

1

příklad 1

úpravy výrazu

$$s = \bar{a}\bar{b}p + \bar{a}b\bar{p} + a\bar{b}\bar{p} + abp = \bar{a}(\bar{b}p + b\bar{p}) + a(\bar{b}\bar{p} + bp) =$$

$$= \bar{a}(b \oplus p) + a(\overline{b \oplus p}) = a \oplus b \oplus p$$

xor

$$q = p(\bar{a}b + a\bar{b}) + ab(\bar{p} + p) = p(a \oplus b) + ab$$

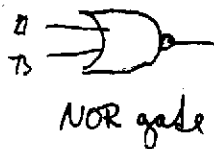
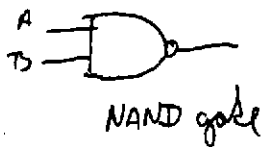
př., že lze dosáhnout  
úpravou těchto výrazů

2

Základní kombinační prvky

wire

inverter



$$\text{out} = \overline{A \cdot B} = \bar{A} + \bar{B}$$

$$\text{out} = \overline{A + B} = \bar{A} \cdot \bar{B}$$

De Morganovy  
zákon



Úplný soubor logických funkcí - lze x něj sestavit všechny fce

- 1) NAND
- 2) NOR
- 3) AND, OR, Negace

Booleovská n-krychle (cube)  $B^n$   
n-počet - počet proměnných

Booleovská funkce

$$f(x) : B^n \rightarrow B$$

ones - množ. stavů, pro které funkce nabývá hodnotu 1  
offs - " " " " " " " " 0

Literál

proměnná nebo její negace  
reprezentuje logickou fci

Krychle

Logický součin

x-j krychle

Cif implikant f - (1 x krychle implikuje 1 funkce

Sum-Of-Products = SOP, v číselné DNF

Příklady  
 $s_i$  stavový index

Příklad

a | 

|  |  |   |   |   |
|--|--|---|---|---|
|  |  |   | 1 |   |
|  |  | 1 | 1 | 1 |

$b$   
 $\bar{p}$  proměnné, aby odpovídaly  
stavovým indexům

hledáme maximální skupiny sousedních stavů  
 $g = bp + ab + ap$

vyjádření fce

↓  
MAPA

↓  
přímé implikandy

- všechny maximální krytky

↓  
nesporné implikandy

↓  
minimální pokrytí

mapa s neurčenyi stavu

A 4x4 grid representing a 2D array with handwritten values and annotations. The grid contains 1s, 0s, and x's. Annotations include 'a' and 'b' at the top right, 'dc' at the bottom left, and various lines and arrows indicating dimensions and specific elements.

|   |   |   |   |
|---|---|---|---|
| 1 | 1 | 0 | 1 |
| 0 | 1 | 0 | 0 |
| x | x | x | x |
| 1 | 1 | x | x |

Annotations: 'a' and 'b' at the top right, 'dc' at the bottom left. Lines and arrows indicate dimensions and specific elements.

answer: 0, 1, 2, 5, 8, 9

don't-care: 10, 11, 12, 13, 14, 15

$$F = \bar{a}\bar{c} + a\bar{b}$$

3

μ.

onsed  
don't care

$$F(d, c, b, a) = \sum_i (0, 2, 3, 5, 9) + \sum_j (4, 10, 12, 15) =$$

A hand-drawn 4x4 grid. The top row contains a circled '1' in the first column, an empty cell in the second column, a circled '1' in the third column, and a circled '2' in the fourth column. The second row contains a circled 'x' in the first column, a circled '1' in the second column, and empty cells in the third and fourth columns. The third row contains an 'x' in the first column, an empty cell in the second column, an 'x' in the third column, and an empty cell in the fourth column. The bottom row contains an empty cell in the first column, a circled '1' in the second column, an empty cell in the third column, and an 'x' in the fourth column. To the right of the grid, the letters 'b' and 'a' are written vertically. Below the grid, the letters 'dc' are written.

$$= \bar{b}\bar{c}\bar{d} + \bar{b}c\bar{d} + a\bar{b}\bar{c}d + \begin{matrix} \bar{a}\bar{c}\bar{d} \\ \bar{a}\bar{b}\bar{d} \end{matrix}$$

# Quine-McCluskey

- vhodné pro počítač, exponenciální složitost, sahá do 15 prom.

$$f(d, c, b, a) = \sum (\underline{1, 4, 5, 6, 9, 10, 12, 13, 14})$$

| d | c | b | a |    |
|---|---|---|---|----|
| 0 | 0 | 0 | 1 | 1  |
| 0 | 1 | 0 | 0 | 4  |
| 0 | 1 | 0 | 1 | 5  |
| 0 | 1 | 1 | 0 | 6  |
| 1 | 0 | 0 | 1 | 9  |
| 1 | 0 | 1 | 0 | 10 |
| 1 | 1 | 0 | 0 | 12 |

