

# TFE4101

## KRETS- OG DIGITALTEKNIKK

### Sekvensielle kretser

Gajski:

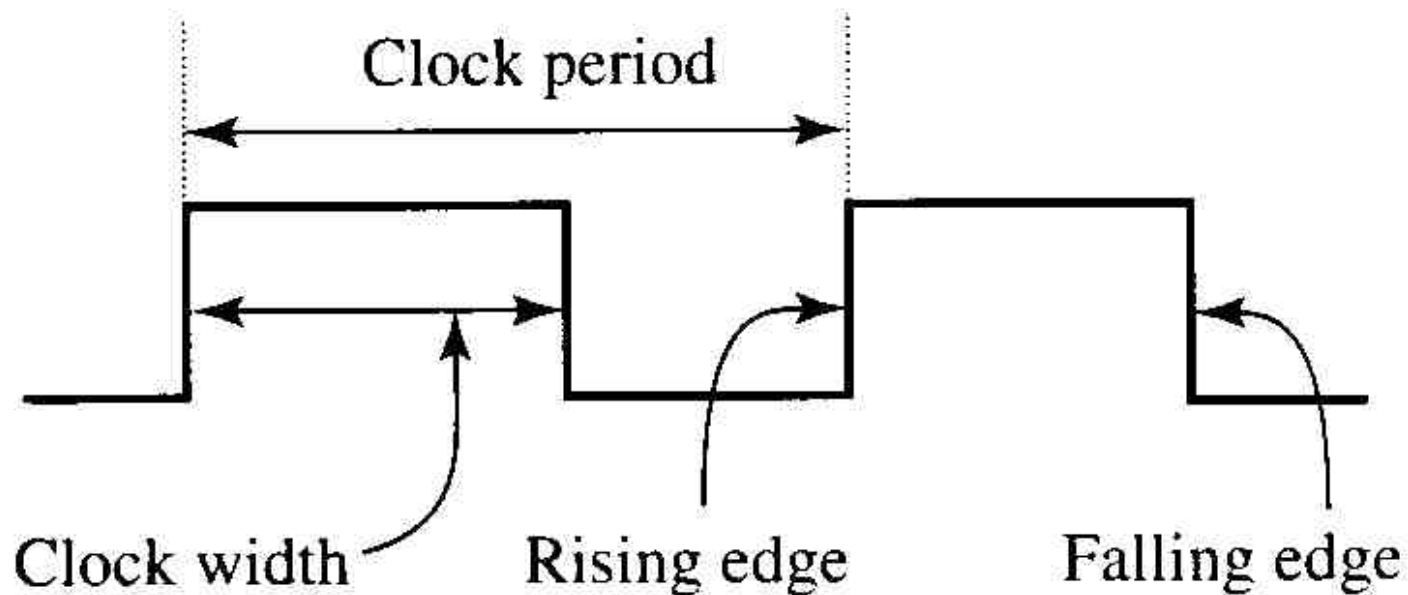
- Kap. 6: Sekvensielle kretser
- Kap. 6.1-6.3: Låser (latch)
- Kap. 6.4-6-5: Vipper (flip-flop)
- Kap. 6.7: Tilstandsmaskinsmodell

# Sekvensielle kretser

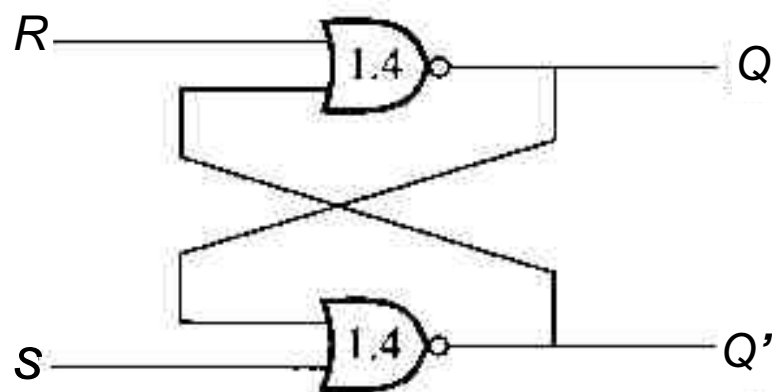
- Kombinatoriske kretser
  - utgangsverdiene gitt av nåværende inngangsverdier
  - endring på inngang gir tilhørende verdi på utgang etter forsinkelse  $\Delta$
- Sekvensielle kretser
  - inneholder minneelementer
  - utgangsverdier gitt av både nåværende og tidligere inngangsverdier (sekvens av inngangsverdier)
  - verdiene lagret i minneelementene angir tilstanden til kretsen
  - endring på inngang gir
    - tilhørende verdi i tilstand etter forsinkelse  $\Delta_1$
    - tilhørende verdi på utgang etter forsinkelse  $\Delta_2$

# (A)synkron sekvensiell krets

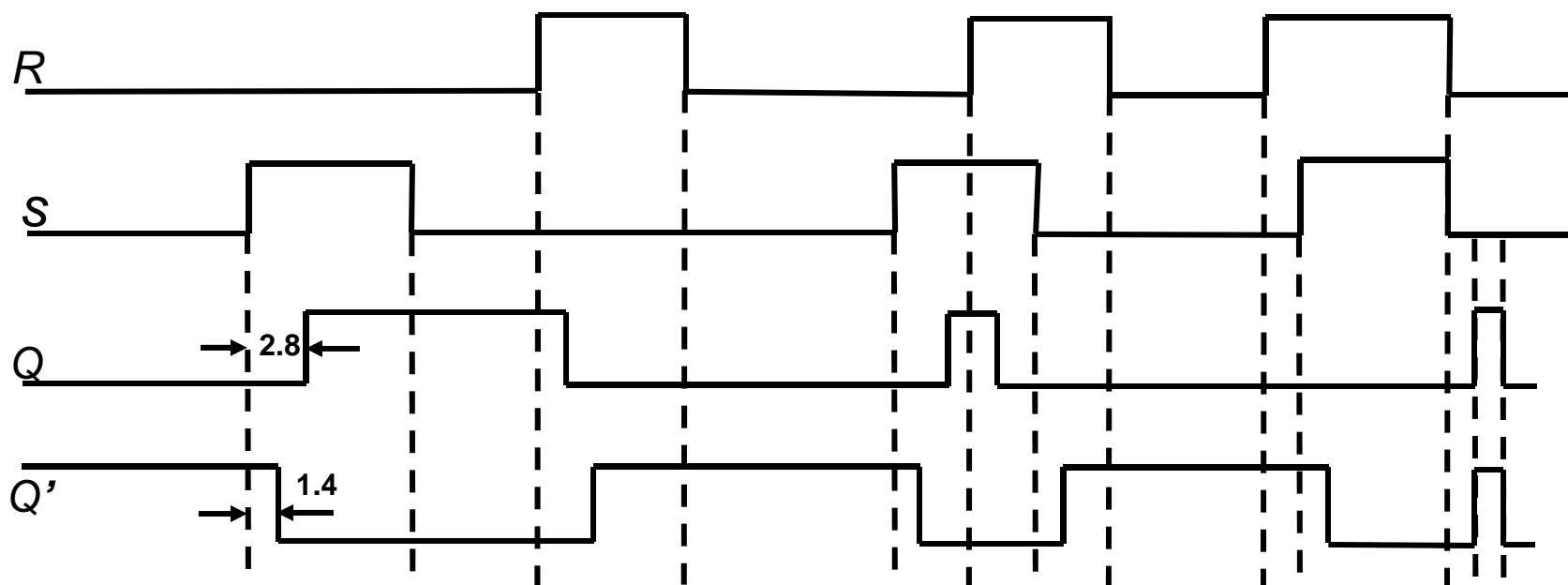
- Asynkron sekvensiell krets
  - tilstand og utgangsverdi endres uansett når inngang endres
- Synkron sekvensiell krets
  - endring i tilstand og utgangsverdi styrt av fallende og stigende flanker på frittstående klokkesignal



