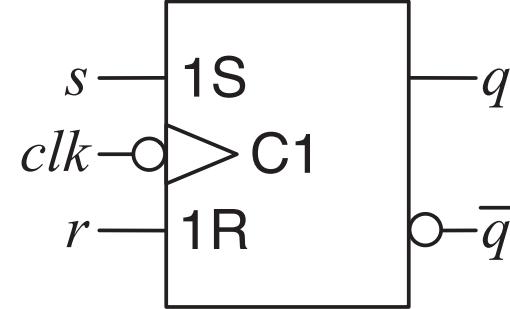
Verschiedene Varianten des RS-Elements



▪ Flipflops

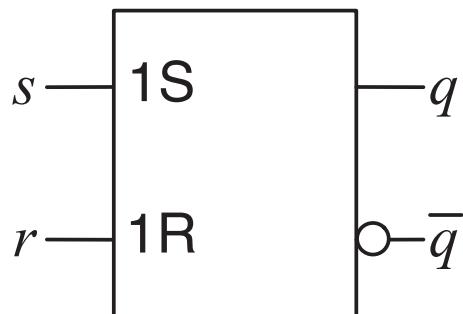


Schaltet bei einer positiven Taktflanke

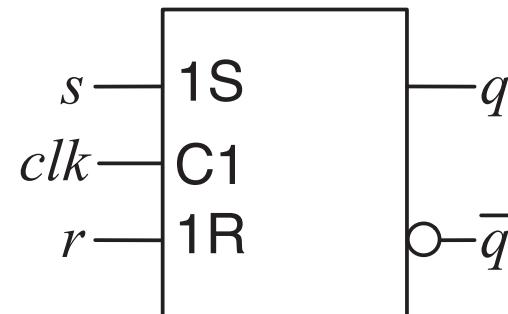


Schaltet bei einer negativen Taktflanke

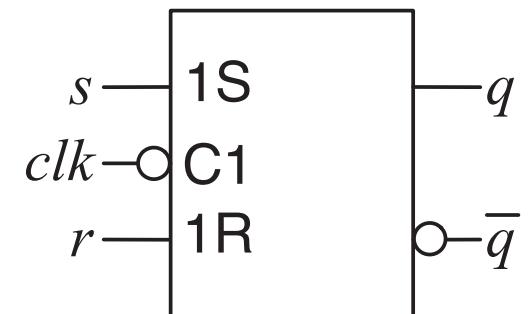
▪ Latches



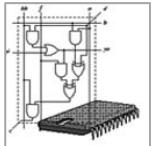
Schaltet zu einem beliebigen Zeitpunkt



Schaltet während der positiven Taktphase



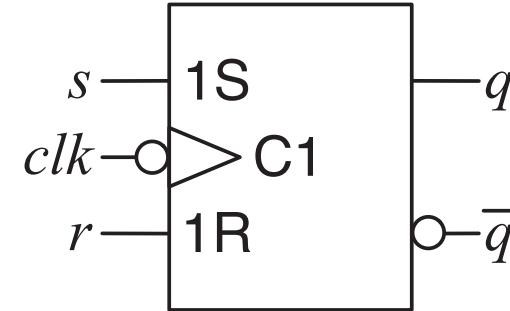
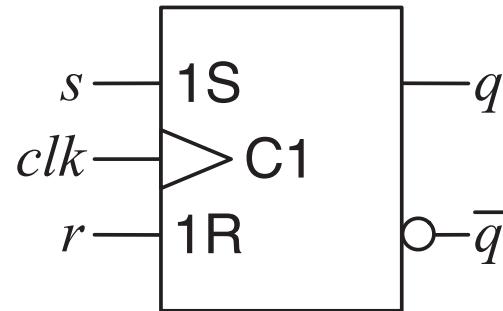
Schaltet während der negativen Taktphase



