

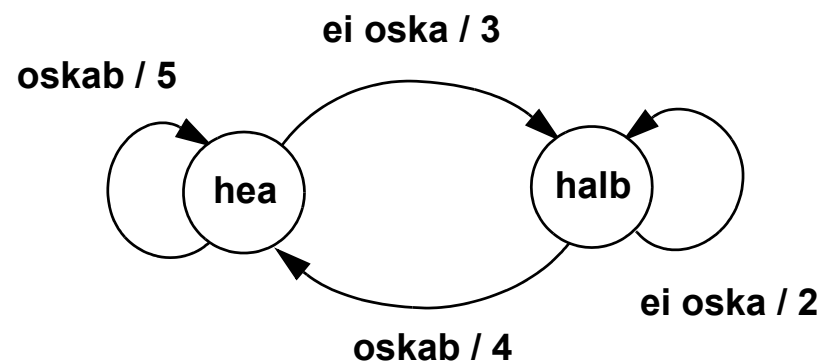


Automaatide süntees

- ***Automaadi olekudiagrammi / tabeli genereerimine (süntees)***
 - *tabeli süntees plokk-skeemist (plokk-diagrammist)*
 - *plokk-skeemi genereerimine kõrgtaseme keeltest*
- **Automaadi süntees olekudiagrammist / tabelist**
 - **eesmärk – automaadi efektiivne realisatsioon**
 - suurus, kiirus, energiatarve, testitavus jne.
 - **sisendite / väljundite kodeerimine**
 - **olekute kodeerimine**
 - **siirde- ja väljundfunktsiooni süntees ja minimeerimine**
 - sõltub valitud mälulementide tüübist (tüüpidest)

Tabel → skeem – Mealy automaat

| <i>sisend</i> | <i>olek</i> | <i>väljund</i> | <i>uus olek</i> |
|---------------|-------------|----------------|-----------------|
| tudeng | õppejõud | hinne | õppejõud |
| oskab | hea tuju | 5 | hea tuju |
| ei oska | hea tuju | 3 | halb tuju |
| ei oska | halb tuju | 2 | halb tuju |
| oskab | halb tuju | 4 | hea tuju |



- **Sisendite kodeerimine:** oskab – “1”, ei oska – “0”
- **Väljundite kodeerimine:** 5 – “11”, 4 – “10”, 3 – “01”, 2 – “00”
- **Olekute kodeerimine:** hea tuju – “1”, halb tuju – “0”

Kodeeritud tabel

| <i>sisend</i> | | <i>olek</i> | | <i>väljund</i> | | <i>uus olek</i> | |
|---------------|-------|-------------|-------|----------------|-------|-----------------|-----------|
| tudeng | i_t | õppejõud | s_t | hinne | o_t | õppejõud | s_{t+1} |
| oskab | 1 | hea tuju | 1 | 5 | 11 | hea tuju | 1 |
| ei oska | 0 | hea tuju | 1 | 3 | 01 | halb tuju | 0 |
| ei oska | 0 | halb tuju | 0 | 2 | 00 | halb tuju | 0 |
| oskab | 1 | halb tuju | 0 | 4 | 10 | hea tuju | 1 |

- Ainult koodid vajalikud
- Siirded sorteeritud (lähte)olekute järgi

| i_t | s_t | s_{t+1} | o_t |
|-------|-------|-----------|-------|
| 0 | 0 | 0 | 00 |
| 1 | | 1 | 10 |
| 0 | 1 | 0 | 01 |
| 1 | | 1 | 11 |

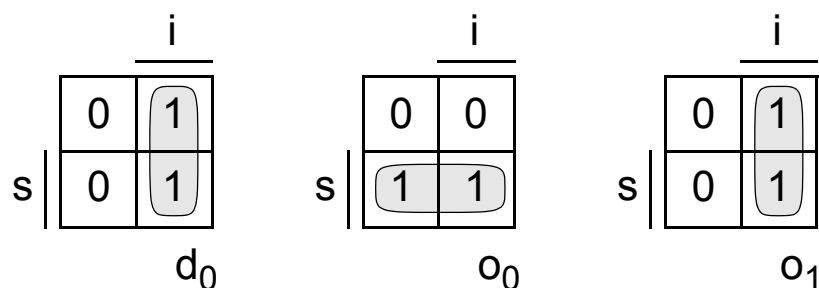
Funktsioonide süntees

- Kodeeritud tabel
- Mäluelemendi tabel
 - vana olek & uus olek → sisendkombinatsioon(id)
 - D-trigger

| i_t | s_t | s_{t+1} | o_t |
|-------|-------|-----------|-------|
| 0 | 0 | 0 | 00 |
| 1 | | 1 | 10 |
| 0 | 1 | 0 | 01 |
| 1 | | 1 | 11 |

| Q_t | Q_{t+1} | D |
|-------|-----------|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

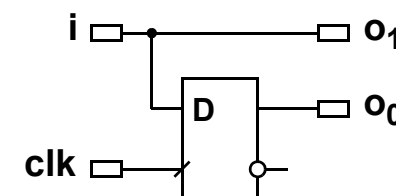
- Funktsioonide minimeerimine



$$d_0 = i$$

$$o_0 = s$$

$$o_1 = i$$



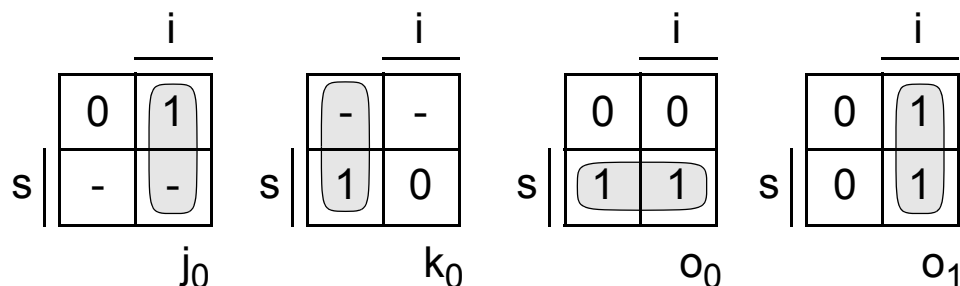
Funktsioonide süntees (variant)

- Kodeeritud tabel
- Mäluelemendi tabel
 - vana olek & uus olek → sisendkombinatsioon(id)
 - JK-trigger

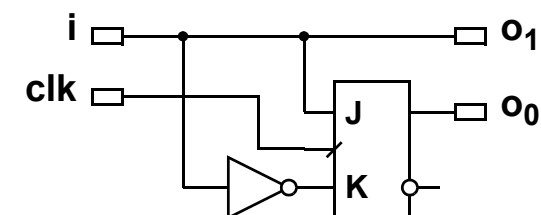
| i_t | s_t | s_{t+1} | o_t |
|-------|-------|-----------|-------|
| 0 | 0 | 0 | 00 |
| 1 | | 1 | 10 |
| 0 | 1 | 0 | 01 |
| 1 | | 1 | 11 |

| Q_t | Q_{t+1} | J | K |
|-------|-----------|---|---|
| 0 | 0 | 0 | - |
| 0 | 1 | 1 | - |
| 1 | 0 | - | 1 |
| 1 | 1 | - | 0 |

- Funktsioonide minimeerimine



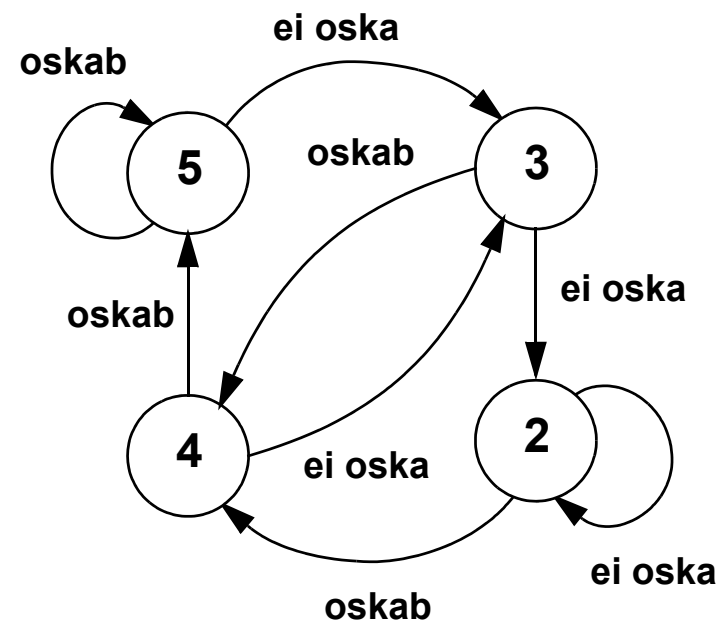
$$\begin{aligned}
 j_0 &= i \\
 k_0 &= \bar{i} \\
 o_0 &= s \\
 o_1 &= i
 \end{aligned}$$