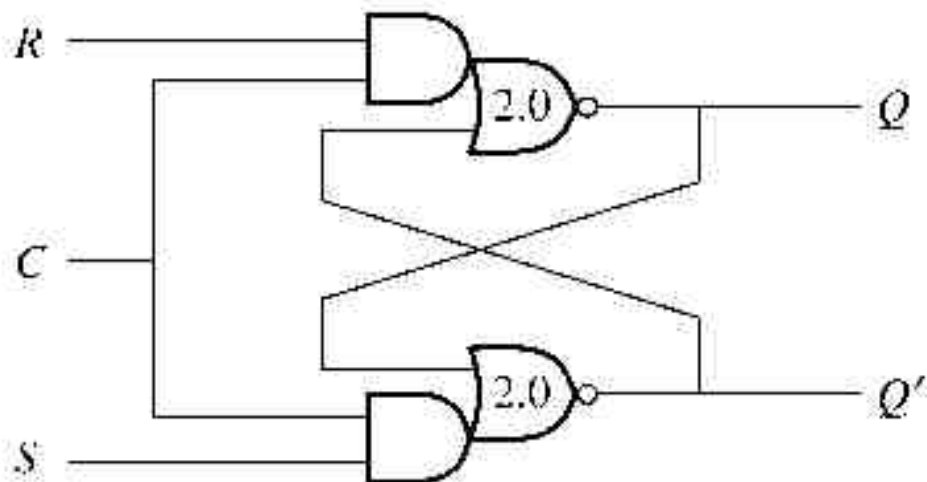
# SR-lås



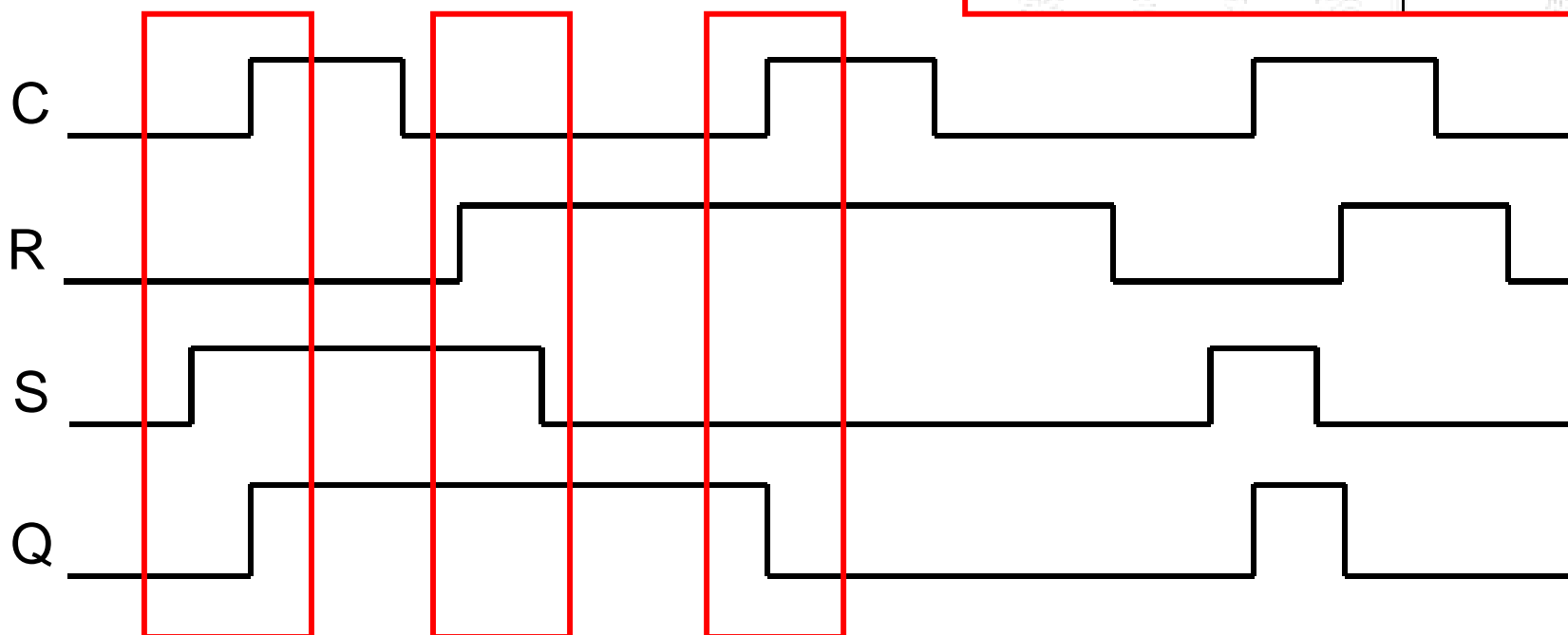
$S$	$R$	$Q$	$Q(next)$	$Q'(next)$
0	0	0	0	1
0	0	1	1	0
0	1	X	0	1
1	0	X	1	0
1	1	X	0	0



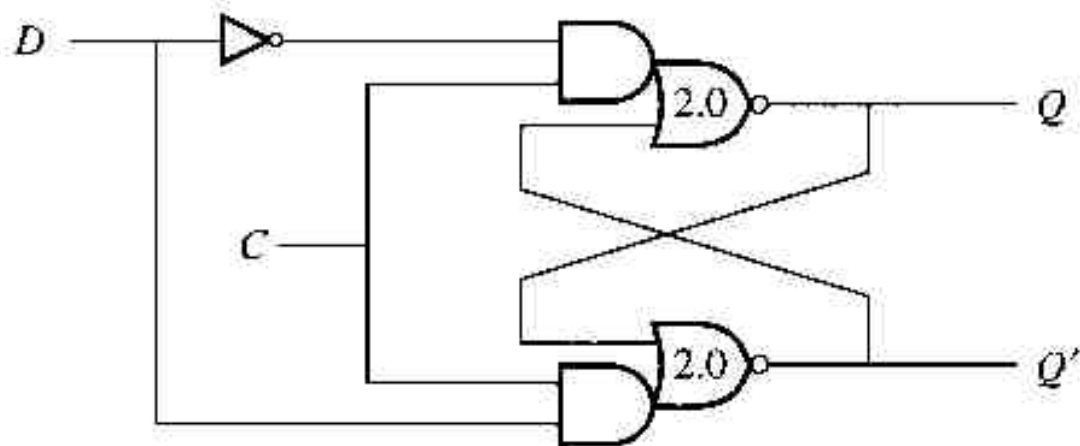
# Styrt SR-lås



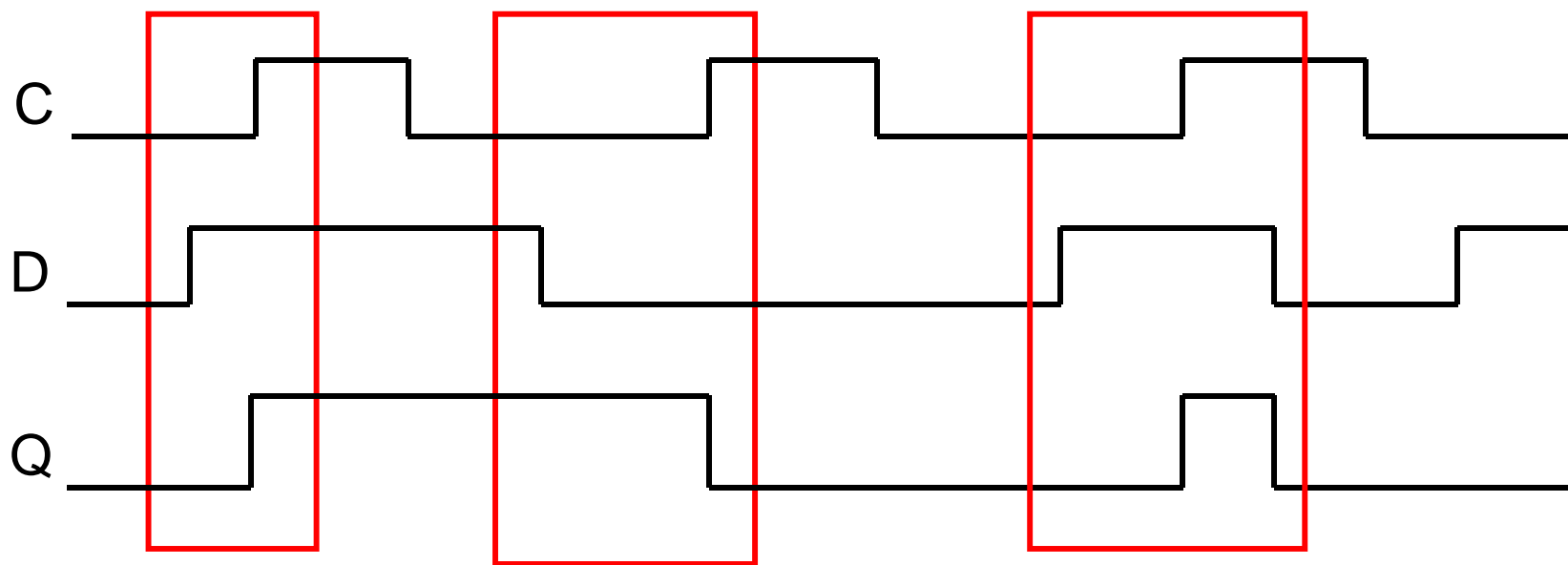
C	S	R	Q	Q(next)
0	X	X	0	0
0	X	X	1	1
1	0	0	0	0
1	0	0	1	1
1	0	1	X	0
1	1	0	X	1
1	1	1	X	NA