Verschiedene Varianten des RS-Elements

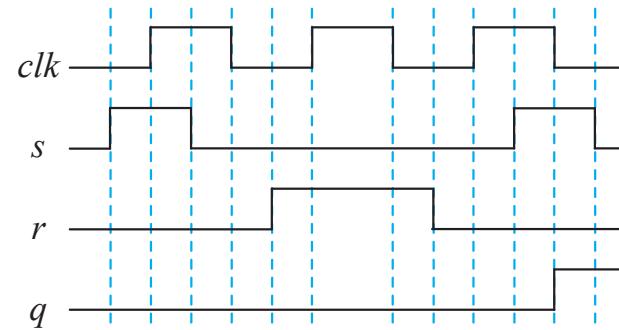
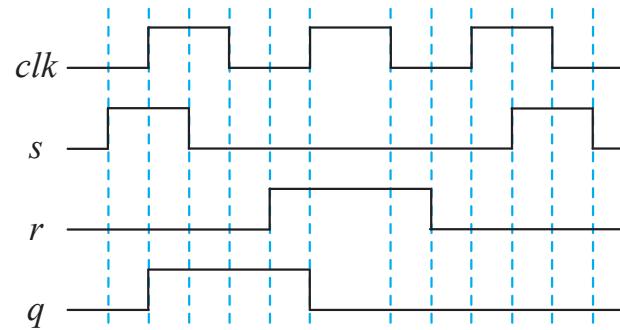


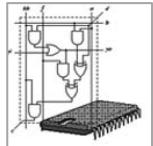
- Flipflops



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	-





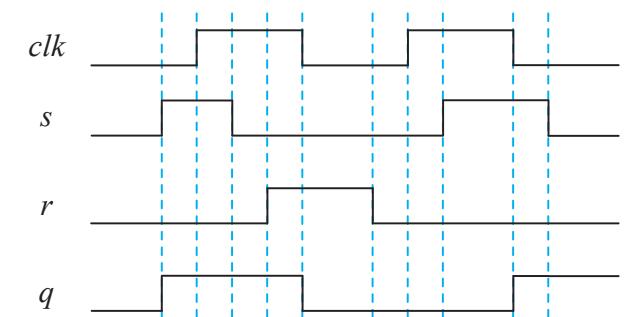
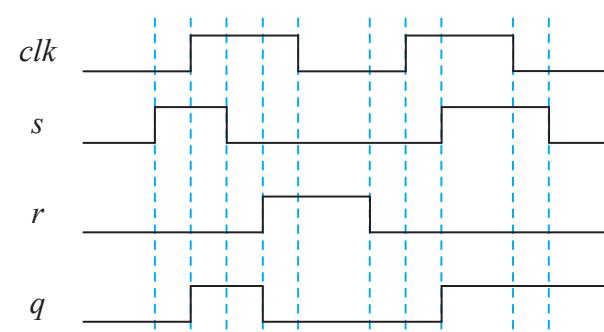
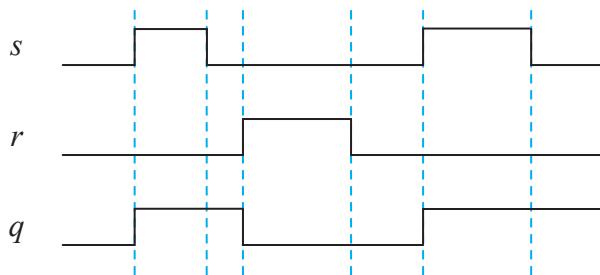
Verschiedene Varianten des RS-Elements



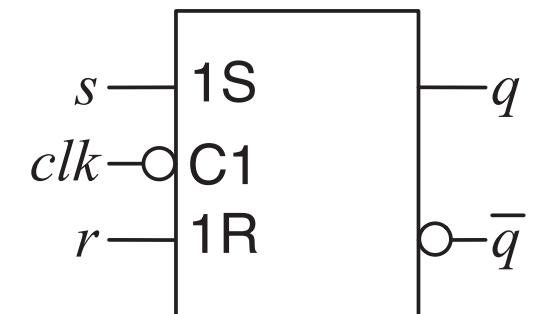
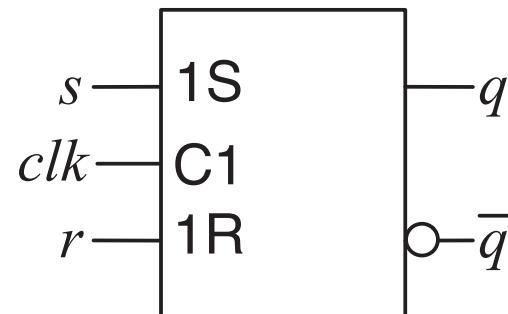
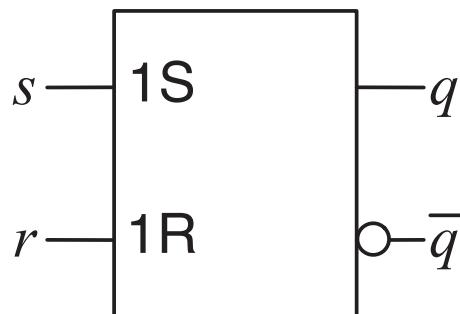
r	s	q^{t+1}
0	0	q^t
0	1	1
1	0	0
1	1	-