špatnej př. :)

$$f(d, c, b, a) = \sum (\underline{1, 4, 7, 8, 9, 10, 11, 12, 14, 15})$$

| d | c | b | a |      |
|---|---|---|---|------|
| 0 | 0 | 0 | 1 | 1 ✓  |
| 0 | 1 | 0 | 0 | 4 ✓  |
| 1 | 0 | 0 | 0 | 8 ✓  |
| 1 | 0 | 0 | 1 | 9 ✓  |
| 1 | 0 | 1 | 0 | 10 ✓ |
| 1 | 1 | 0 | 0 | 12 ✓ |
| 0 | 1 | 1 | 1 | 7 ✓  |
| 1 | 0 | 1 | 1 | 11 ✓ |
| 1 | 1 | 1 | 0 | 14 ✓ |
| 1 | 1 | 1 | 1 | 15 ✓ |

hledání sousedních stavů  
všechny dvojice

|      |             |      |                |
|------|-------------|------|----------------|
| -001 | 1, 9 → abe  | 10-- | 8, 9, 10, 11   |
| -100 | 4, 12 → abc | 10-- | 8, 10, 9, 11   |
| 100- | 8, 9 ✓      | 10-- | 8, 10, 12, 14  |
| 10-0 | 8, 10 ✓     | 1--0 | 8, 12, 10, 14  |
| 1-00 | 8, 12 ✓     | 1--0 | 10, 11, 14, 15 |
| 10-1 | 9, 11 ✓     | 1-1- | 10, 14, 11, 15 |
| 101- | 10, 11 ✓    | 1-1- |                |
| 1-10 | 10, 14 ✓    |      |                |
| 11-0 | 12, 14 ✓    |      |                |
| -111 | 7, 15 → abc |      |                |
| 1-11 | 11, 15 ✓    |      |                |
| 111- | 14, 15 ✓    |      |                |

✓ každý má to dál  
nejde

pak hledáme neornatě

- generování všech mintermů

|                         | 1 | 4 | 7 | 8 | 9 | 10 | 11 | 12 | 14 | 15 |
|-------------------------|---|---|---|---|---|----|----|----|----|----|
| $bd$                    |   |   |   |   |   | •  | •  |    | •  | •  |
| $\bar{a}d$              |   |   |   | • |   | •  |    | •  | •  |    |
| $\bar{c}d$              |   |   |   | • | • | •  | •  |    |    |    |
| $abc$                   |   |   | • |   |   |    |    |    |    | •  |
| $\bar{a}\bar{b}c$       |   | • |   |   |   |    |    | •  |    |    |
| $\bar{a}\bar{b}\bar{c}$ | • |   |   |   |   |    |    |    |    |    |

tabulka pokrytí

10 pokryjeme navíc

↑ ↑ ↑  
rep. impl.

↑  
 $\bar{a}\bar{b}\bar{c}$   
negativní

|            | 8 | 11 | 14 |
|------------|---|----|----|
| $bd$       |   | •  | •  |
| $\bar{a}d$ | • |    | •  |
| $\bar{c}d$ | • | •  |    |

z těchto libovolně 2

$$f = \bar{a}\bar{b}\bar{c} + \bar{a}\bar{b}c + abc + \begin{cases} bd + \bar{a}d \\ bd + \bar{c}d \\ \bar{a}d + \bar{c}d \end{cases}$$

Dominance sloupců - vždy pokryt, můžeme vyškrtnout  
(škrtnat podmnožinu)

Dominance řádků - zde by znamenalo chybu  
(škrtnat podmnožinu)

- stejná  $f$  se má

|     | $\bar{b}$ |   |   |   | $b$ |  |  |  |
|-----|-----------|---|---|---|-----|--|--|--|
| $d$ | $\bar{c}$ |   |   |   | $c$ |  |  |  |
|     |           | 1 |   |   |     |  |  |  |
|     | 1         |   |   | 1 |     |  |  |  |
|     | 1         |   |   | 1 | 1   |  |  |  |
| $c$ | 1         | 1 | 1 | 1 |     |  |  |  |
|     |           |   |   |   |     |  |  |  |

(4)

Mapování na technologii

$$a \cdot b = \overline{\overline{a \cdot b}}$$

$$a + b = \overline{\overline{a + b}}$$

$$\overline{\overline{a + b}} = \overline{\overline{a} \cdot \overline{b}}$$

str. 17

$$\overline{a + \overline{b}c + cd} = \overline{\overline{a} \cdot \overline{\overline{b}c} \cdot \overline{cd}}$$

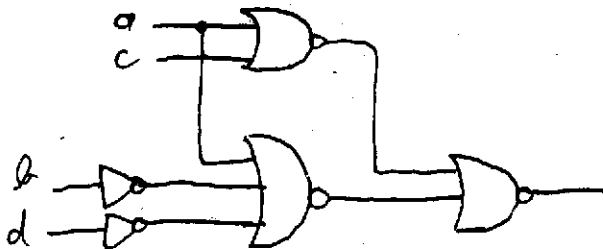
pokud fce v DNF realizovat NAND, tak vše NAND a proměnné vstupující do bradla na liché úrovni od konce musí být negované

str. 18

|   |   |   |   |   |                |
|---|---|---|---|---|----------------|
|   |   |   |   |   | $\overline{b}$ |
|   |   | 1 | 1 |   | $\overline{a}$ |
| 1 | 1 | 1 | 1 | 1 |                |
| 1 | 1 | 1 | 1 |   |                |
|   | 1 | 1 |   |   |                |
| d | c |   |   |   |                |

$$\overline{F} = \overline{a} \overline{c} + \overline{a} b d$$

$$F = \overline{\overline{a} \cdot \overline{c}} \cdot \overline{\overline{a} b d} = (a + c) \cdot (a + \overline{b} + \overline{d})$$