# Styrt D-lås

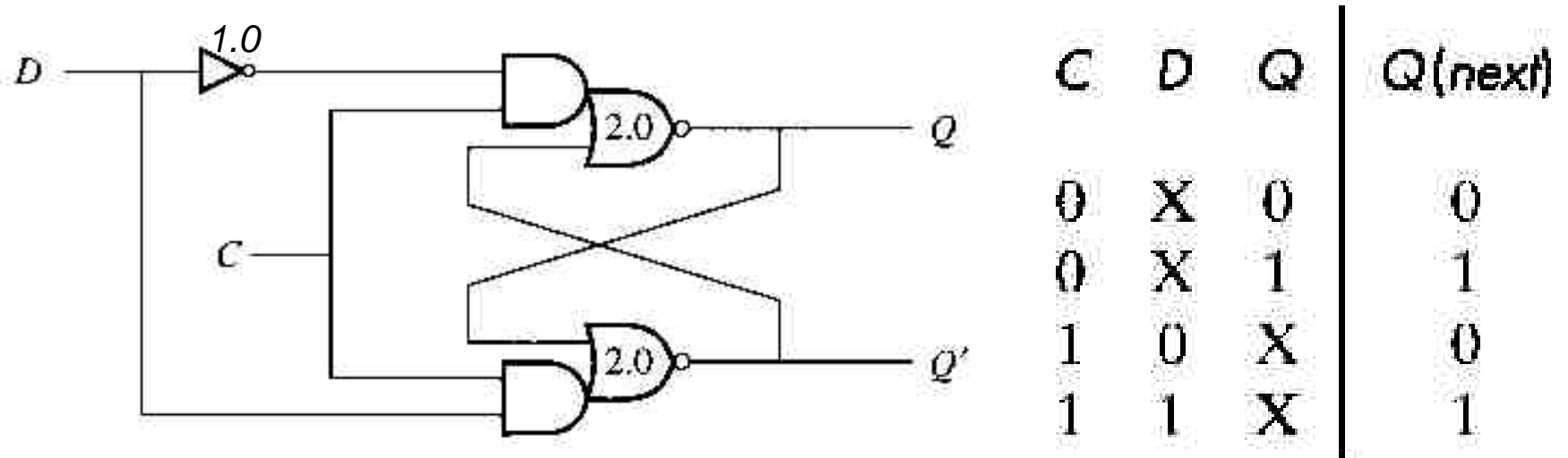


C	D	Q	Q(next)
0	X	0	0
0	X	1	1
1	0	X	0
1	1	X	1



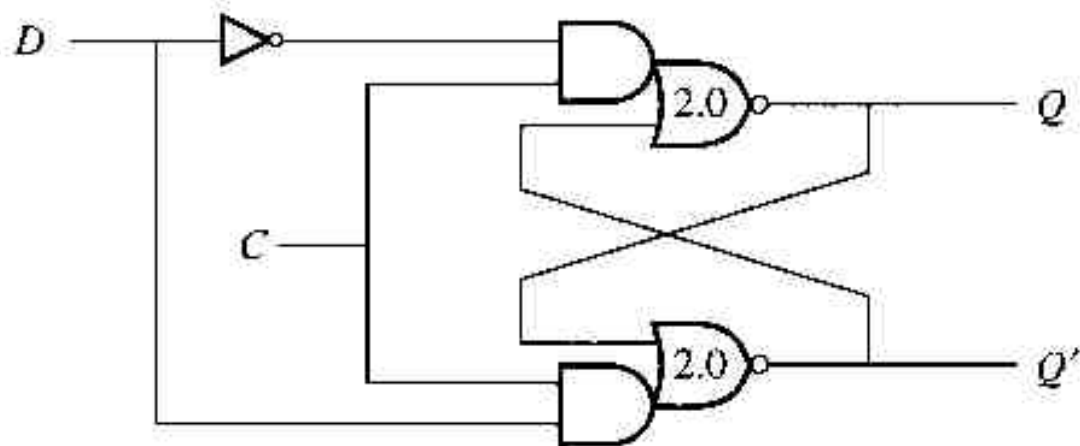
Signalet C er ofte systemklokka → Klokket D-lås

# Gruppeoppgave, to minutter

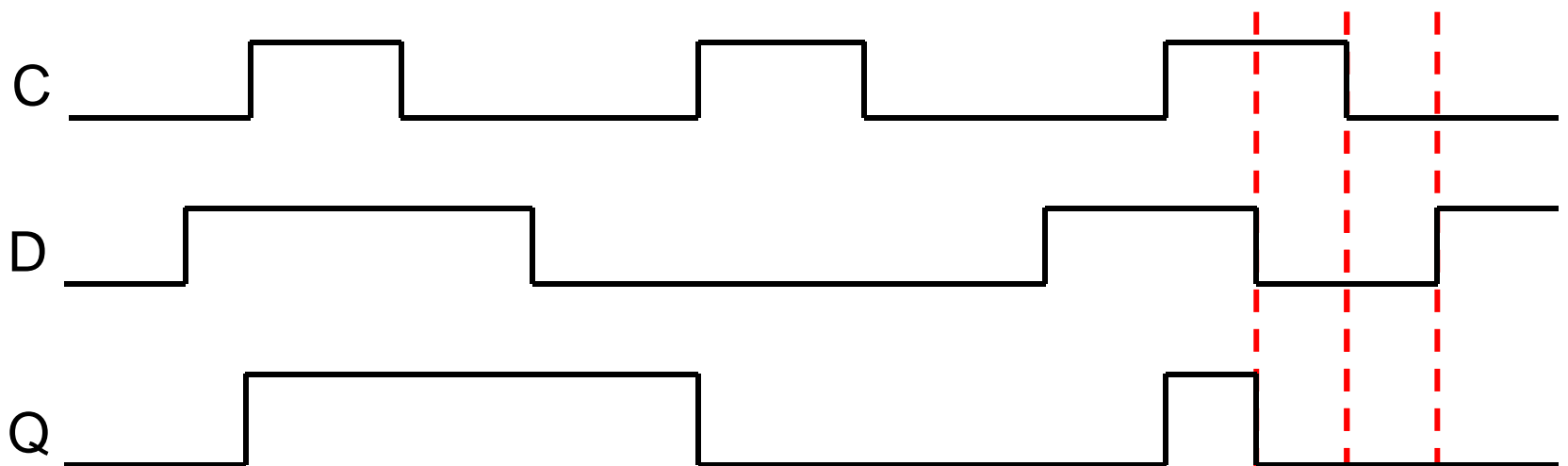


- Hva skjer dersom
  - D skifter fra 0 til 1 ved tid  $t_1$
  - C skifter fra 1 til 0 ved tid  $t_1 + 0,5\text{ns}$