Moore automaadi süntees

- Põhimõtteliselt sama
 - olekuid rohkem
 - väljundfunktsioon lihtsam

| <i>sisend</i> | <i>olek</i> | <i>väljund</i> | <i>uus olek</i> |
|---------------|---------------|----------------|-----------------|
| ei oksa | halb tuju & 2 | 2 | halb tuju & 2 |
| oskab | | | hea tuju & 4 |
| ei oksa | halb tuju & 3 | 3 | halb tuju & 2 |
| oskab | | | hea tuju & 4 |
| ei oksa | hea tuju & 4 | 4 | halb tuju & 3 |
| oskab | | | hea tuju & 5 |
| ei oksa | hea tuju & 5 | 5 | halb tuju & 3 |
| oskab | | | hea tuju & 5 |



Moore automaadi süntees (järg)

- Kodeerimine**

- sisend ja väljundkoodid samad
- olekud – halb tuju & 2 – “00”, halb tuju & 3 – “01”, hea tuju & 4 – “10”, hea tuju & 5 – “11”

| i_t | s_t | s_{t+1} | o_t |
|-------|-------|-----------|-------|
| 0 | 00 | 00 | 00 |
| 1 | | 10 | |
| 0 | 01 | 00 | 01 |
| 1 | | 10 | |
| 0 | 10 | 01 | 10 |
| 1 | | 11 | |
| 0 | 11 | 01 | 11 |
| 1 | | 11 | |

| Q_t | Q_{t+1} | D |
|-------|-----------|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

- Funktsioonide minimeerimine**

| | s_0 | | s_1 | |
|-----|-------|---|-------|---|
| | 0 | 0 | 1 | 1 |
| i | 0 | 0 | 1 | 1 |

d_0

| | s_0 | | s_1 | |
|-----|-------|---|-------|---|
| | 0 | 0 | 0 | 0 |
| i | 1 | 1 | 1 | 1 |

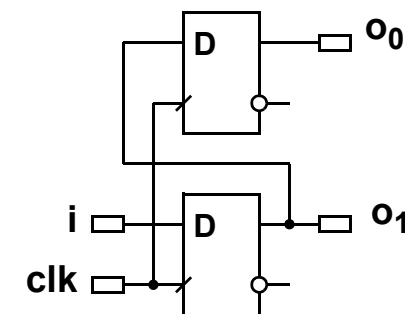
d_1

$$d_0 = s_1$$

$$d_1 = i$$

$$o_0 = s_0$$

$$o_1 = s_1$$





Automaadi tabeli süntees

- Tabeli / olekudiagrammi genereerimine
 - käsitsi kirjutamine
 - abstraktsemast esitusviisist
 - riistvara kirjelduskeel (hardware description language)
 - plokk-skeem (~~algoritm)

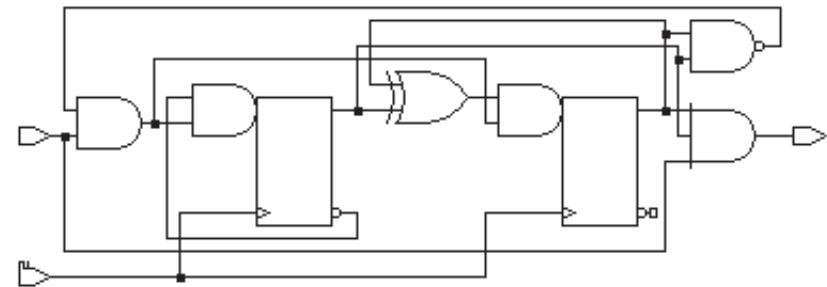
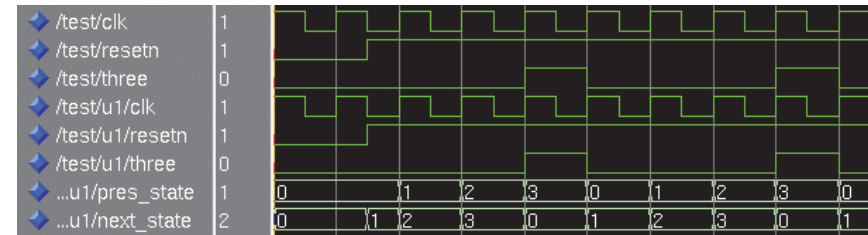
```
process
  type states is (s0, s1, s2);
  variable state: states := s0;
begin
  wait on clk until clk='1';
  case state is
    when s0 => outputs<="001"; state:=s1;
    when s1 => if inputs="--00--" then outputs<="010";
               else state:=s2; end if;
    when s2 => if inputs="-1--0-" then
                 output<="110"; state:=s2;
               else output<="101"; state:=s1; end if;
  end case;
end process;
```


Automaat & VHDL – kirjeldus-stiilid & süntees

```

library IEEE; use IEEE.std_logic_1164.all;
entity counter03 is
  port ( clk: in bit;
         resetn: in std_logic;
         three: out std_logic );
end entity counter03;
architecture fsm2 of counter03 is
  subtype state_type is integer range 0 to 3;
  signal pres_state, next_state: state_type := 0;
begin
  process (clk) begin -- State memory
    if clk'event and clk = '1' then
      pres_state <= next_state;
    end if;
  end process;
  -- Next state & output functions
  process (resetn, pres_state) begin
    three <= '0';
    if resetn='0' then      next_state <= 0;
    else
      case pres_state is
        when 0 to 2 => next_state <= pres_state + 1;
        when 3 => next_state <= 0;  three <= '1';
      end case;
    end if;
  end process;
end architecture fsm2;
  
```

Kaks protsessi

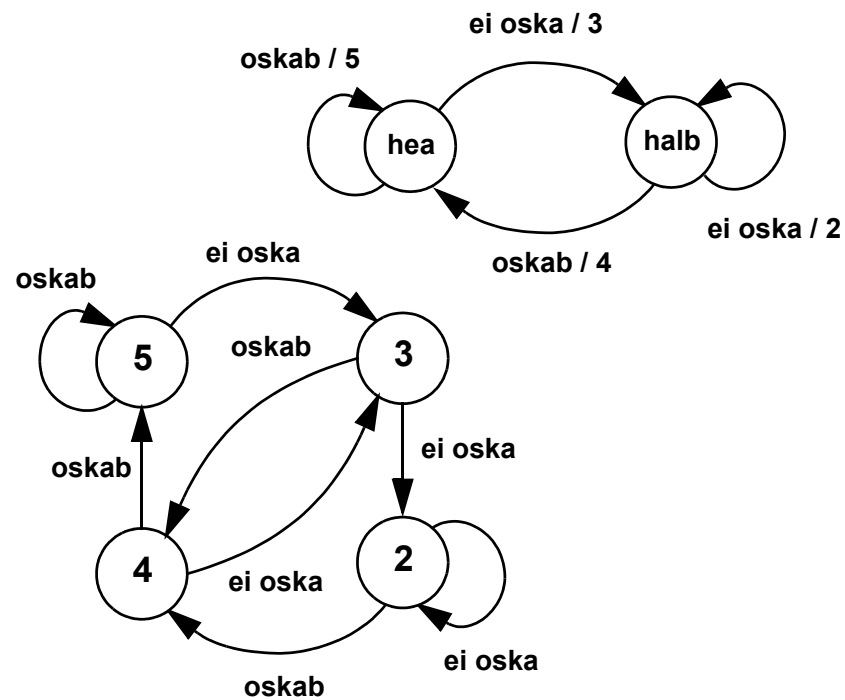
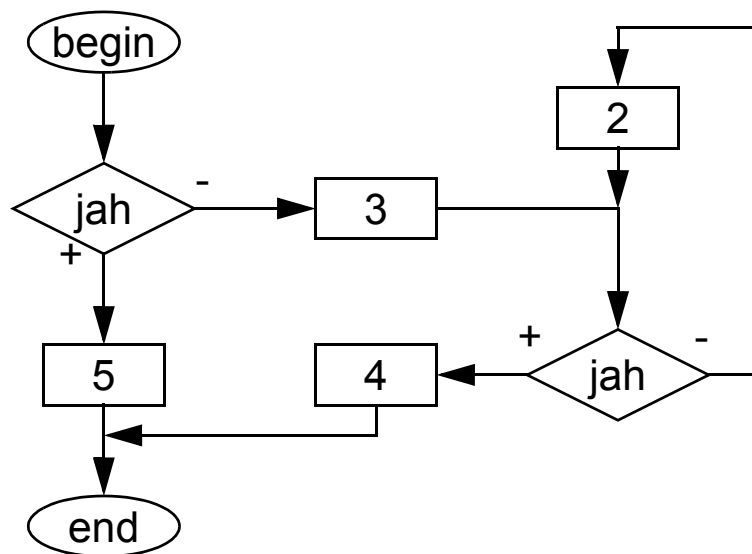