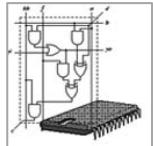
clk	r	s	q^{t+1}
0	-	-	q^t
1	0	0	q^t
1	0	1	1
1	1	0	0
1	1	1	-

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

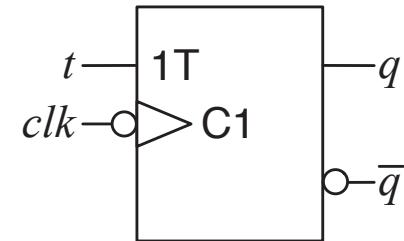
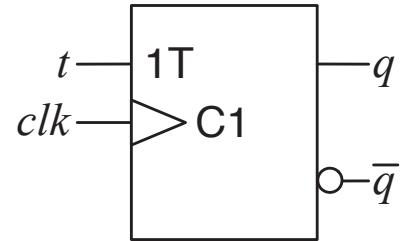


Latches



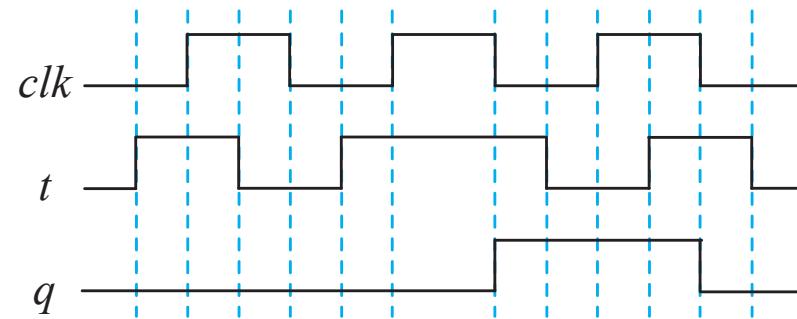
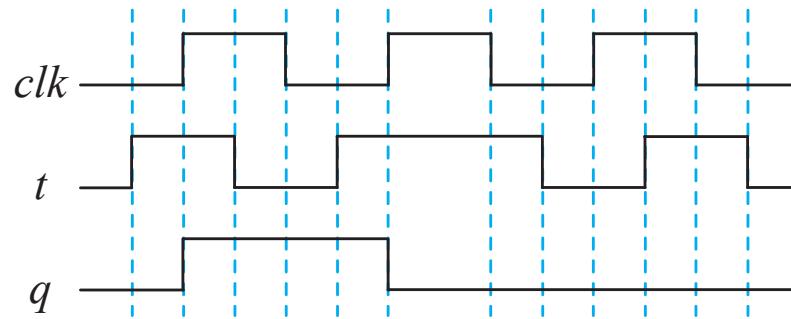


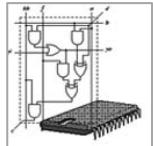
T-Flipflops



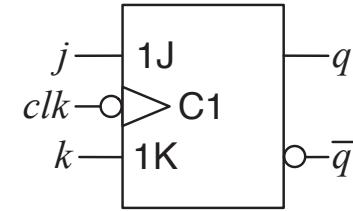
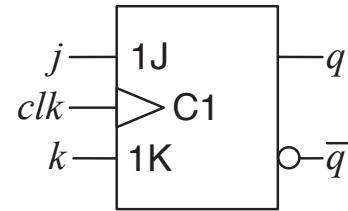
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0/1/ \downarrow	-	q^t
\uparrow	0	q^t
\uparrow	1	$\neg q^t$