# Styrt D-lås



C	D	Q	Q(next)
0	X	0	0
0	X	1	1
1	0	X	0
1	1	X	1

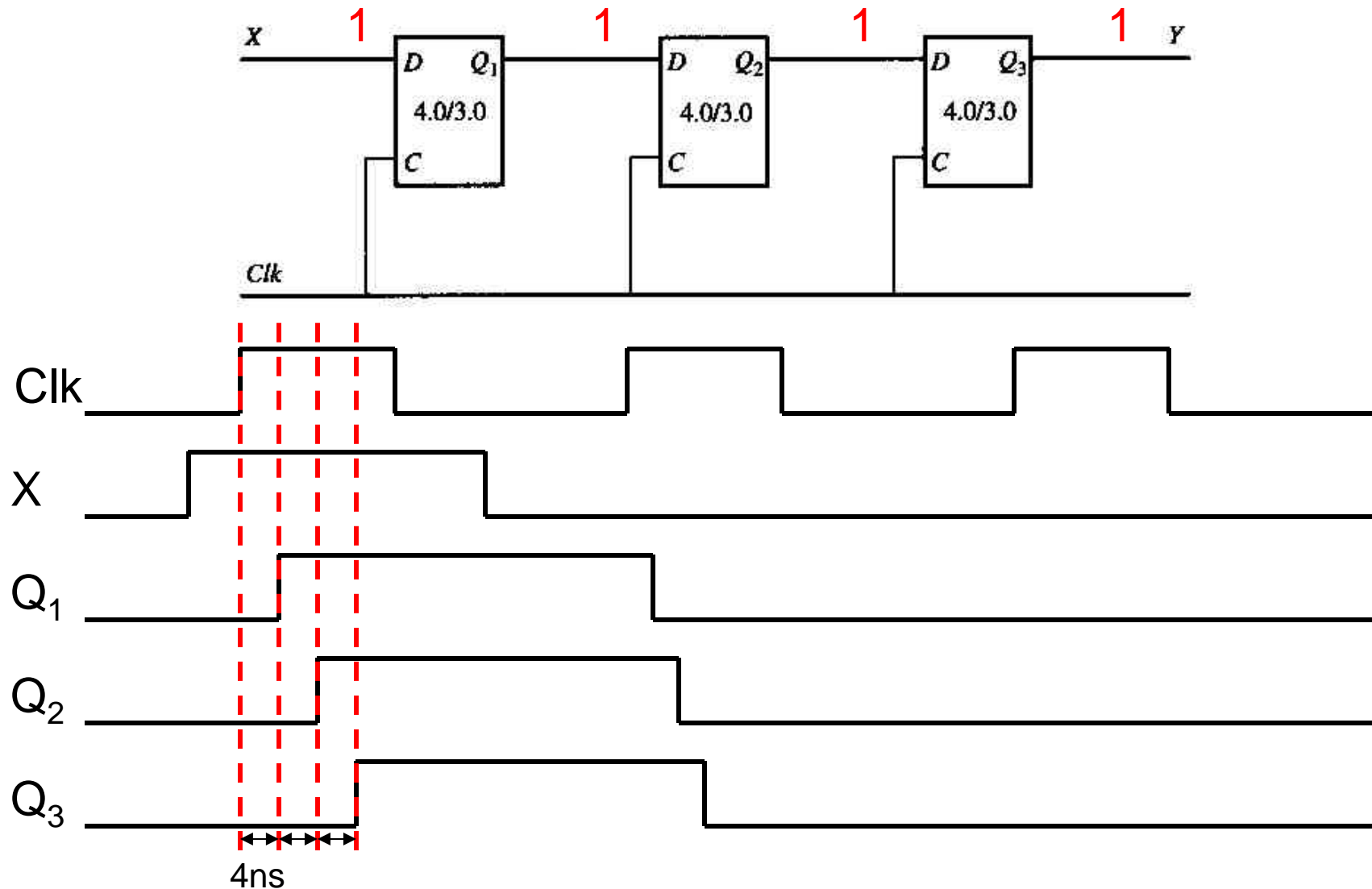


$\geq t_{\text{setup}}$   $\geq t_{\text{hold}}$

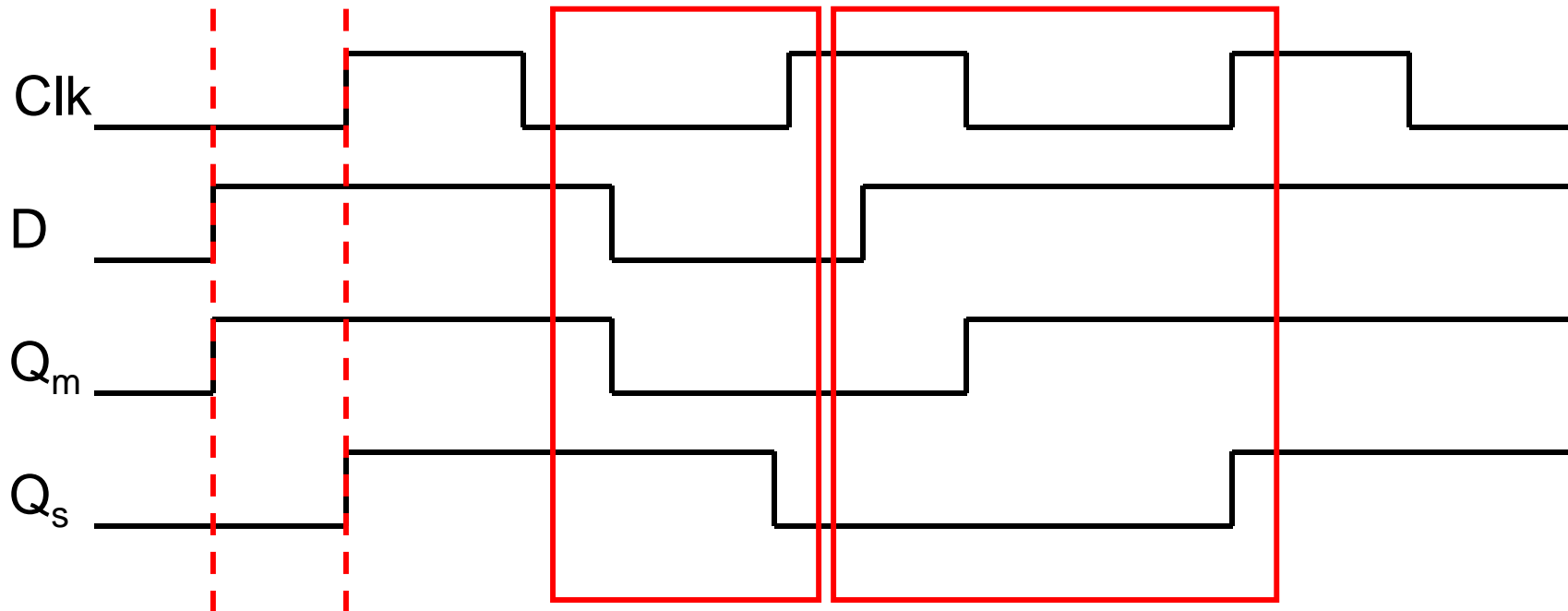
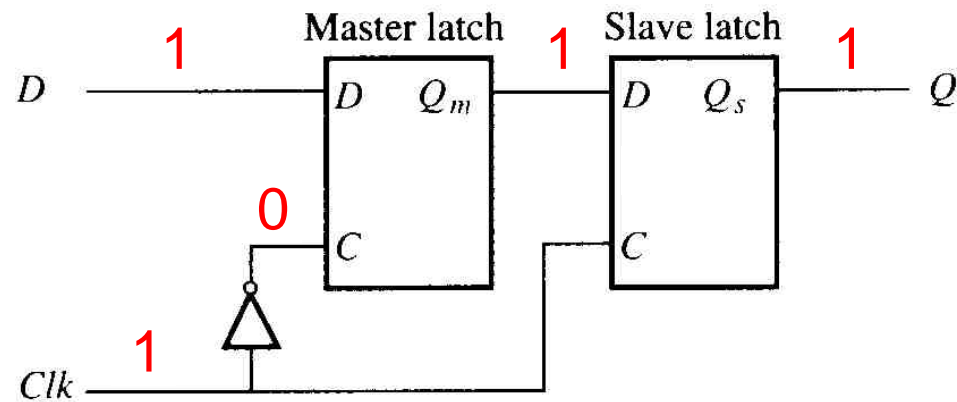