22 gates / 3.70 ns

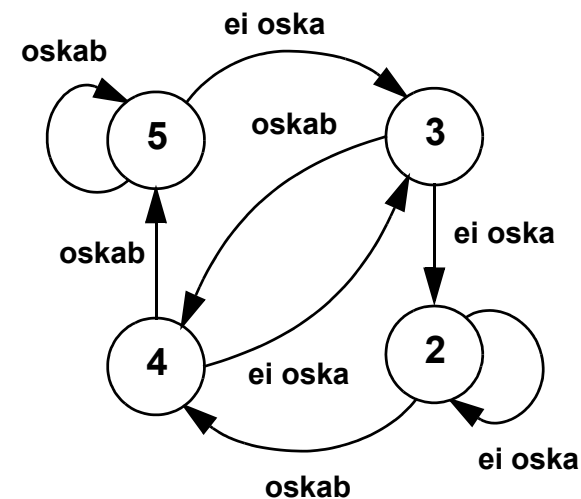
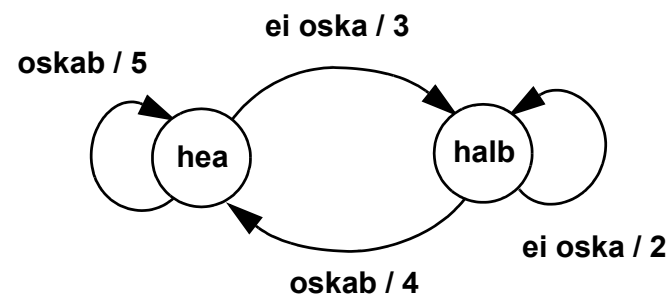
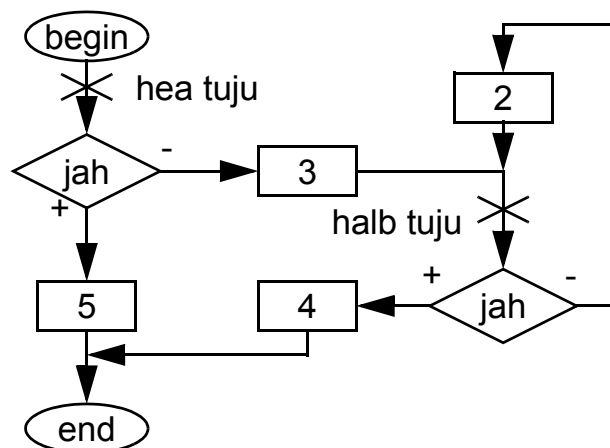
- **Vt. ka ühe ja kolme protsessiga näiteid VHDL-i loengumaterjalides**

Tabeli / olekudiagrammi süntees plokkskeemist

- Algoritmi graaf-skeem (GSA)
- Behavioral FSM



Tabeli / olekudiagrammi süntees plokkskeemist – reeglid



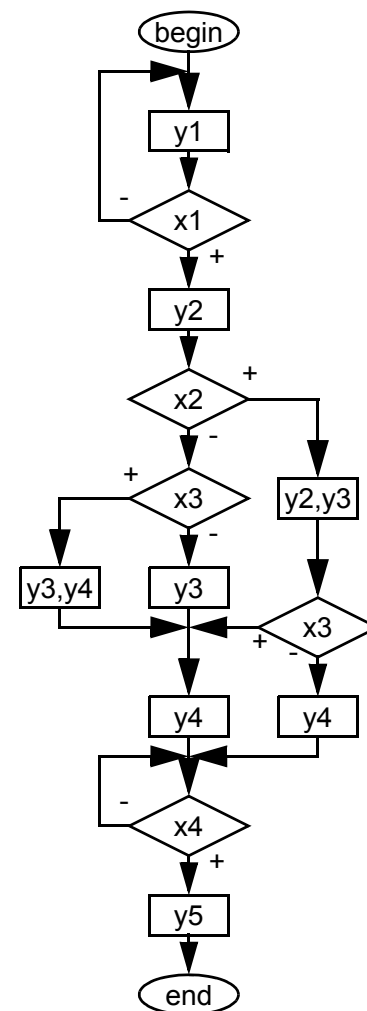
- **Mealy automaat**
 - kahe väljundploki vahel peab olema olek
 - tsükel peab sisaldama olekut
- **Moore automaat**
 - väljundplokk on olek
 - tsükel peab sisaldama olekut

Plokkskeemi genereerimine

- Automaatne genereerimine kõrgtaseme kirjeldusest
 - programmeerimiskeel või riistvara kirjelduskeel

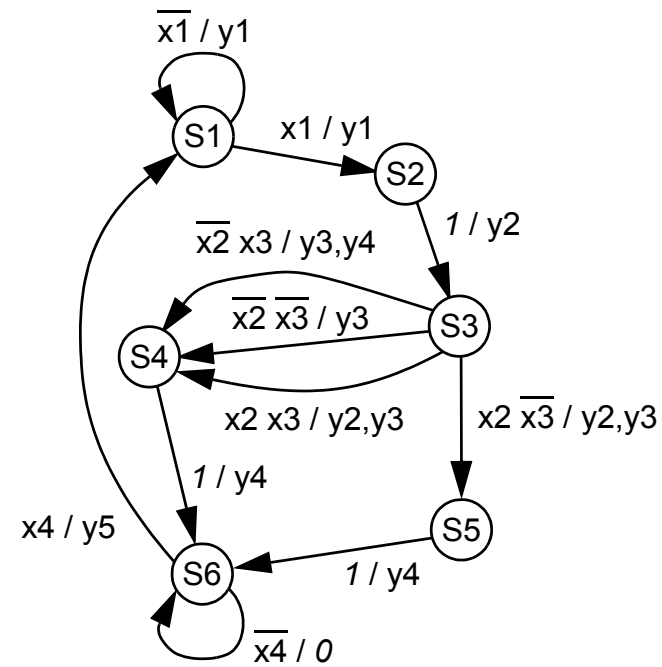
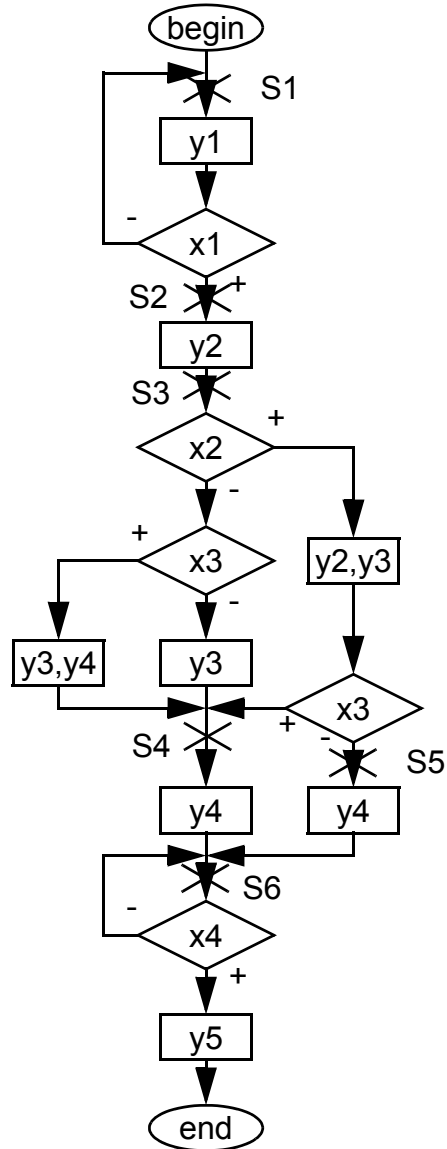
```

process fsm (x1,x2,x3,x4,y1,y2,y3,y4,y5)
  bit in x1,x2,x3,x4;  bit out y1,y2,y3,y4,y5;
{
  while (!x1)  out (y1);
  out (y2);
  if (x2) {
    out (y2,y3);
    if (!x3) { out (y4); goto L1; }
  }
  else { if (x3) out (y3,y4);  else out (y3); }
  out (y4);
L1: while (!x4);
  out (y5);
}
  