Robbroy mürky

NOR!



$$\frac{a \cdot \bar{b} + a \cdot b \cdot \bar{c}}{+ \quad + \quad + \quad +}$$

|           |           |           |           |           |
|-----------|-----------|-----------|-----------|-----------|
| $\bar{a}$ | $\bar{b}$ | $\bar{a}$ | $\bar{b}$ | $\bar{c}$ |
|-----------|-----------|-----------|-----------|-----------|

2nd.  
NAND



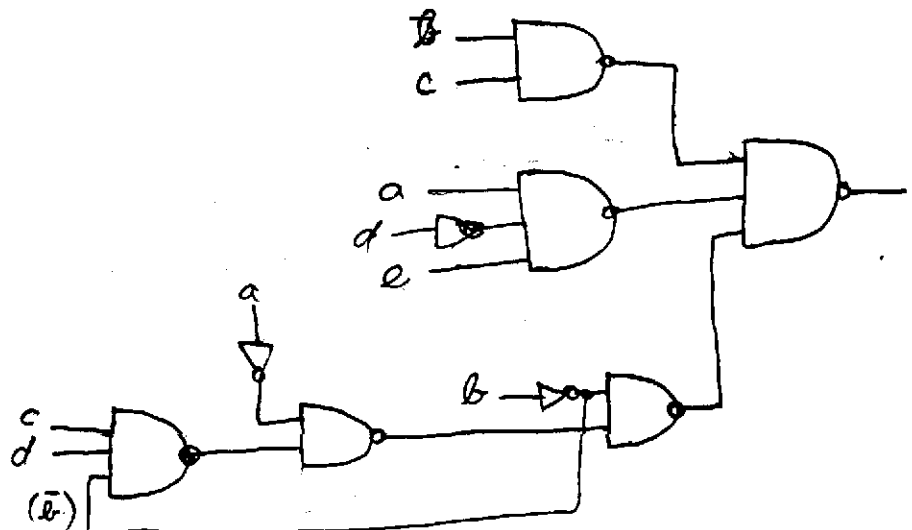
$$\frac{a \cdot \bar{b} + a \cdot b \cdot \bar{c}}{+ \quad + \quad + \quad +}$$

|     |           |     |     |           |
|-----|-----------|-----|-----|-----------|
| $a$ | $\bar{b}$ | $a$ | $b$ | $\bar{c}$ |
|-----|-----------|-----|-----|-----------|

NAND

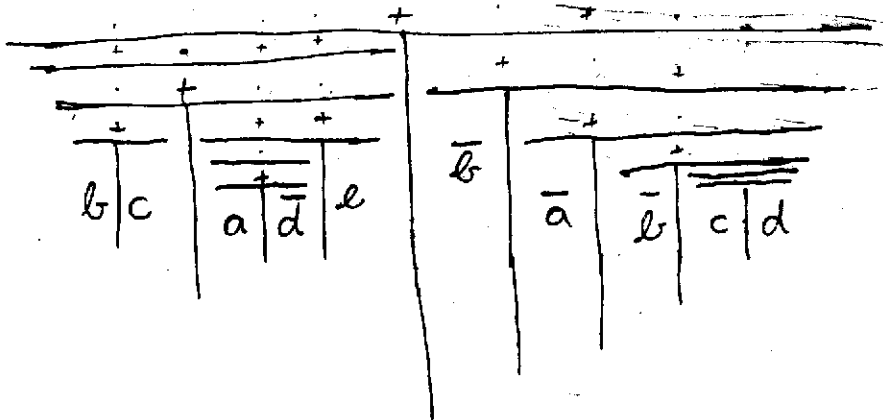
$$bc + a\bar{d}e + \bar{b}(a + \bar{b}cd)$$

|     |     |     |           |     |           |           |           |     |     |
|-----|-----|-----|-----------|-----|-----------|-----------|-----------|-----|-----|
| $b$ | $c$ | $a$ | $\bar{d}$ | $e$ | $\bar{b}$ | $\bar{a}$ | $\bar{b}$ | $c$ | $d$ |
|-----|-----|-----|-----------|-----|-----------|-----------|-----------|-----|-----|