# Problem: skiftregister med D-lås

- Ønsker at data skal "skiftes" en posisjon til høyre for hver klokkepuls

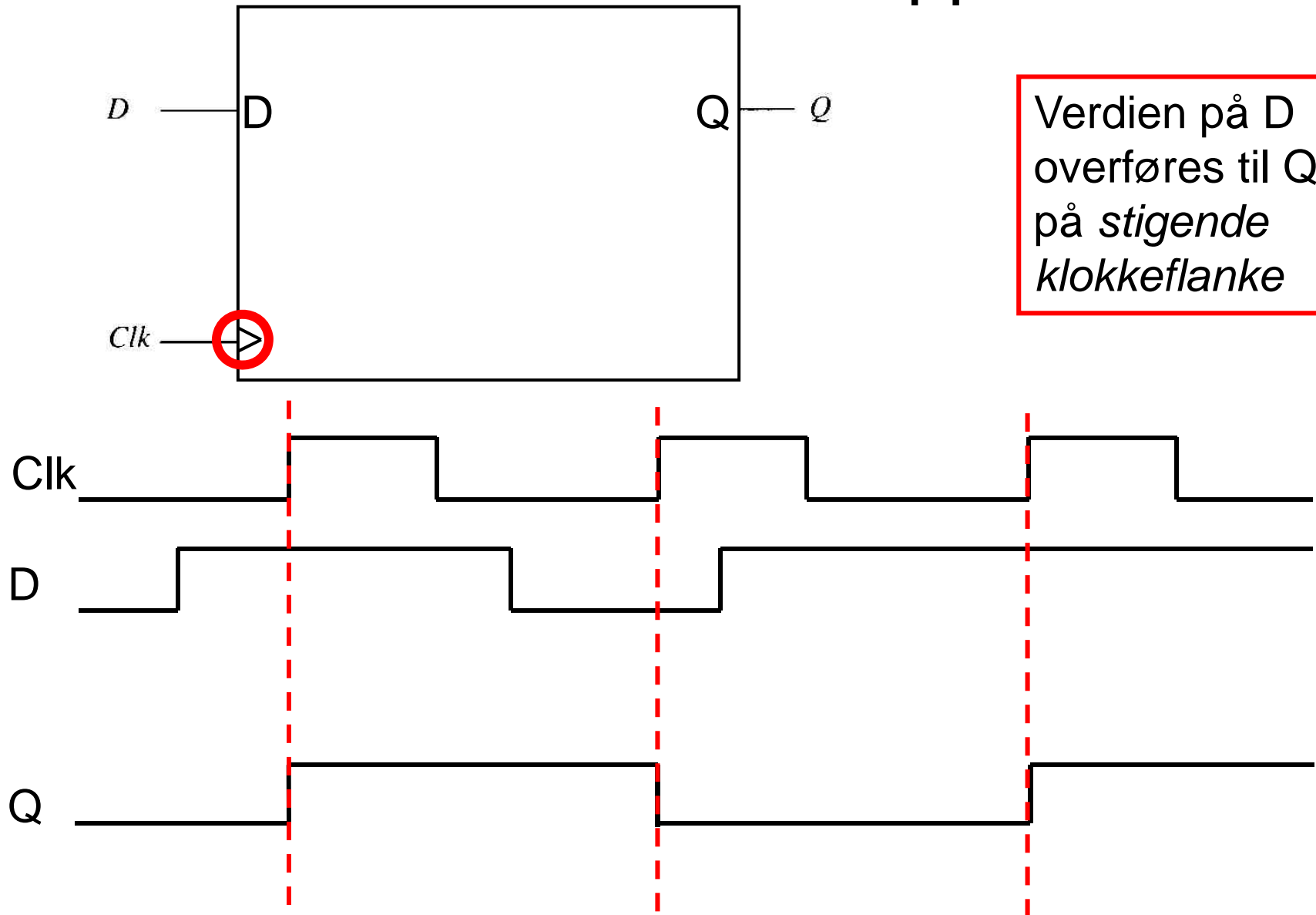


# "Herre - slave" vippe

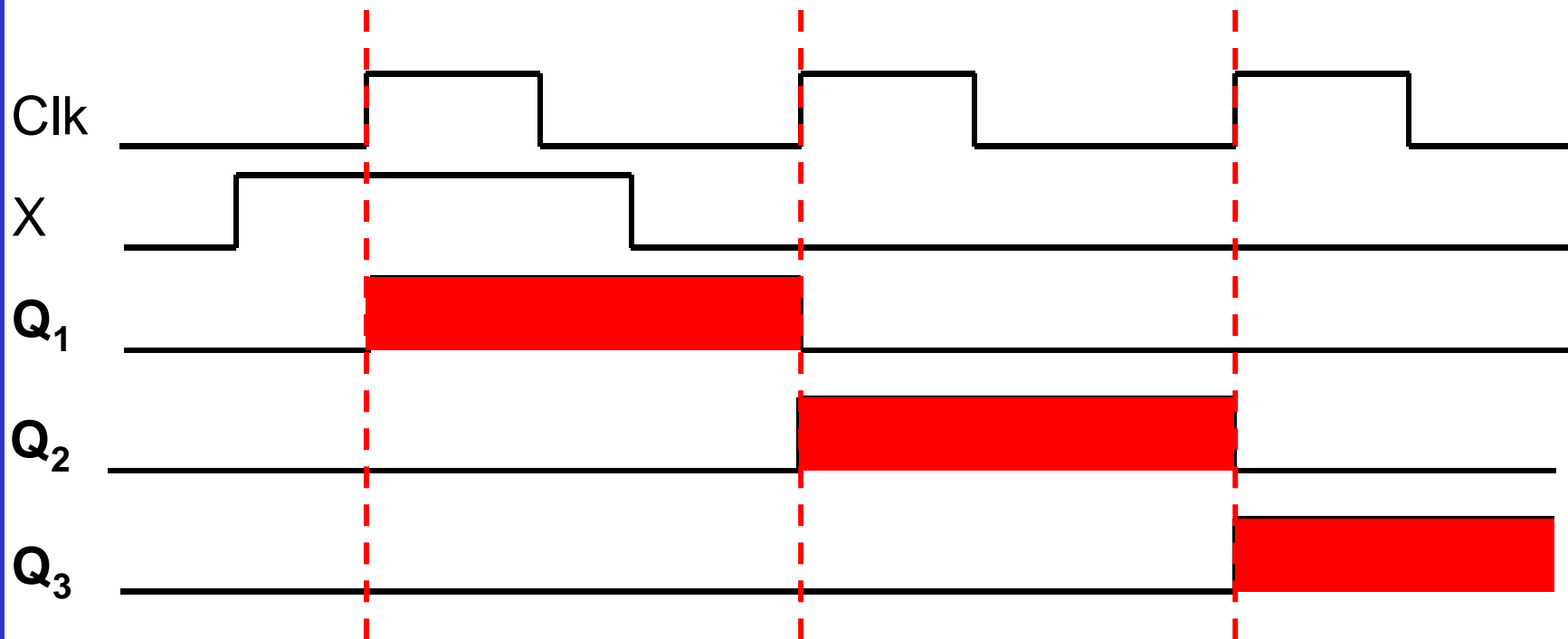
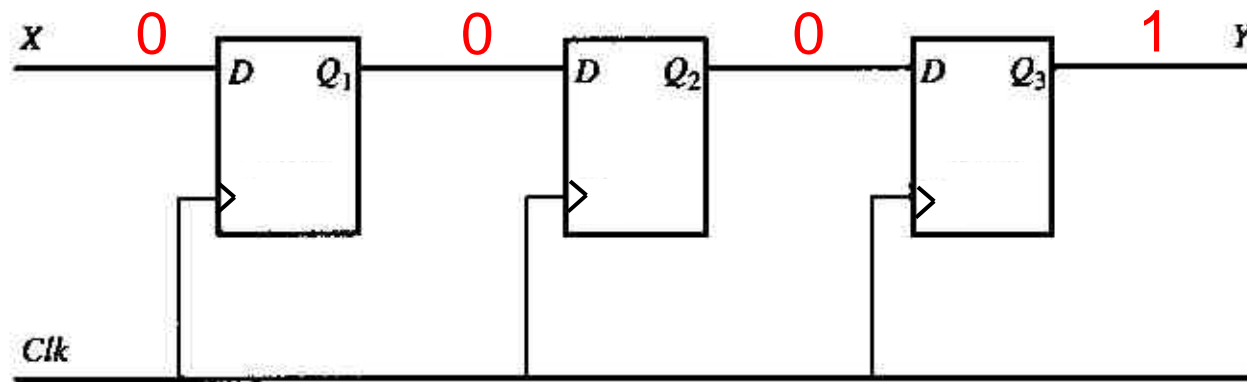