```



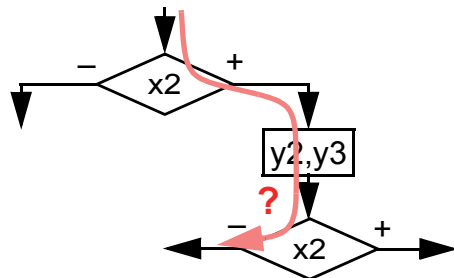


Mealy automaat

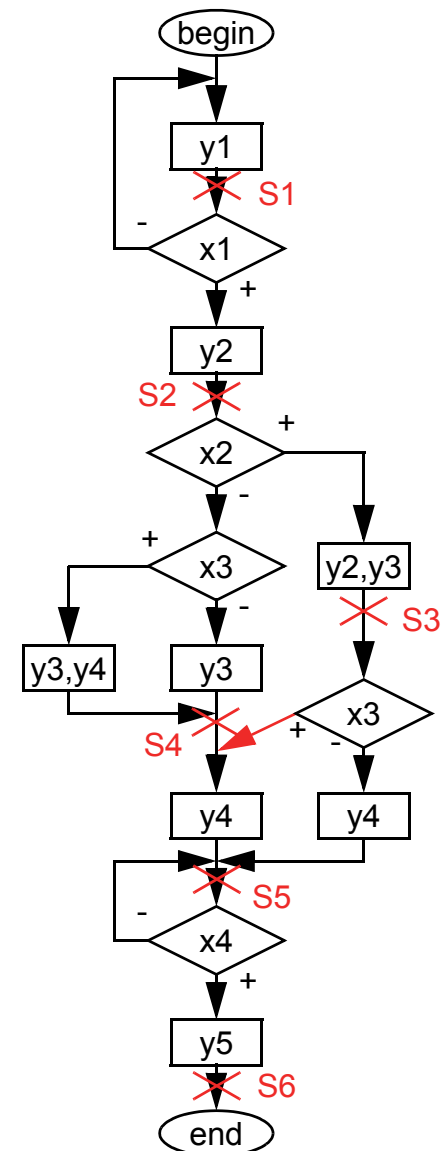
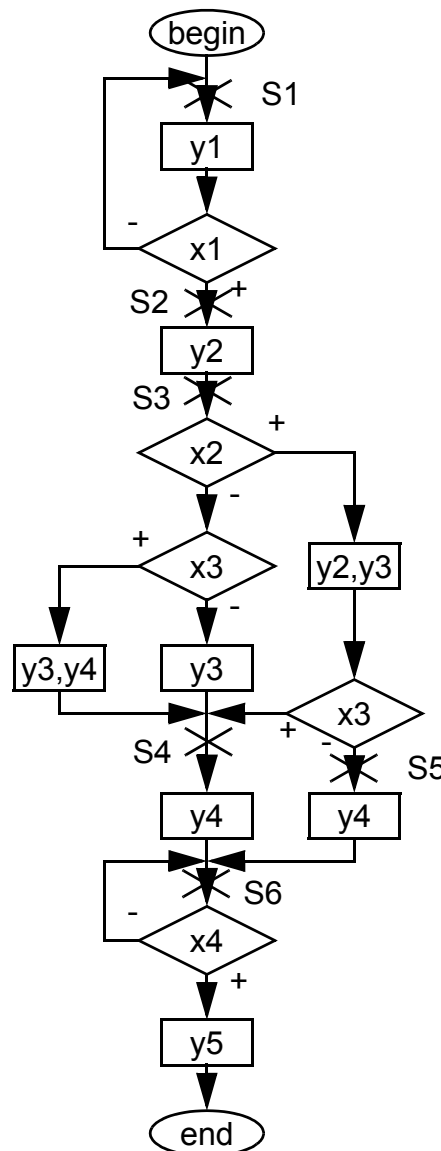


Olekute asukohad?

- **Probleem** – mis saab siis, kui enne ja pärast väljundplokki on sama sisendsignaal?
- osa teid jääb katmata!!!



- **Lahendus** – olek väljundploki järel (ehk enne esimest tingimust)
- Antud juhul on mõlemad variandid õiged
- Olekute arv jääb samaks
- vt. ka “ümbersuunamist”