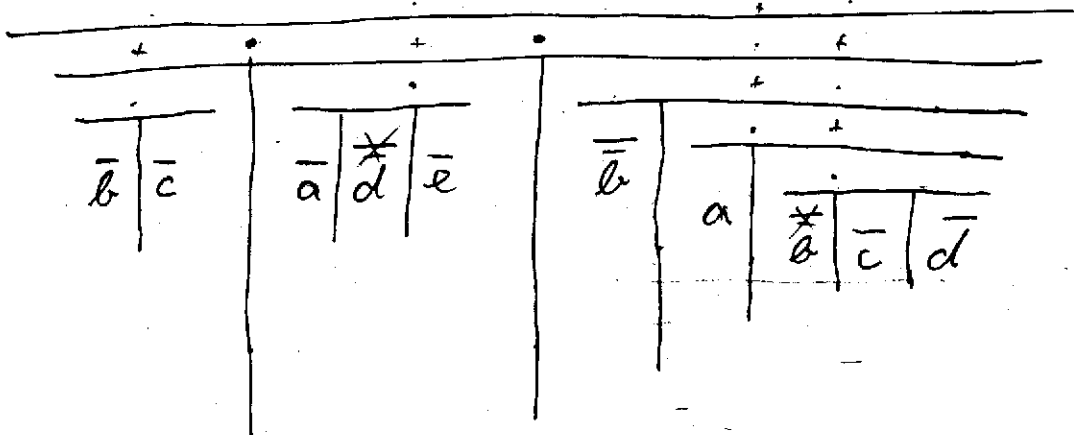
## 2nd step NAND

$$bc + ade + \bar{b}(a + \bar{b}cd)$$



## NOR

$$bc + ade + \bar{b}(a + \bar{b}cd)$$



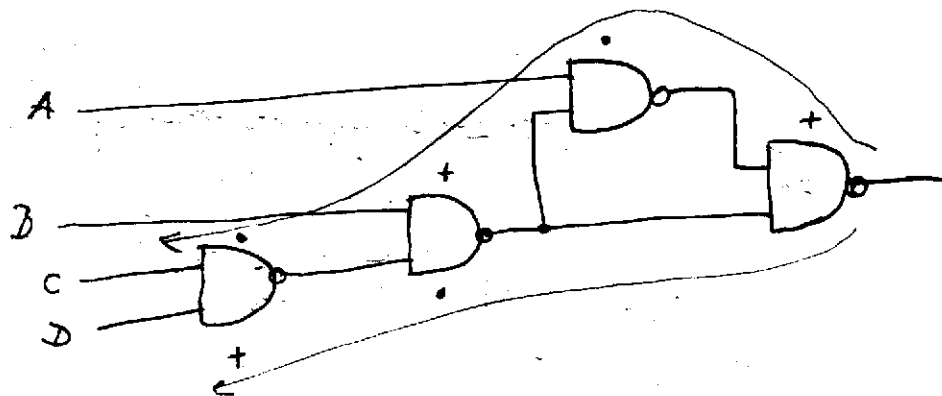
## Analysis

str. 30

$$y_1 = x_1 \cdot x_3 + x_2 \cdot (\bar{x}_3 + \bar{x}_4)$$

$$y_2 = x_2 \cdot (\bar{x}_3 + \bar{x}_4) + x_5 \cdot (\bar{x}_3 + \bar{x}_4)$$

str 31



$$A \cdot (\bar{B} + C \cdot D) + (\bar{C} + \bar{D}) \cdot B$$

dado Foss

5

str 4 Prákovice

1)

|  |  |  |  |  |
|--|--|--|--|--|
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

$F = b + c$

2)

$$F_5^2 = ab + d + a\bar{c}$$

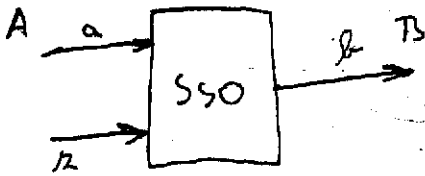
6

str 4

$$FSM = \langle X, Y, Q, \delta, \rangle, (Q_0) \rangle$$

inicialni automat - má def.  $Q_0$

str. 7. pr

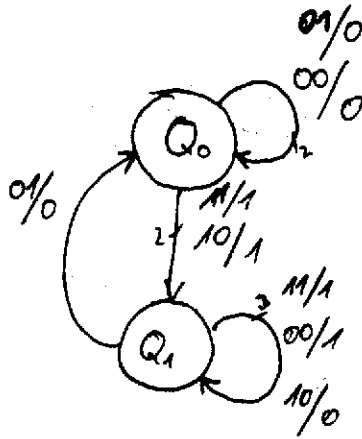


prevod v doplnkovém k. na opačném c.