Idealisert:  $t_{pd} = 0ns$

# "Herre - slave" vippe

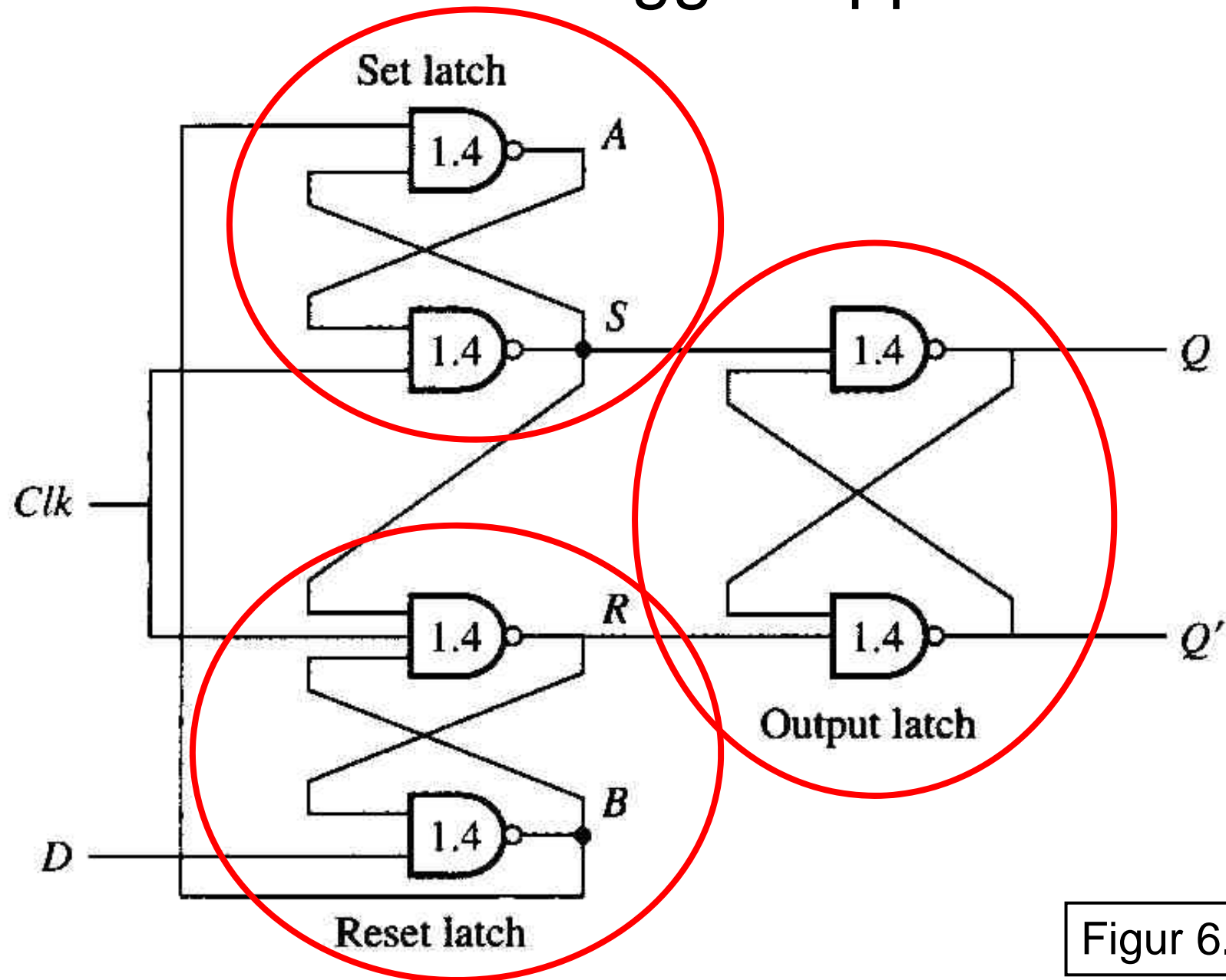


# Skiftregister med "herre-slave" vippe



Idealisert:  $t_{pd} = 0ns$

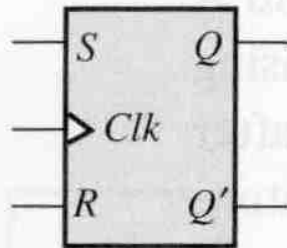
# Flanketrigget vippe



Figur 6.9

# Ulike vippetyper (SR-vippe)

SYMBOL



KARAKTERISK  
TABELL

S	R	$Q(next)$
0	0	Q
0	1	0
1	0	1
1	1	NA

KARAKTERISK  
LIKNING

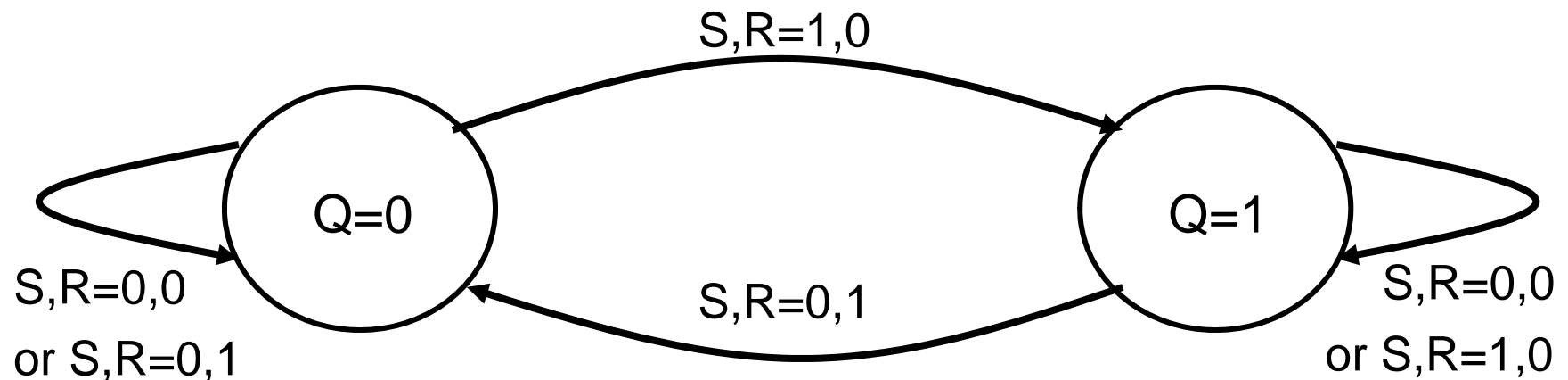
$$Q(next) = S + R'Q$$

$$SR = 0$$

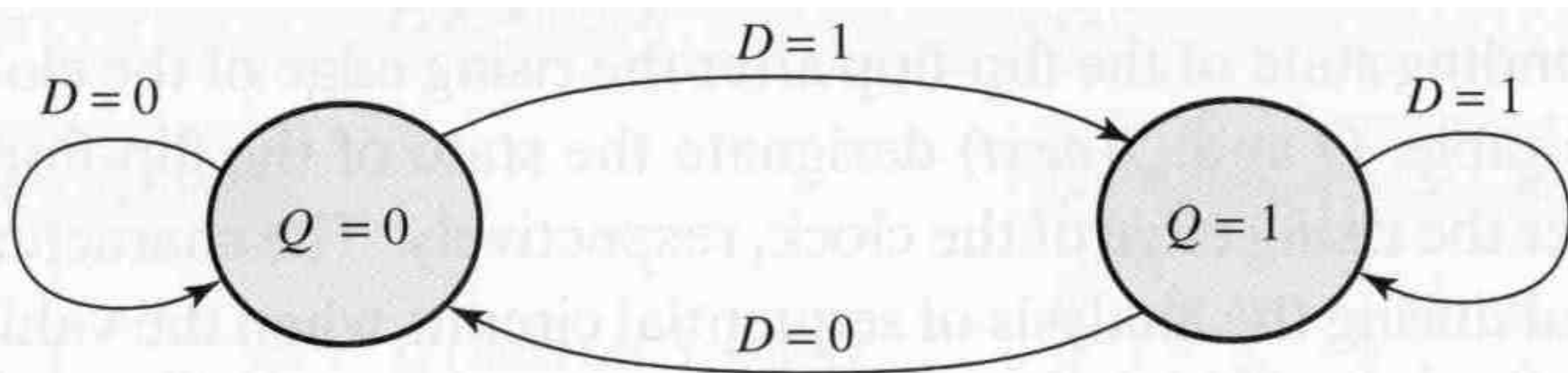
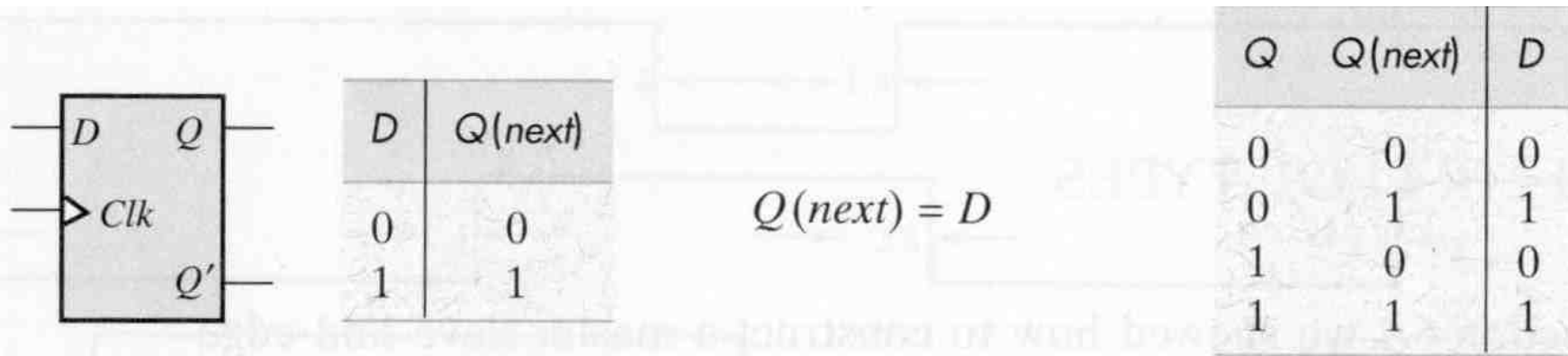
EKSITASJONS  
TABELL

Q	$Q(next)$	S	R
0	0	0	X
0	1	1	0
1	0	0	1
1	1	X	0

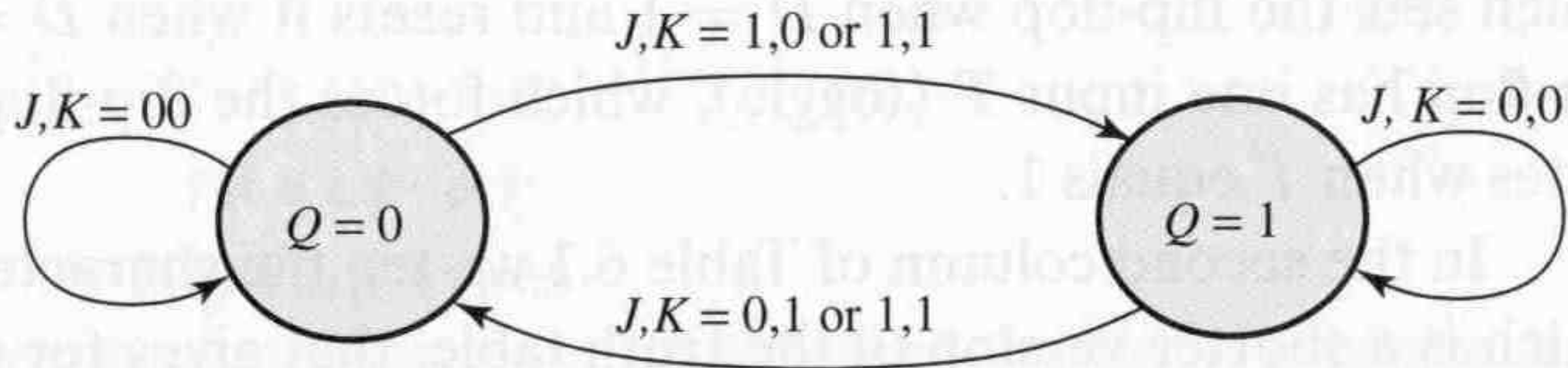
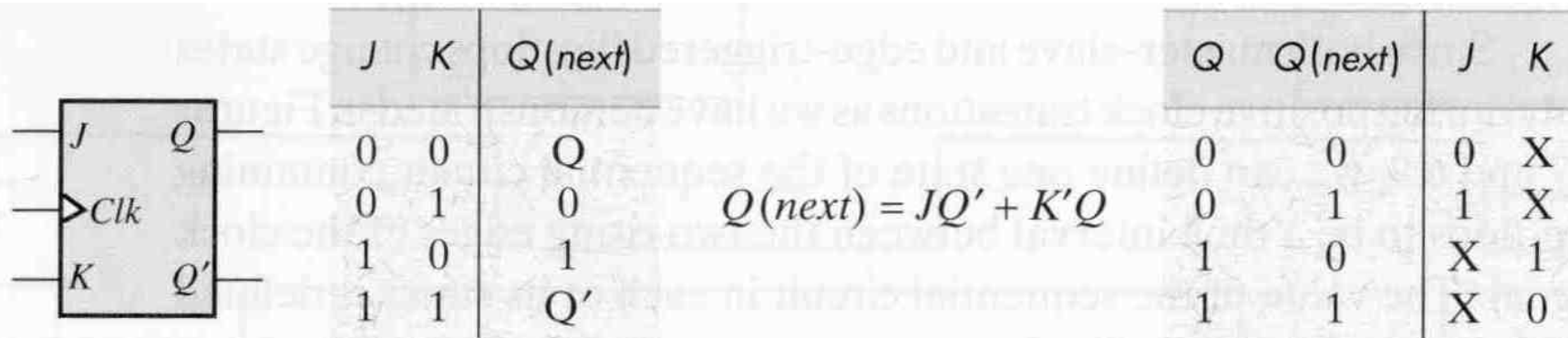
TILSTANDSDIAGRAM