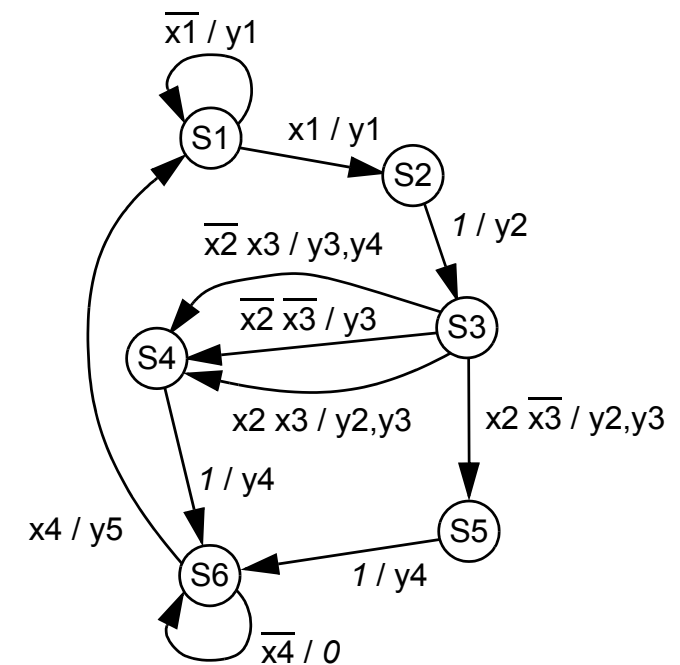




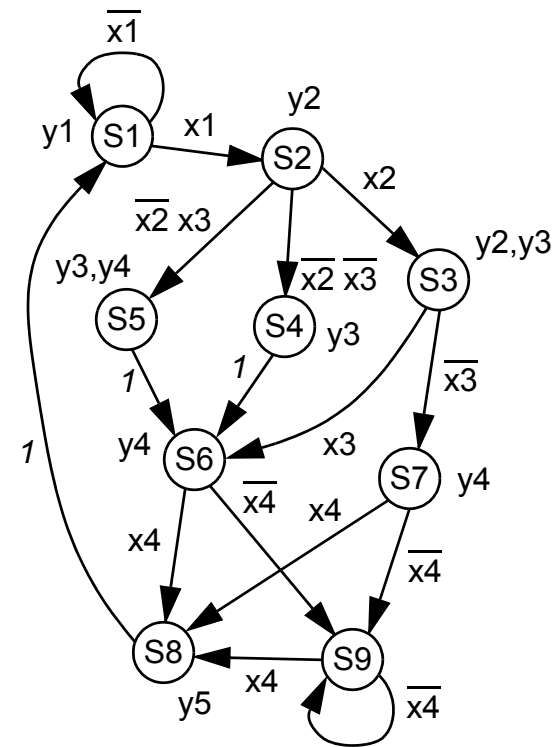
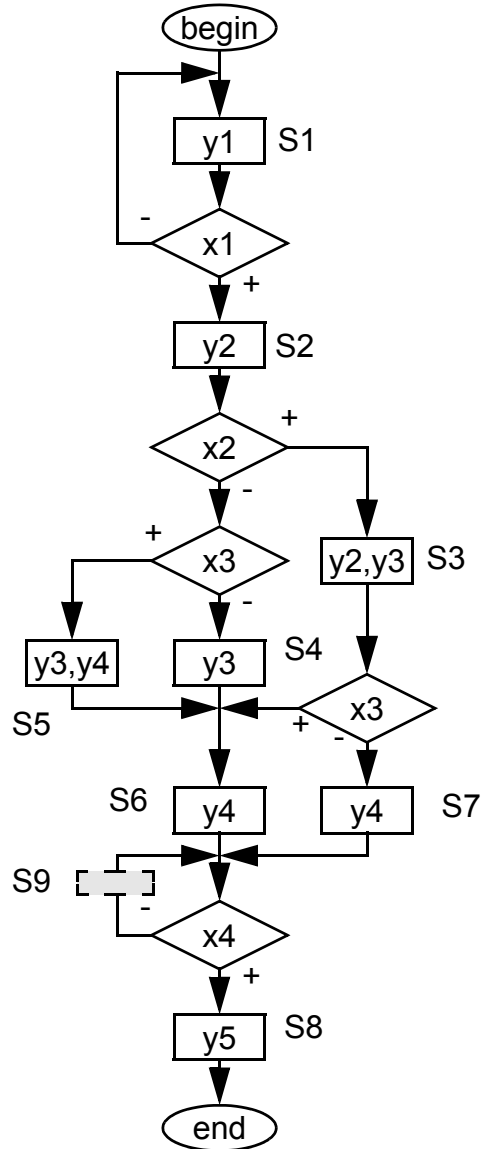
Mealy automaat – tabel

| i^t | s^t | s^{t+1} | o^t |
|-------------------------------|-------|-----------|--------|
| $\overline{x1}$ | S1 | S1 | y1 |
| x1 | | S2 | y1 |
| 1 | S2 | S3 | y2 |
| $\overline{x2} \overline{x3}$ | S3 | S4 | y3 |
| $\overline{x2} x3$ | | S4 | y3, y4 |
| $x2 \overline{x3}$ | | S5 | y2, y3 |
| $x2 x3$ | | S4 | y2, y3 |
| 1 | S4 | S6 | y4 |
| 1 | S5 | S6 | y4 |
| x4 | S6 | S1 | y5 |
| $\overline{x4}$ | | S6 | 0 |

| i^t | s^t | s^{t+1} | o^t |
|-------|-------|-----------|-------|
| 0--- | S1 | S1 | 10000 |
| 1--- | | S2 | 10000 |
| ---- | S2 | S3 | 01000 |
| -00- | S3 | S4 | 00100 |
| -01- | | S4 | 00110 |
| -10- | | S5 | 01100 |
| -11- | | S4 | 01100 |
| ---- | S4 | S6 | 00010 |
| ---- | S5 | S6 | 00010 |
| ---1 | S6 | S1 | 00001 |
| ---0 | | S6 | 00000 |



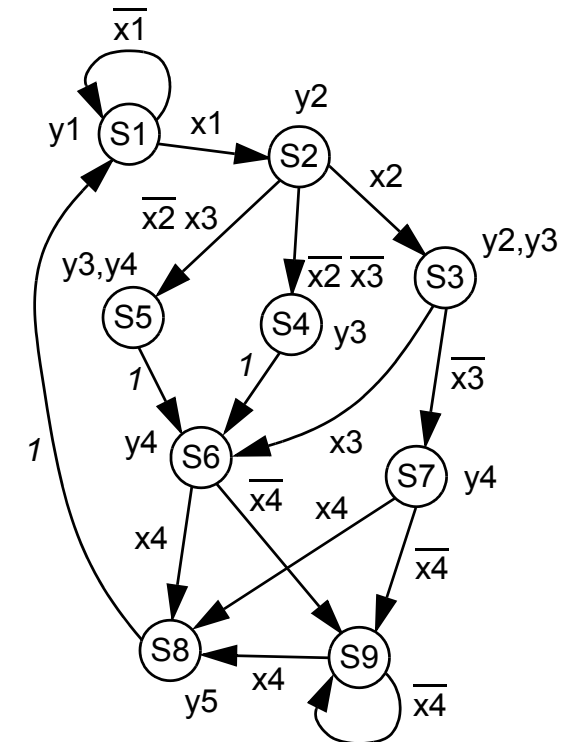
Moore automaat



Moore automaat – tabel

| i^t | s^t | s^{t+1} | o^t |
|-------------------------------|-------|-----------|--------|
| $\overline{x1}$ | S1 | S1 | y1 |
| x1 | | S2 | |
| $\overline{x2} \overline{x3}$ | S2 | S4 | y2 |
| $\overline{x2} x3$ | | S5 | |
| x2 | | S3 | |
| $\overline{x3}$ | S3 | S7 | y2, y3 |
| x3 | | S6 | |
| 1 | S4 | S6 | y3 |
| 1 | S5 | S6 | y3, y4 |
| x4 | S6 | S8 | y4 |
| $\overline{x4}$ | | S9 | |
| x4 | S7 | S8 | y4 |
| $\overline{x4}$ | | S9 | |
| 1 | S8 | S1 | y5 |
| x4 | S9 | S8 | 0 |
| $\overline{x4}$ | | S9 | |

| i^t | s^t | s^{t+1} | o^t |
|-------|-------|-----------|-------|
| 0--- | S1 | S1 | 10000 |
| 1--- | | S2 | |
| -00- | S2 | S4 | 01000 |
| -01- | | S5 | |
| -1-- | | S3 | |
| --0- | S3 | S7 | 01100 |
| --1- | | S6 | |
| ---- | S4 | S6 | 00100 |
| ---- | S5 | S6 | 00110 |
| ---1 | S6 | S8 | 00010 |
| ---0 | | S9 | |
| ---1 | S7 | S8 | 00010 |
| ---0 | | S9 | |
| ---- | S8 | S1 | 00001 |
| ---1 | S9 | S8 | 00000 |
| ---0 | | S9 | |





Olekute kodeerimine

- **Leida olekutele sellised koodid, et siirde- ja väljundfunktsioonid oleksid minimaalsed**
 - osaliselt määratud funktsioonid aitavad sellele kaasa
- **Heuristilised reeglid**
 - **Kõik mälualemendid**
 - olekud, mis samade sisendtingimuste korral viivad samasse olekusse, peaksid olema naaberkodeidiga – võimaldab kaks konjunktsiooni kokku kleepida
 - **D-trigerid – mida rohkem siirdeid mingisse olekusse, seda vähem peaks selle kood sisaldama 1**
 - iga siire vastab ühele konjunktsioonile
 - olek, millesse toimub kõige rohkem siirdeid, peaks olema ainult 0-dest koosneva koodiga
 - **SR-, JK- & T-trigerid – siirdele vastava jooksva ja järgnev oleku koodid peaksid võimalikult kokku langema**
 - ideaaljuhul naaberkodeid
 - sarnane sobivusgraafi servakatte leidmise ülesandega