1001100

← k 1. přechodu opad, další negovat

a/b

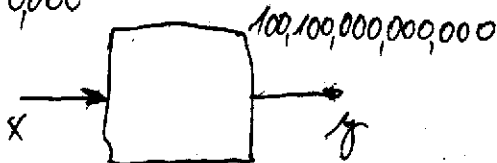


6b

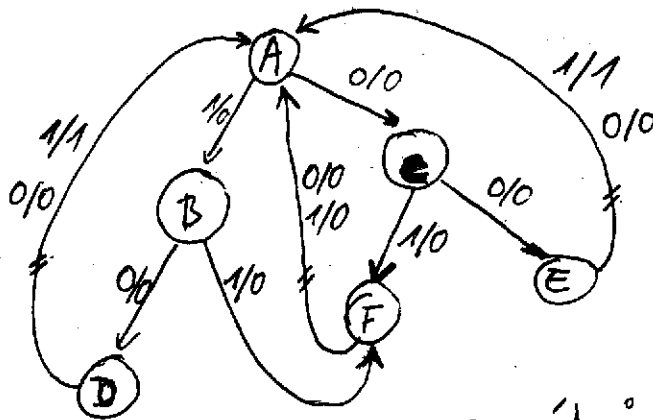
Pr 1 negativ

str. 24. Příklad

5 4 1 2 0  
101,100,001,010,000



Mealy



Tabulka přechodů a výstupů

Zakódování vnitřních stavů

|   | $x$ | $y$ |
|---|-----|-----|
|   | 0 1 | 0 1 |
| A | CB  | 0 0 |
| B | DF  | 0 0 |
| C | EF  | 0 0 |
| D | AA  | 0 1 |
| E | AA  | 0 1 |
| F | AA  | 0 0 |

|   | $x$ | $y$ |
|---|-----|-----|
|   | 0 1 | 0 1 |
| A | B B | 0 0 |
| B | D F | 0 0 |
| D | A A | 0 1 |
| F | A A | 0 0 |

|   | b | a |
|---|---|---|
| A | 0 | 0 |
| B | 0 | 1 |
| D | 1 | 0 |
| F | 1 | 1 |

kvůli jme kódování stavů

$$D = E$$

$$B = C$$

Zakódování tabulky př. a výst.

| $b \ a \ x$ | 0   | 1   | 0 | 1 |
|-------------|-----|-----|---|---|
| 0 0         | 0 1 | 0 1 | 0 | 0 |
| 0 1         | 1 0 | 1 1 | 0 | 0 |
| 1 0         | 0 0 | 0 0 | 0 | 1 |
| 1 1         | 0 0 | 0 0 | 0 | 0 |

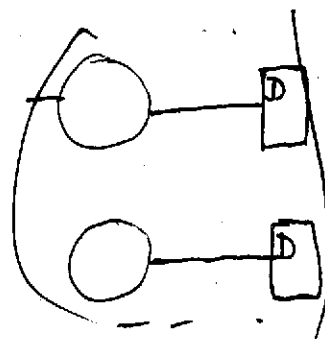
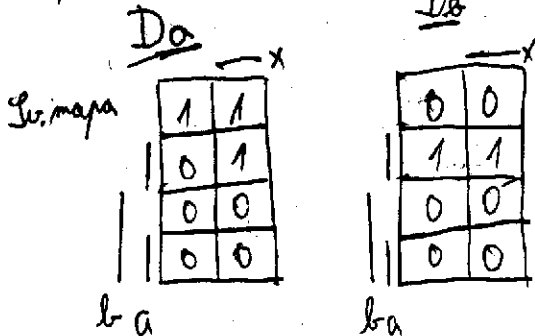
kópné obvody D