# Ulike vippetyper (D-vippe)

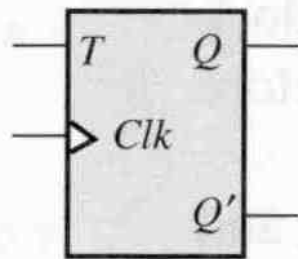


# Ulike vippetyper (JK-vippe)





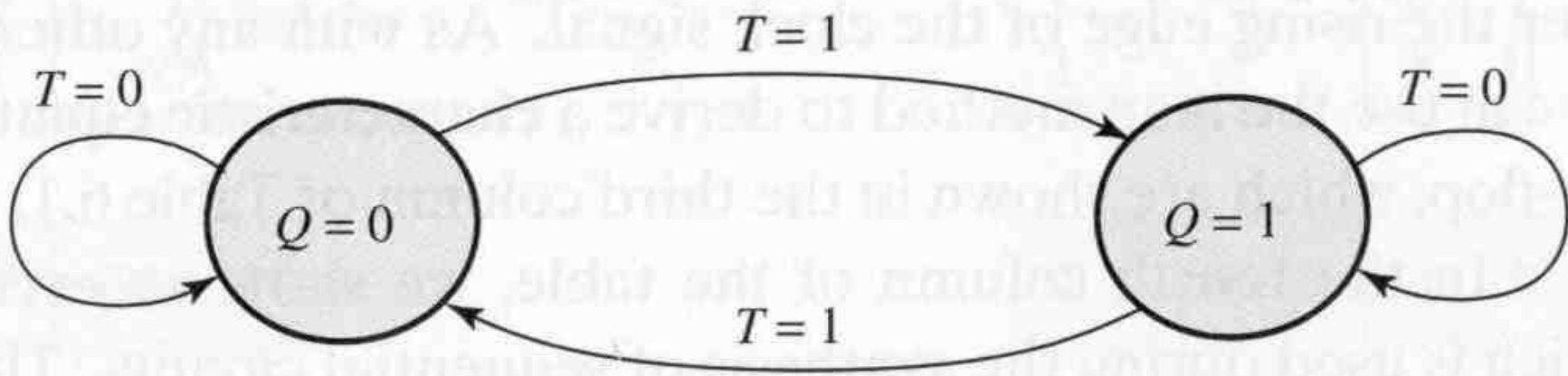
# Ulike vippetyper (T-vippe)



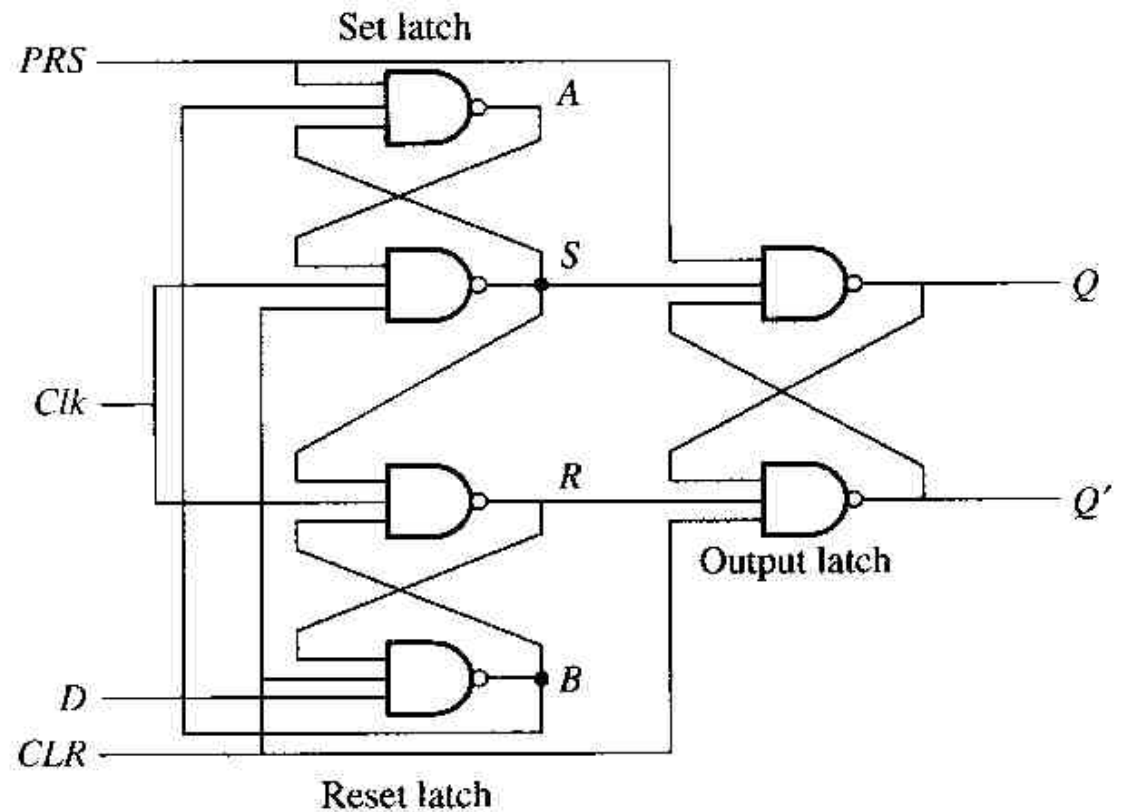
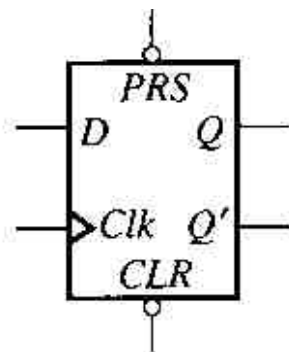
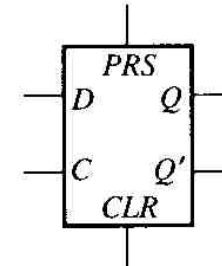
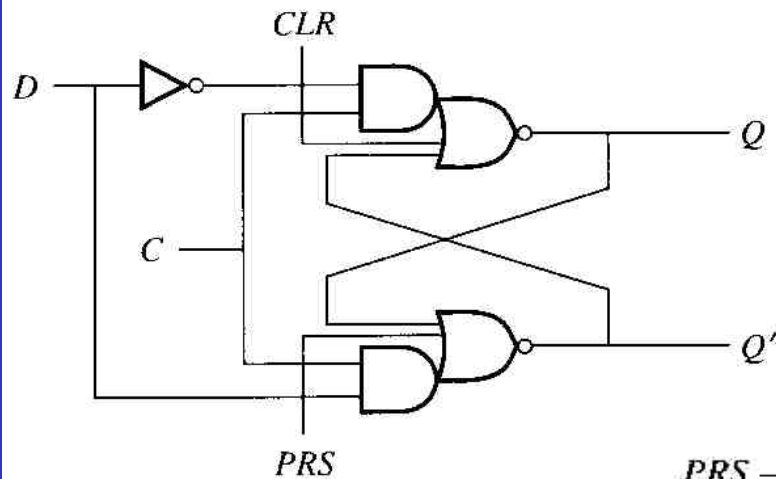
T	Q(next)
0	Q
1	Q'