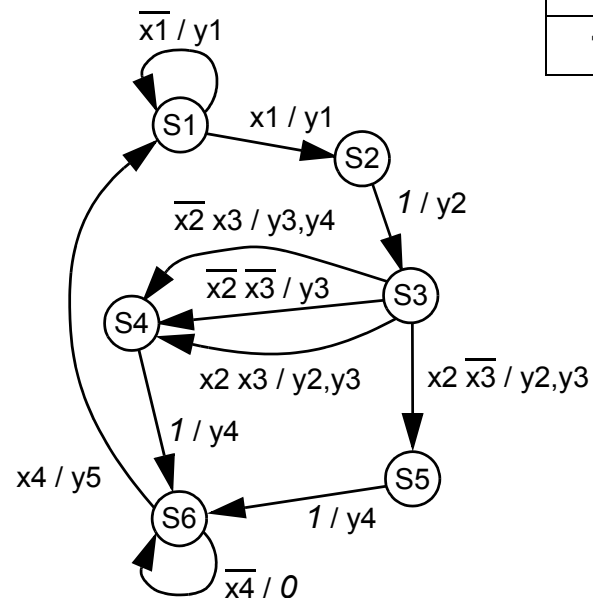


Mealy automaat – olekute kodeerimine

| i^t | s^t | | s^{t+1} | | o^t |
|-------|-------|-----|-----------|-----|-------|
| 0--- | S1 | 000 | S1 | 000 | 10000 |
| 1--- | | | S2 | 001 | 10000 |
| ---- | S2 | 001 | S3 | 111 | 01000 |
| -00- | S3 | 111 | S4 | 101 | 00100 |
| -01- | | | S4 | 101 | 00110 |
| -10- | | | S5 | 110 | 01100 |
| -11- | | | S4 | 101 | 01100 |
| ---- | S4 | 101 | S6 | 100 | 00010 |
| ---- | S5 | 110 | S6 | 100 | 00010 |
| ---1 | S6 | 100 | S1 | 000 | 00001 |
| ---0 | | | S6 | 100 | 00000 |

- Naabrid: S1-S2, S2-S3, S3-S4, S3-S5, S4-S6, S5-S6, S6-S1

| Q_t | Q_{t+1} | J | K |
|-------|-----------|---|---|
| 0 | 0 | 0 | - |
| 0 | 1 | 1 | - |
| 1 | 0 | - | 1 |
| 1 | 1 | - | 0 |





Mealy automaat – funktsioonide süntees

| i^t | s^t | | s^{t+1} | | JK^{t+1} | o^t |
|-------|-------|-----|-----------|-----|------------|-------|
| 0--- | S1 | 000 | S1 | 000 | 0- 0- 0- | 10000 |
| 1--- | | | S2 | 001 | 0- 0- 1- | 10000 |
| ---- | S2 | 001 | S3 | 111 | 1- 1- -0 | 01000 |
| -00- | S3 | 111 | S4 | 101 | -0 -1 -0 | 00100 |
| -01- | | | S4 | 101 | -0 -1 -0 | 00110 |
| -10- | | | S5 | 110 | -0 -0 -1 | 01100 |
| -11- | | | S4 | 101 | -0 -1 -0 | 01100 |
| ---- | S4 | 101 | S6 | 100 | -0 0- -1 | 00010 |
| ---- | S5 | 110 | S6 | 100 | -0 -1 0- | 00010 |
| ---1 | S6 | 100 | S1 | 000 | -1 0- 0- | 00001 |
| ---0 | | | S6 | 100 | -0 0- 0- | 00000 |

| Q_t | Q_{t+1} | J | K |
|-------|-----------|---|---|
| 0 | 0 | 0 | - |
| 0 | 1 | 1 | - |
| 1 | 0 | - | 1 |
| 1 | 1 | - | 0 |

JK^{t+1} - JK
trigerite
sisendid

Kasutamata
olekukoodid:
010, 011



Mealy automaat – funktsioonide minimeerimine

funktsioonid

```

xxxx qqg | jkjkjk yyyyyy
1234 123 | 112233 12345
-----+-----
0--- 000 | 0-0-0- 10000
1--- 000 | 0-0-1- 10000
---- 001 | 1-1--0 01000
-00- 111 | -0-1-0 00100
-01- 111 | -0-1-0 00110
-10- 111 | -0-0-1 01100
-11- 111 | -0-1-0 01100
---- 101 | -00--1 00010
---- 110 | -0-10- 00010
---1 100 | -10-0- 00001
---0 100 | -00-0- 00000
---- 010 | -----
---- 011 | -----

```

espresso sisend

```

.i 7
.o 11
0---000 0-0-0-10000
1---000 0-0-1-10000
----001 1-1--001000
-00-111 -0-1-000100
-01-111 -0-1-000110
-10-111 -0-0-101100
-11-111 -0-1-001100
----101 -00--100010
----110 -0-10-00010
---1100 -10-0-00001
---0100 -00-0-00000
----010 -----
----011 -----
.e

```

espresso väljund

```

.i 7
.o 11
---1100 01000000001
-01--1- 00000000010
1---0-- 00001000000
-10--11 00000101100
-11--11 00010001100
----101 00000100010
----0-0 00000010000
-0---11 00010000100
----0-1 10100001000
----10 00010000010
.e

```



Mealy automaat – skeem

espresso väljund

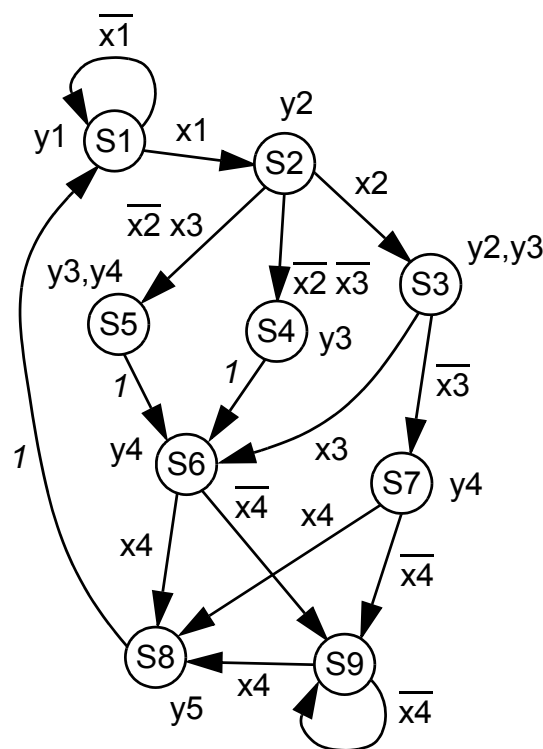
```
.i 7
.o 11
---1100 01000000001
-01--1- 00000000010
1---0-- 00001000000
-10--11 00000101100
-11--11 00010001100
----101 00000100010
----0-0 00000010000
-0---11 00010000100
----0-1 10100001000
-----10 00010000010
.e
```

- $j1 = j2 = \overline{q1} q3$
- $k1 = x4 q1 \overline{q2} \overline{q3}$
- $k2 = x2 x3 q2 q3 + \overline{x2} q2 q3 + q2 \overline{q3}$
- $j3 = x1 \overline{q1}$
- $k3 = x2 \overline{x3} q2 q3 + q1 \overline{q2} q3$
- $y1 = \overline{q1} \overline{q3}$
- $y2 = x2 \overline{x3} q2 q3 + x2 x3 q2 q3 + \overline{q1} q3$
- $y3 = x2 \overline{x3} q2 q3 + x2 x3 q2 q3 + \overline{x2} q2 q3$
- $y4 = \overline{x2} x3 q2 + q1 \overline{q2} q3 + q2 \overline{q3}$
- $y5 = x4 q1 \overline{q2} \overline{q3}$



Moore automaat – olekute kodeerimine

| i^t | s^t | | s^{t+1} | | o^t |
|-------|-------|------|-----------|------|-------|
| 0--- | S1 | 0000 | S1 | 0000 | 10000 |
| 1--- | | | S2 | 0011 | |
| -00- | S2 | 0011 | S4 | 1100 | 01000 |
| -01- | | | S5 | 0101 | |
| -1-- | | | S3 | 0110 | |
| --0- | S3 | 0110 | S7 | 1000 | 01100 |
| --1- | | | S6 | 0001 | |
| ---- | S4 | 1100 | S6 | 0001 | 00100 |
| ---- | S5 | 0101 | S6 | 0001 | 00110 |
| ----1 | S6 | 0001 | S8 | 0010 | 00010 |
| ----0 | | | S9 | 0100 | |
| ----1 | S7 | 1000 | S8 | 0010 | 00010 |
| ----0 | | | S9 | 0100 | |
| ---- | S8 | 0010 | S1 | 0000 | 00001 |
| ----1 | S9 | 0100 | S8 | 0010 | 00000 |
| ----0 | | | S9 | 0100 | |



| Q_t | Q_{t+1} | D |
|-------|-----------|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

Siirete arv:
 S1 - 2, S2 - 1,
 S3 - 1, S4 - 1,
 S5 - 1, S6 - 3,
 S7 - 1, S8 - 3,
 S9 - 3