$$D_a = \bar{a}\bar{b} + x\bar{b}$$

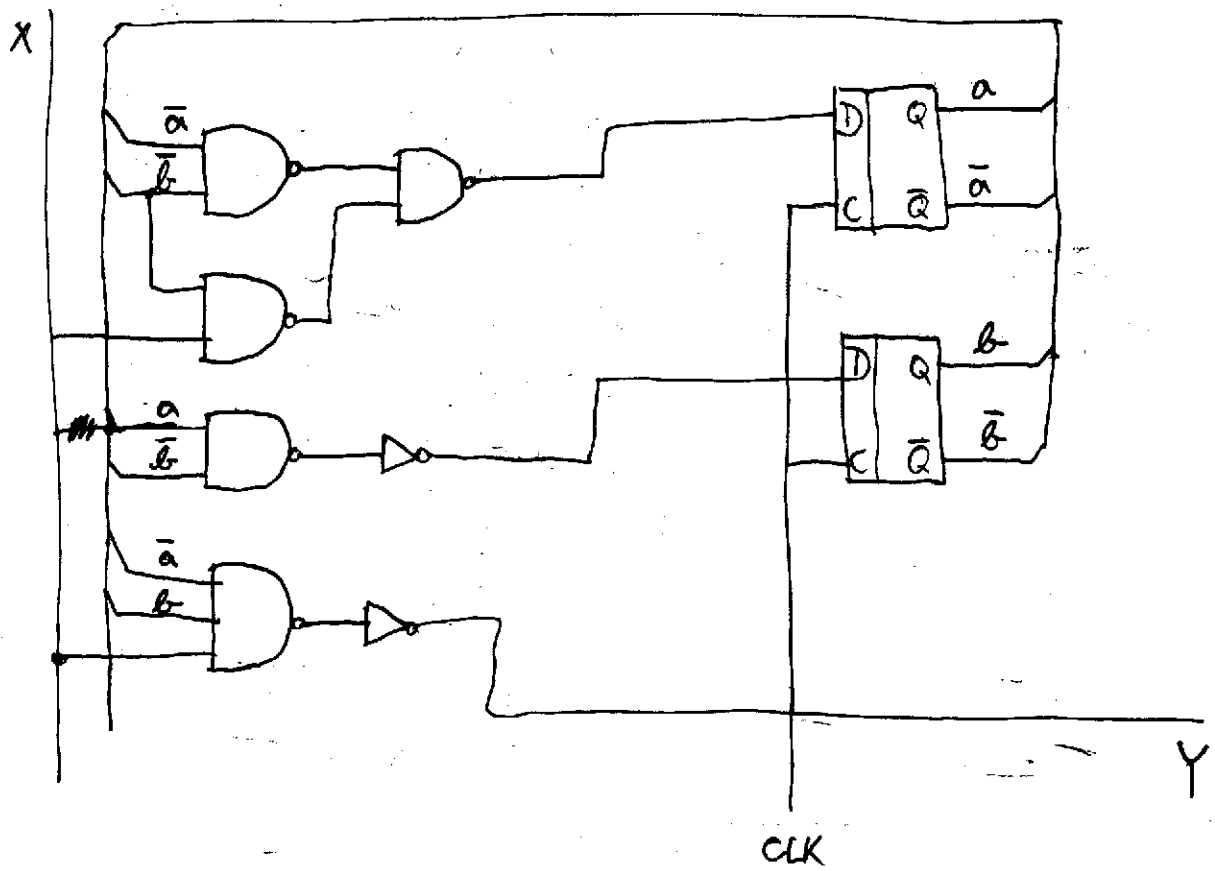
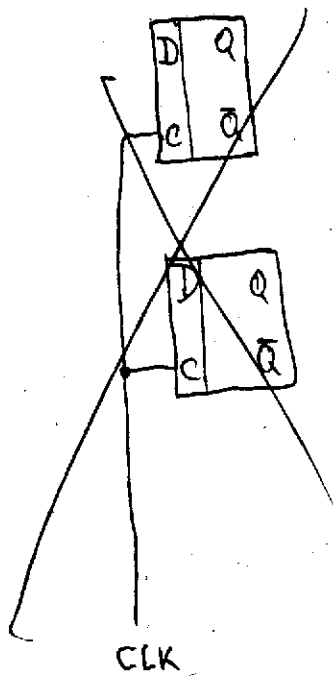
$$D_b = a\bar{b}$$

$$Y = \bar{a}bx$$

kombinační část



uvádění na tabuli



7

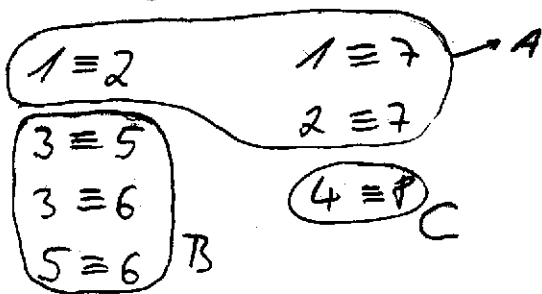
Příklad

a) stejné výklady,  
kapsa, které slavy musí být ekv,  
aby přišel 2 ekv.

b) pocházejí znovu a škrtnutí, počty  
co ~~ne~~ škrtnutí  
existuje, co neplatí

|   |            |            |                                  |                                  |                                  |                                  |   |   |  |
|---|------------|------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|---|---|--|
| 1 |            |            |                                  |                                  |                                  |                                  |   |   |  |
| 2 | 4,8<br>3,5 |            |                                  |                                  |                                  |                                  |   |   |  |
| 3 | X          | X          |                                  |                                  |                                  |                                  |   |   |  |
| 4 | X          | X          | <del>4,4</del><br><del>2,2</del> |                                  |                                  |                                  |   |   |  |
| 5 | X          | X          | 4,8                              | <del>4,8</del><br><del>2,2</del> |                                  |                                  |   |   |  |
| 6 | X          | X          | 1,2                              | <del>4,4</del><br><del>1,1</del> | 1,2<br>4,8                       |                                  |   |   |  |
| 7 | 5,6        | 4,8<br>3,6 | X                                | X                                | X                                | X                                |   |   |  |
| 8 | X          | X          | <del>7,4</del>                   | 1,2                              | <del>2,8</del><br><del>2,4</del> | <del>2,4</del><br><del>1,4</del> | X |   |  |
|   | 1          | 2          | 3                                | 4                                | 5                                | 6                                | 7 | 8 |  |

c) slavy, které můžeme sloučit

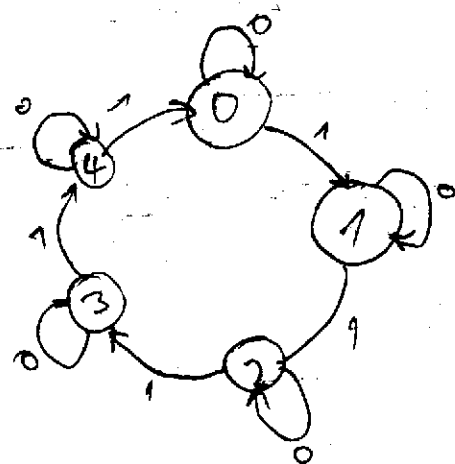


při slučování 3 slavy  
musí vyjít 3 ekvivalence

|   |   |   |   |   |
|---|---|---|---|---|
|   | 0 | 1 | 0 | 1 |
| A | C | B | 0 | 0 |
| B | C | A | 1 | 0 |
| C | A | C | 1 | 0 |