$$Q(next) = TQ' + T'Q$$

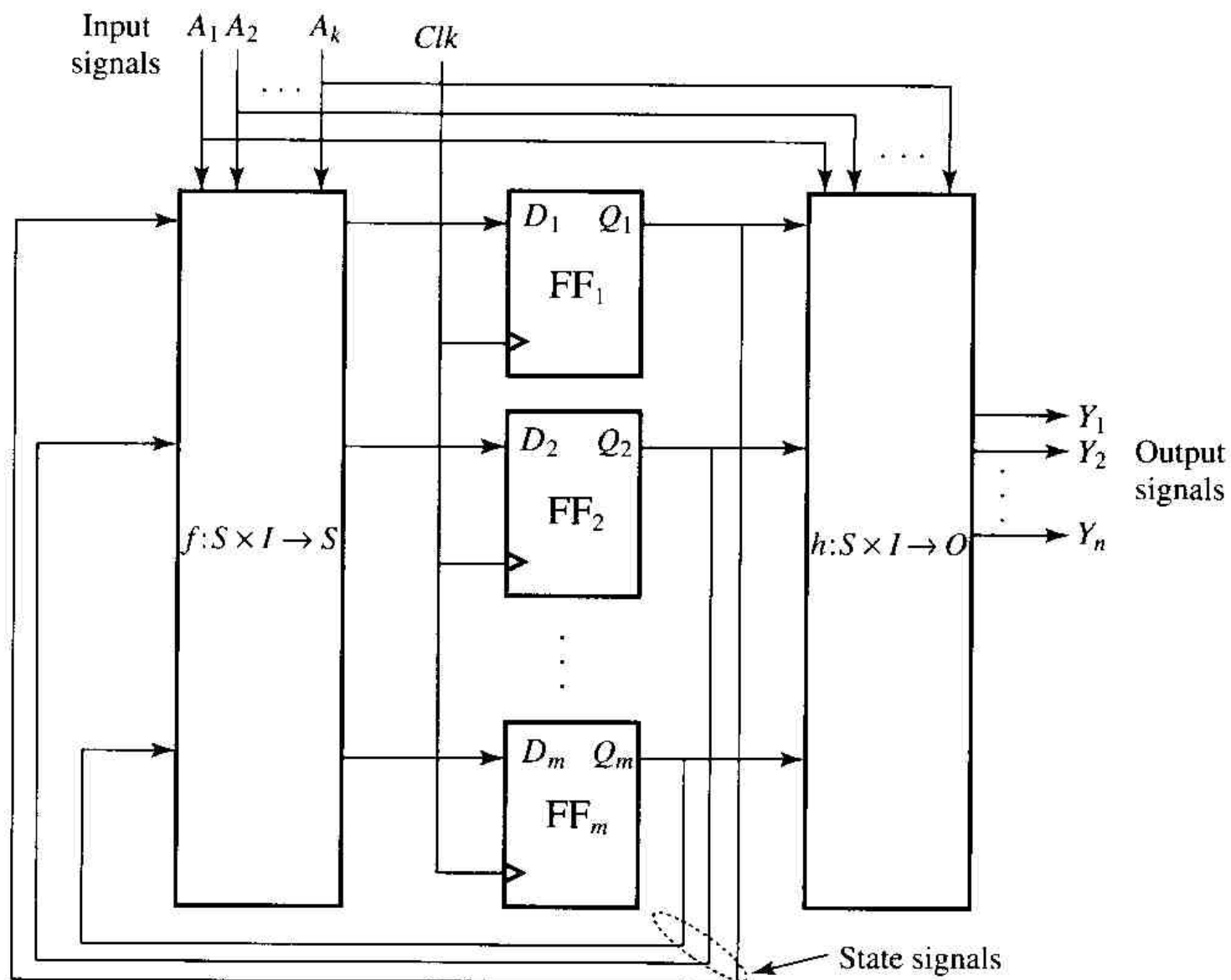
Q	Q(next)	T
0	0	0
0	1	1
1	0	1
1	1	0



# Asynkrone innganger

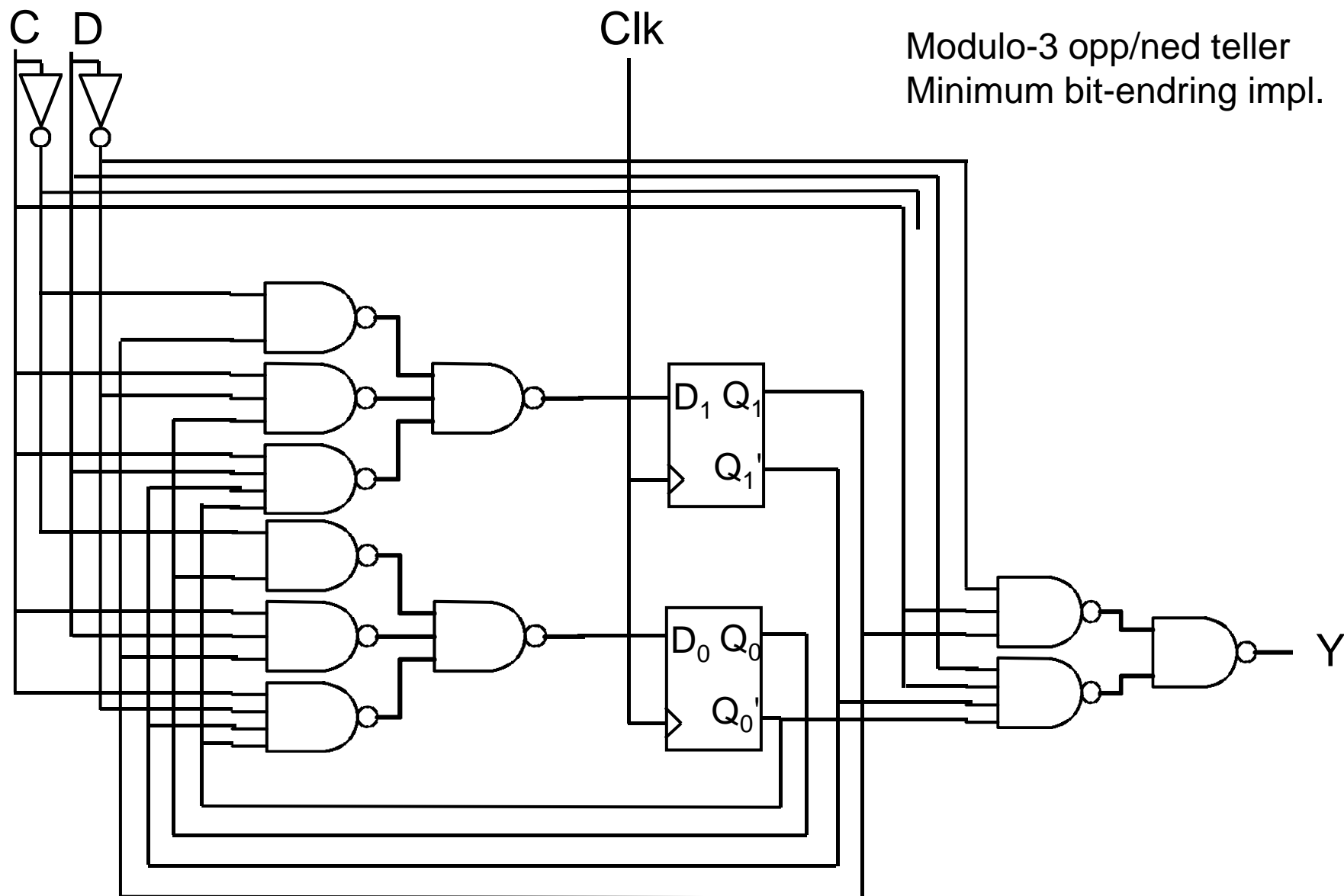


# Implementasjon av tilstandsmaskin

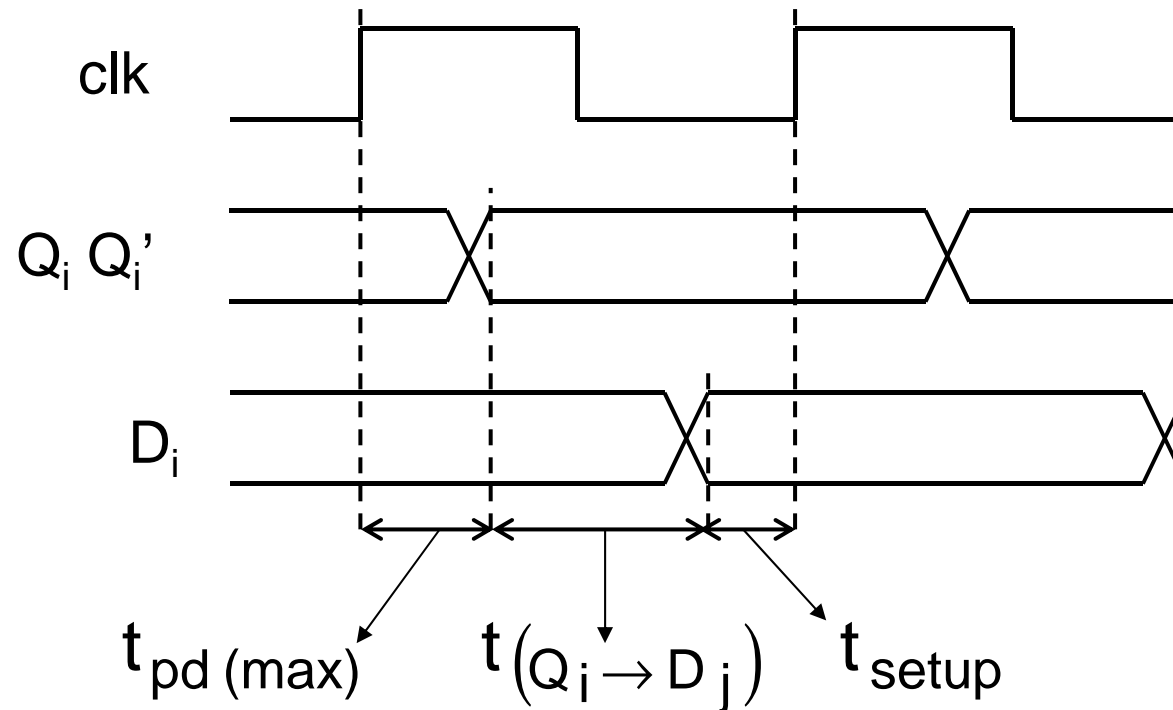


Mealy maskin

# Beregning av klokkehastighet



# Beregning av klokkehastighet



$$f_{clk}|_{max} = \frac{1}{t_{pd(max)} + t_{(Q_i \rightarrow D_j)}|_{max} + t_{setup}}$$