Moore automaat – funktsioonide süntees

| i^t | s^t | | s^{t+1} | | D^{t+1} | o^t |
|-------|-------|------|-----------|------|-----------|-------|
| 0--- | S1 | 0000 | S1 | 0000 | 0000 | 10000 |
| 1--- | | | S2 | 0011 | 0011 | |
| -00- | S2 | 0011 | S4 | 1100 | 1100 | 01000 |
| -01- | | | S5 | 0101 | 0101 | |
| -1-- | | | S3 | 0110 | 0110 | |
| --0- | S3 | 0110 | S7 | 1000 | 1000 | 01100 |
| --1- | | | S6 | 0001 | 0001 | |
| ---- | S4 | 1100 | S6 | 0001 | 0001 | 00100 |
| ---- | S5 | 0101 | S6 | 0001 | 0001 | 00110 |
| ---1 | S6 | 0001 | S8 | 0010 | 0010 | 00010 |
| ---0 | | | S9 | 0100 | 0100 | |
| ---1 | S7 | 1000 | S8 | 0010 | 0010 | 00010 |
| ---0 | | | S9 | 0100 | 0100 | |
| ---- | S8 | 0010 | S1 | 0000 | 0000 | 00001 |
| ---1 | S9 | 0100 | S8 | 0010 | 0010 | 00000 |
| ---0 | | | S9 | 0100 | 0100 | |

| Q_t | Q_{t+1} | D |
|-------|-----------|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

D^{t+1} - D-trigerite sisendid

Kasutatata olekukoodid:
0111, 1001, 1010,
1011, 1101, 1110,
1111



| xxxx | qqqq | dddd | siirde- |
|------|------|------|--------------|
| 1234 | 1234 | 1234 | funktsioon |
| 0--- | 0000 | 0000 | |
| 1--- | 0000 | 0011 | |
| -00- | 0011 | 1100 | väljund- |
| -01- | 0011 | 0101 | funktsioon |
| -1-- | 0011 | 0110 | qqqq yyyy |
| --0- | 0110 | 1000 | 1234 12345 |
| --1- | 0110 | 0001 | -----+----- |
| ---- | 1100 | 0001 | 0000 10000 |
| ---- | 0101 | 0001 | 0011 01000 |
| ---1 | 0001 | 0010 | 0110 01100 |
| ---0 | 0001 | 0100 | 1100 00100 |
| ---1 | 1000 | 0010 | 0101 00110 |
| ---0 | 1000 | 0100 | 0001 00010 |
| ---- | 0010 | 0000 | 1000 00010 |
| ---1 | 0100 | 0010 | 0010 00001 |
| ---0 | 0100 | 0100 | 0100 00000 |
| ---- | 0111 | ---- | 0111 ----- |
| ---- | 1001 | ---- | 1001 ----- |
| ---- | 1010 | ---- | 1010 ----- |
| ---- | 1011 | ---- | 1011 ----- |
| ---- | 1101 | ---- | 1101 ----- |
| ---- | 1110 | ---- | 1110 ----- |
| ---- | 1111 | ---- | 1111 ----- |

espresso sisend:

| .i | 8 | siirde- |
|----------|------|------------|
| .o | 4 | funktsioon |
| 0--- | 0000 | 0000 |
| 1--- | 0000 | 0011 |
| -00- | 0011 | 1100 |
| -01- | 0011 | 0101 |
| -1-- | 0011 | 0110 |
| --0- | 0110 | 1000 |
| --1- | 0110 | 0001 |
| ---- | 1100 | 0001 |
| ---- | 0101 | 0001 |
| ---10001 | 0010 | 0011 01000 |
| ---00001 | 0100 | 0110 01100 |
| ---11000 | 0010 | 1100 00100 |
| ---01000 | 0100 | 0101 00110 |
| ----0010 | 0000 | 0001 00010 |
| ---10100 | 0010 | 1000 00010 |
| ---00100 | 0100 | 0010 00001 |
| ----0111 | ---- | 0100 00000 |
| ----1001 | ---- | 0111 ----- |
| ----1010 | ---- | 1001 ----- |
| ----1011 | ---- | 1010 ----- |
| ----1011 | ---- | 1011 ----- |
| ----1101 | ---- | 1010 ----- |
| ----1110 | ---- | 1101 ----- |
| ----1111 | ---- | 1110 ----- |
| .e | | 1111 ----- |
| .e | | .e |



Moore automaat – funktsioonide minimeerimine

```
.i 8
.o 4
0---0000 0000
1---0000 0011
-00-0011 1100
-01-0011 0101
-1--0011 0110
--0-0110 1000
--1-0110 0001
----1100 0001
----0101 0001
---10001 0010
---00001 0100
---11000 0010
---01000 0100
----0010 0000
---10100 0010
---00100 0100
----0111 ----
----1001 ----
----1010 ----
----1011 ----
----1101 ----
----1110 ----
----1111 ----
.e
```

siirde-
funktsioon

espresso sisend

väljund-
funktsioon

```
.i 4
.o 5
0000 10000
0011 01000
0110 01100
1100 00100
0101 00110
0001 00010
1000 00010
0010 00001
0100 00000
0111 -----
1001 -----
1010 -----
1011 -----
1101 -----
1110 -----
1111 -----
.e
```

espresso väljund

```
.i 8
.o 4
-00---11 1100
-01---11 0101
---110-- 0010
--0--11- 1000
---010-- 0100
--1--11- 0001
---10100 0010
---00100 0100
-1----11 0110
----11-- 0001
1---0000 0011
---1-001 0010
---0-0-1 0100
----1-1 0001
.e
```

siirde-
funktsioon

väljund-
funktsioon

```
.i 4
.o 5
0000 10000
-010 00001
--01 00010
10-- 00010
--11 01000
11-- 00100
-1-1 00100
-11- 01100
.e
```



Moore automaat – skeem

```
.i 8
.o 4
-00---11 1100
-01---11 0101
---110-- 0010
--0--11- 1000
---010-- 0100
--1--11- 0001
---10100 0010
---00100 0100
-1----11 0110
----11-- 0001
1---0000 0011
---1-001 0010
---0-0-1 0100
-----1-1 0001
.e
```

siirde-
funktsioon

$$\begin{aligned}
 d1 &= \overline{x2} \overline{x3} q3 q4 + \overline{x3} q2 q3 \\
 d2 &= \overline{x2} \overline{x3} q3 q4 + \overline{x2} x3 q3 q4 + \\
 &\quad + \overline{x4} q1 q2 + \overline{x4} q1 q2 q3 q4 + \\
 &\quad + x2 q3 q4 + \overline{x4} q2 q4 \\
 d3 &= x4 q1 q2 + x4 q1 q2 q3 q4 + \\
 &\quad + x2 q3 q4 + x1 q1 q2 q3 q4 + \\
 &\quad + \overline{x4} q2 q3 q4 \\
 d4 &= \overline{x2} x3 q3 q4 + x3 q2 q3 + \\
 &\quad + q1 q2 + x1 \overline{q1} \overline{q2} \overline{q3} \overline{q4} + \\
 &\quad + q2 q4
 \end{aligned}$$

```
.i 4
```

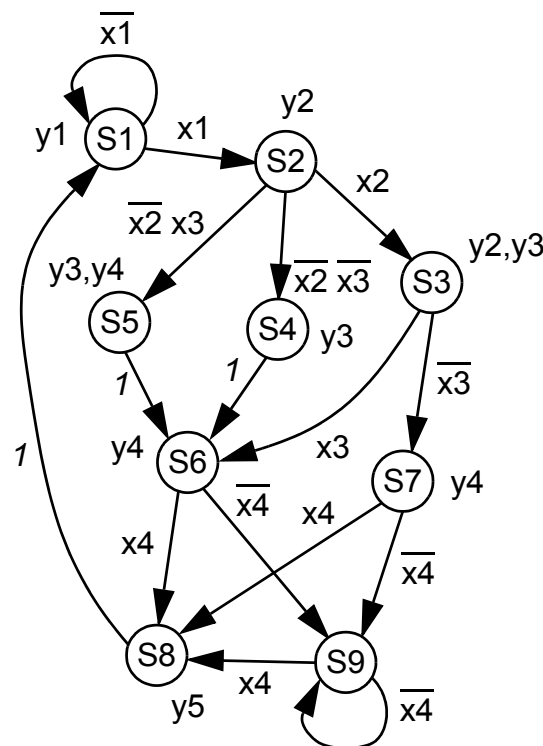
```
.o 5
0000 10000
-010 00001
--01 00010
10-- 00010
--11 01000
11-- 00100
-1-1 00100
-11- 01100
.e
```

väljund-
funktsioon

$$\begin{aligned}
 y1 &= \overline{q1} \overline{q2} \overline{q3} \overline{q4} \\
 y2 &= q3 q4 + q2 q3 \\
 y3 &= \overline{q1} q2 + q2 \overline{q4} + q2 q3 \\
 y4 &= \overline{q3} q4 + q1 \overline{q2} \\
 y5 &= \overline{q2} q3 \overline{q4}
 \end{aligned}$$