clk	t	q^{t+1}
0/1/ \uparrow	-	q^t
\downarrow	0	q^t
\downarrow	1	$\neg q^t$



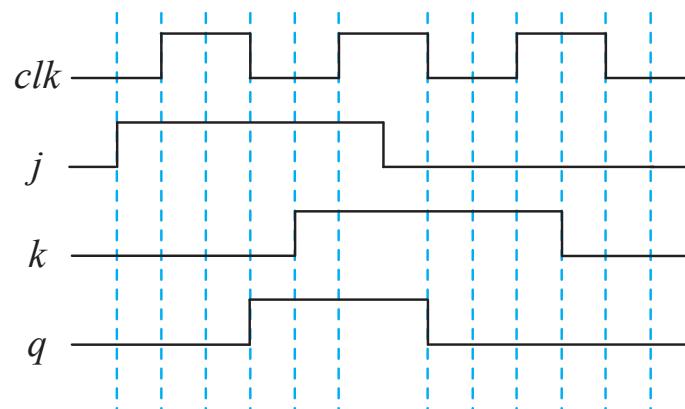
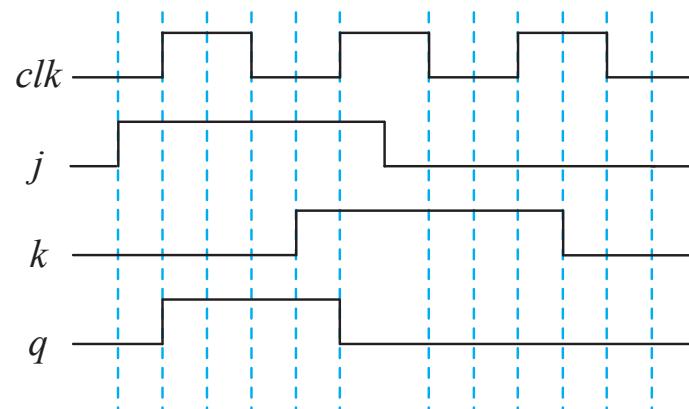


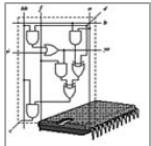
JK-Flipflops



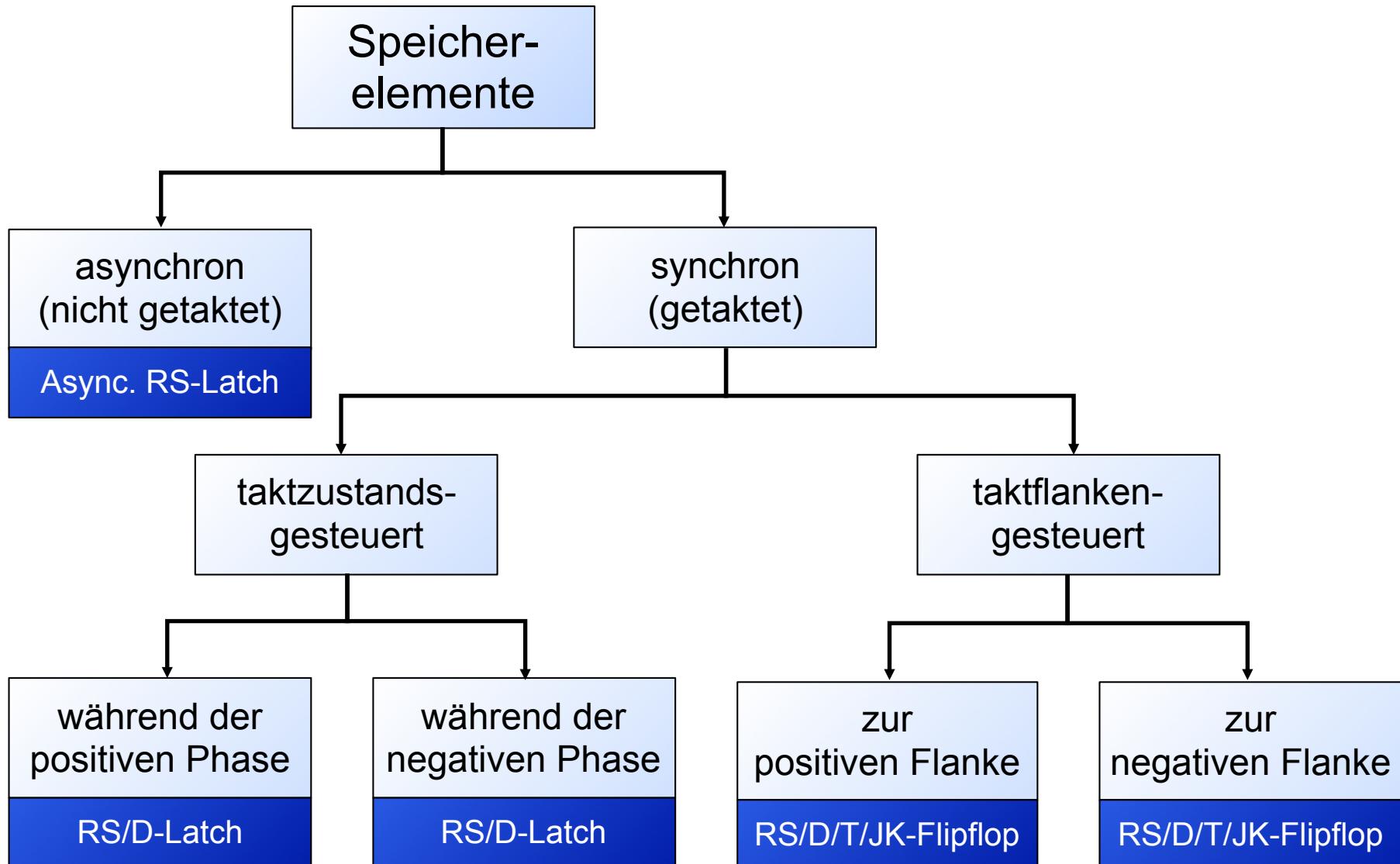
clk	j	k	q^{t+1}
$0/1/\downarrow$	-	-	q^t
\uparrow	0	0	q^t
\uparrow	0	1	0
\uparrow	1	0	1
\uparrow	1	1	$\neg q^t$