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circ M5



$D_a$ :

|   |   |   |   |
|---|---|---|---|
|   | 0 | 1 | 0 |
| 0 | X | X | X |
| 1 | X | X | X |
| 2 | 0 | 0 | 1 |

EC

|   | E   | 0   | 1   |
|---|-----|-----|-----|
| 0 | 000 | 000 | 001 |
| 1 | 001 | 001 | 010 |
| 2 | 010 | 010 | 011 |
| 3 | 011 | 011 | 100 |
| 4 | 100 | 100 | 000 |

$$D_a = a\bar{E} + \bar{a}\bar{c}E$$

$D_b$

$D_c$

sdn 17.

|   | B<br>A |   |   |  |
|---|--------|---|---|--|
| 0 | X      | 1 | 1 |  |
| 1 | X      | X | X |  |
| 2 | X      | X |   |  |
| 3 | X      | X |   |  |

DC

| D | C | B | A |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 1 |
| 1 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 1 | 0 |

A:

|   | B<br>A |   |   |  |
|---|--------|---|---|--|
| 0 | X      | 1 | 1 |  |
| 1 | 1      | X | X |  |
| 2 | 1      | X | 0 |  |
| 3 | 0      | X | 0 |  |

DC

$$D_A = AC + BD$$

$$J_A = BD$$

$$K_A = \bar{C}D$$

$$T_A = ACD + \bar{A}B\bar{D}$$

B:

|   | B<br>A |   |   |  |
|---|--------|---|---|--|
| 1 | X      | 0 | 1 |  |
| 2 | 0      | X | X |  |
| 3 | 0      | X | 0 |  |
| 4 | 1      | X | 1 |  |

$$D_B = \bar{C}D + \bar{A}D$$

D:

|   | B<br>A |   |   |  |
|---|--------|---|---|--|
| 0 | X      | 0 | 0 |  |
| 1 | 1      | X | X |  |
| 2 | 1      | X | 0 |  |
| 3 | 1      | X | 1 |  |

DC

$$D_D = \bar{A}\bar{B} + \bar{C}D$$

C:

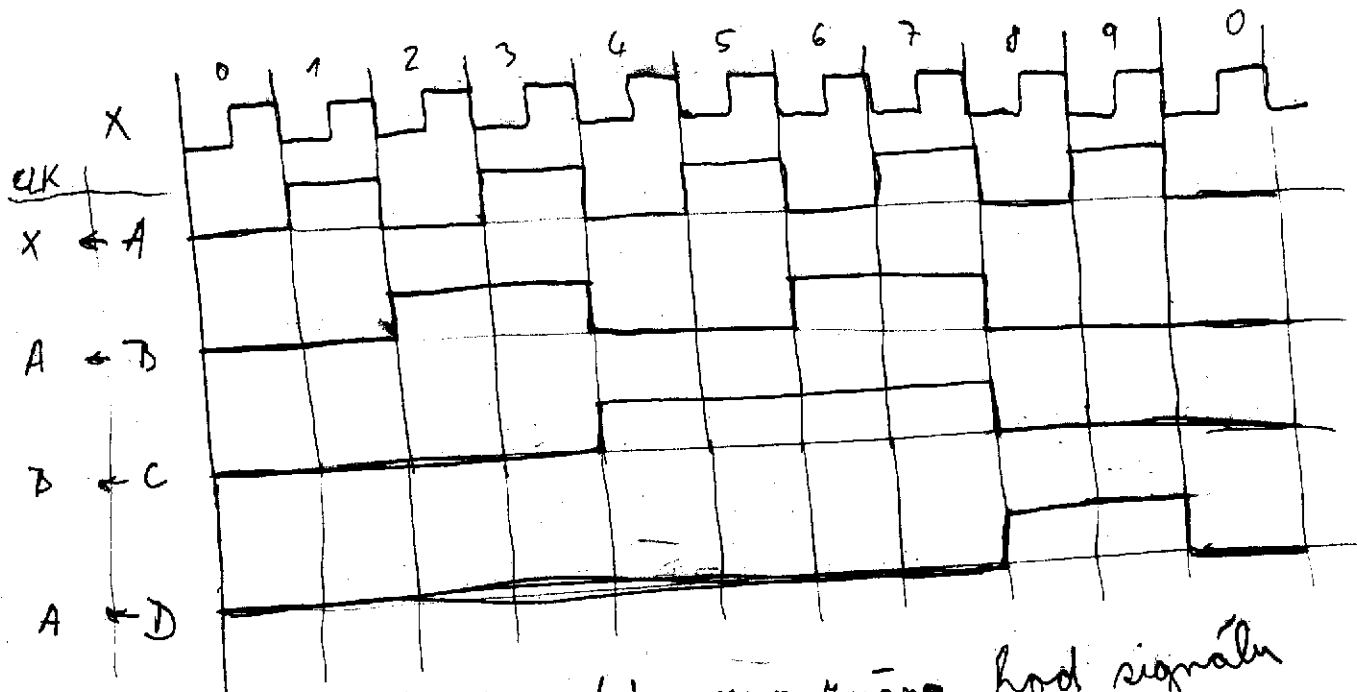
|   | B<br>A |   |   |  |
|---|--------|---|---|--|
| 0 | X      | 1 | 0 |  |
| 1 | 1      | X | X |  |
| 2 | 0      | X | 0 |  |
| 3 | 0      | X | 1 |  |