Moore automaat – olekute kodeerimine #2

| i^t | s^t | | s^{t+1} | | o^t |
|-------|-------|------|-----------|------|-------|
| 0--- | S1 | 0000 | S1 | 0000 | 10000 |
| 1--- | | | S2 | 0001 | |
| -00- | S2 | 0001 | S4 | 0101 | 01000 |
| -01- | | | S5 | 0011 | |
| -1-- | | | S3 | 1001 | |
| --0- | S3 | 1001 | S7 | 1010 | 01100 |
| --1- | | | S6 | 0110 | |
| ---- | S4 | 0101 | S6 | 0110 | 00100 |
| ---- | S5 | 0011 | S6 | 0110 | 00110 |
| ---1 | S6 | 0110 | S8 | 1100 | 00010 |
| ---0 | | | S9 | 1110 | |
| ---1 | S7 | 1010 | S8 | 1100 | 00010 |
| ---0 | | | S9 | 1110 | |
| ---- | S8 | 1100 | S1 | 0000 | 00001 |
| ---1 | S9 | 1110 | S8 | 1100 | 00000 |
| ---0 | | | S9 | 1110 | |



| Q_t | Q_{t+1} | J | K |
|-------|-----------|---|---|
| 0 | 0 | 0 | - |
| 0 | 1 | 1 | - |
| 1 | 0 | - | 1 |
| 1 | 1 | - | 0 |

Võimalikult vähe muutuvad koodid:

S1 - 0000, S2 - 0001,
 S3 - 1001, S4 - 0101,
 S5 - 0011, S6 - 0110,
 S7 - 1010, S8 - 1100,
 S9 - 1110



Moore automaat – funktsioonide süntees #2

| i^t | s^t | | s^{t+1} | | JK^{t+1} | o^t |
|-------|-------|------|-----------|------|------------|-------|
| 0--- | S1 | 0000 | S1 | 0000 | 0-0-0-0- | 10000 |
| 1--- | | | S2 | 0001 | 0-0-0-1- | |
| -00- | S2 | 0001 | S4 | 0101 | 0-1-0--0 | 01000 |
| -01- | | | S5 | 0011 | 0-0-1--0 | |
| -1-- | | | S3 | 1001 | 1-0-0--0 | |
| --0- | S3 | 1001 | S7 | 1010 | -00-1--1 | 01100 |
| --1- | | | S6 | 0110 | -11-1--1 | |
| ---- | S4 | 0101 | S6 | 0110 | 0--01--1 | 00100 |
| ---- | S5 | 0011 | S6 | 0110 | 0-1--0-1 | 00110 |
| ---1 | S6 | 0110 | S8 | 1100 | 1--0-00- | 00010 |
| ---0 | | | S9 | 1110 | 1--0-10- | |
| ---1 | S7 | 1010 | S8 | 1100 | -01--00- | 00010 |
| ---0 | | | S9 | 1110 | -01--10- | |
| ---- | S8 | 1100 | S1 | 0000 | -1-10-0- | 00001 |
| ---1 | S9 | 1110 | S8 | 1100 | -0-0-00- | 00000 |
| ---0 | | | S9 | 1110 | -0-0-10- | |

| Q_t | Q_{t+1} | J | K |
|-------|-----------|---|---|
| 0 | 0 | 0 | - |
| 0 | 1 | 1 | - |
| 1 | 0 | - | 1 |
| 1 | 1 | - | 0 |

JK^{t+1} - JK-trigerite
sisendid

Kasutamata
olekukoodid:
0010, 0100, 0111,
1000, 1011, 1101,
1111



Moore automaat – funktsioonide minimeerimine #2

```

.i 8
.o 8
0---0000 0-0-0-0-
1---0000 0-0-0-1-
-00-0001 0-1-0--0
-01-0001 0-0-1--0
-1--0001 1-0-0--0
--0-1001 -00-1--1
--1-1001 -11-1--1
----0101 0--01--1
----0011 0-1--0-1
---00110 1--0-00-
---10110 1--0-10-
---01010 -01--00-
---11010 -01--10-
----1100 -1-10-0-
---01110 -0-0-00-
---11110 -0-0-10-
----0010 -----
----0100 -----
----0111 -----
----1000 -----
----1011 -----
----1101 -----
----1111 -----
.e

```

siirde-
funktsioon

espresso sisend

väljund-
funktsioon

```

.i 4
.o 5
0000 10000
0001 01000
1001 01100
0101 00100
0011 00110
0110 00010
1010 01010
1100 00001
1110 00000
0010 -----
0100 -----
0111 -----
1000 -----
1011 -----
1101 -----
1111 -----
.e

```

espresso väljund

siirde-funktsioon

```

.i 8
.o 8
-00-0--1 00100000
-1---001 10000000
1----00- 00000010
-01----1 00001000
--1-1--1 01100000
---1---0 00000100
-----10 10000000
-----00 01010000
-----1-1 00001001
----1--1 00001001
-----1- 00100001
.e

```

väljund-
funktsioon

```

.i 4
.o 5
0-00 10000
-100 00001
-001 01000
-010 01010
0-1- 00010
1--1 00100
-1-1 00100
--11 00100
.e

```



Moore automaat – skeem #2

| siirde- funktsioon | | | väljund- funktsioon | |
|-----------------------|----------|---|--|-------|
| .i 8 | | | .i 4 | |
| .o 8 | | | .o 5 | |
| -00-0--1 | 00100000 | $j1 = x2 \overline{q2} \overline{q3} q4 + q3 \overline{q4}$ | 0-00 | 10000 |
| -1---001 | 10000000 | $k1 = x3 \overline{q1} \overline{q4} + \overline{q3} \overline{q4}$ | -100 | 00001 |
| 1----00- | 00000010 | $j2 = \overline{x2} \overline{x3} \overline{q1} q4 + x3 q1 q4 + q3$ | -001 | 01000 |
| -01----1 | 00001000 | $k2 = \overline{q3} \overline{q4}$ | -010 | 01010 |
| --1-1--1 | 01100000 | $j3 = x2 \overline{x3} q4 + q2 q4 + q1 q4$ | 0-1- | 00010 |
| ---1---0 | 00000100 | $k3 = x4 \overline{q4}$ | 1--1 | 00100 |
| -----10 | 10000000 | $j4 = x1 \overline{q2} \overline{q3}$ | -1-1 | 00100 |
| -----00 | 01010000 | $k4 = q2 q4 + q1 q4 + q3$ | --11 | 00100 |
| -----1-1 | 00001001 | | .e | |
| ----1--1 | 00001001 | | $y1 = \overline{q1} \overline{q3} \overline{q4}$ | |
| -----1- | 00100001 | | $y2 = \overline{q2} \overline{q3} q4 + \overline{q2} q3 \overline{q4}$ | |
| .e | | | $y3 = \overline{q1} q4 + q2 \overline{q4} + q3 q4$ | |
| | | | $y4 = q2 \overline{q3} \overline{q4} + \overline{q1} q3$ | |
| | | | $y5 = q2 \overline{q3} \overline{q4}$ | |

Mealy või Moore?

- **Mealy**
 - vähem olekuid → vähem mälulemente
 - keerulisemad väljundfunktsioonid
 - puhverdamata väljundid → asünkroonse tagasiside oht
- **Moore**
 - rohkem olekuid → rohkem mälulemente
 - lihtsamad väljundfunktsioonid
 - “puhverdatud” väljundid