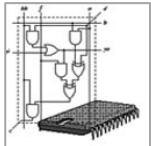
clk	j	k	q^{t+1}
$0/1/\uparrow$	-	-	q^t
\downarrow	0	0	q^t
\downarrow	0	1	0
\downarrow	1	0	1
\downarrow	1	1	$\neg q^t$





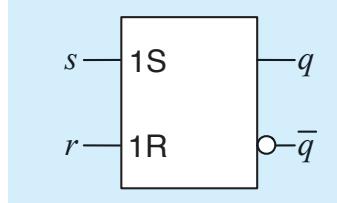
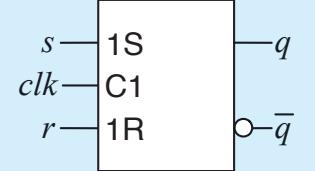
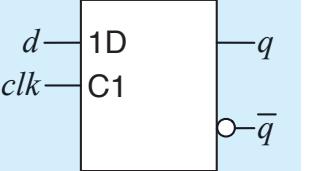
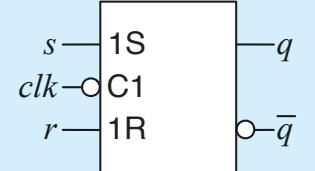
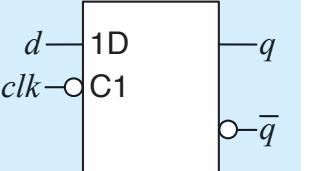
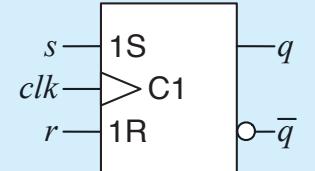
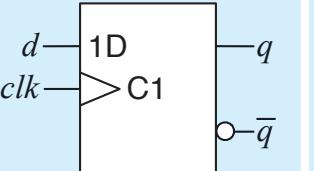
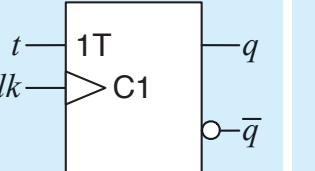
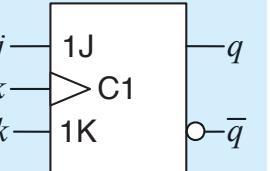
Zusammenfassung: Speicherelemente





Zusammenfassung: Schalsymbole



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