DC

$$D_C = A\bar{D} + \bar{B}\bar{C}D + \bar{A}\bar{C}D$$

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asynchronní álsí M10



výpočet chýbných, kde ~~ne~~ změna hod signálu

A:

|    |                  |   |   |   |
|----|------------------|---|---|---|
|    | $\overline{D_A}$ |   |   |   |
|    | 1                | 0 | 0 | 1 |
|    | 1                | 0 | 0 | 1 |
|    | x                | x | x | x |
| DC | 1                | 0 | x | x |

$$J_A = K_A = T_A = 1$$

B:

|    |                  |   |   |   |
|----|------------------|---|---|---|
|    | $\overline{D_A}$ |   |   |   |
|    | x                | 1 | 0 | x |
|    | x                | 1 | 0 | x |
|    | x                | x | x | x |
| DC | x                | 0 | x | x |

$$J_B = \overline{D} = T_B$$

$$K_B = 1$$

C:

|    |                  |   |   |   |
|----|------------------|---|---|---|
|    | $\overline{D_A}$ |   |   |   |
|    | x                | x | 1 | x |
|    | x                | x | 0 | x |
|    | x                | x | x | x |
| DC | x                | x | x | x |

$$J_C = K_C = T_C = 1$$

D:

|    |                  |   |   |   |
|----|------------------|---|---|---|
|    | $\overline{D_A}$ |   |   |   |
|    | x                | 0 | 0 | x |
|    | x                | 0 | 1 | x |
|    | x                | x | x | x |
| DC | x                | 0 | x | x |

$$J_D = BC$$

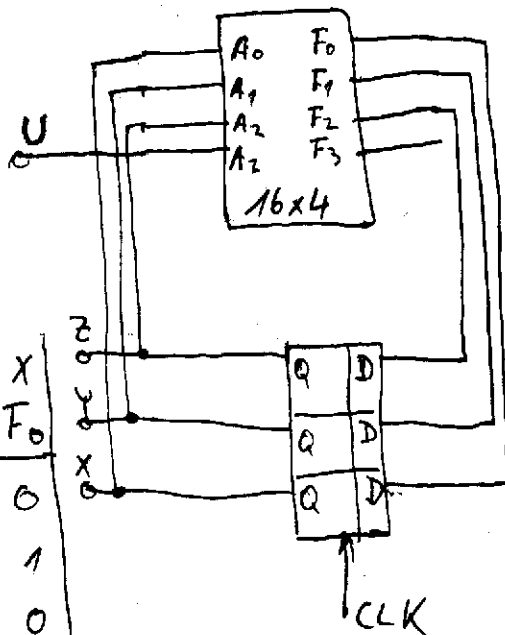
$$K_D = 1$$

$$T_D = BC + D$$

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čítač MS v bin. kódu pomocí paměti

| $A_3 A_2 A_1 A_0$ | 0   | 1   |
|-------------------|-----|-----|
| 000               | 000 | 001 |
| 001               | 001 | 010 |
| 010               | 010 | 011 |
| 011               | 011 | 100 |
| 100               | 100 | 000 |



| $U$ | $A_3$ | $A_2$ | $A_1$ | $A_0$ | $Z$<br>$F_3$ | $Y$<br>$F_2$ | $X$<br>$F_1$ | $F_0$ |
|-----|-------|-------|-------|-------|--------------|--------------|--------------|-------|
| 0   | 0     | 0     | 0     | 0     |              | 0            | 0            | 0     |
| 0   | 0     | 0     | 0     | 1     |              | 0            | 0            | 1     |
| 0   | 0     | 0     | 1     | 0     |              | 0            | 1            | 0     |
| 0   | 0     | 0     | 1     | 1     |              | 0            | 1            | 1     |
| 0   | 0     | 1     | 0     | 0     |              | 1            | 0            | 0     |
|     |       |       |       |       |              |              |              |       |
| 1   | 0     | 0     | 0     | 0     |              | 0            | 0            | 1     |
| 1   | 0     | 0     | 0     | 1     |              | 0            | 1            | 0     |
| 1   | 0     | 0     | 1     | 0     |              | 0            | 1            | 1     |
| 1   | 0     | 0     | 1     | 1     |              | 1            | 0            | 0     |
| 1   | 0     | 1     | 0     | 0     |              | 0            | 0            | 0     |
|     |       |       |       |       |              |              |              |       |