



Министерство науки и высшего образования Российской Федерации
Федеральное государственное бюджетное образовательное учреждение
высшего образования
«Московский государственный технический университет
имени Н. Э. Баумана
(национальный исследовательский университет)»
(МГТУ им. Н. Э. Баумана)

ФАКУЛЬТЕТ «Радиоэлектроника и лазерная техника (РЛ)»

КАФЕДРА «Технология приборостроения (РЛ6)»

ОТЧЕТ

по домашней работе №1

по курсу «Цифровые устройства и микропроцессоры»

на тему: «ПЛИС Altera ССИ, минимизация алгебраических функций»

Вариант № 20Л274

Студент РЛ6-61
(Группа)

(Подпись, дата)

Филимонов С. В.
(И. О. Фамилия)

Преподаватель

(Подпись, дата)

Семеренко Д. А.
(И. О. Фамилия)

2023 г.

Оглавление

1	Реализация шифратора для вывода знака на ССИ.	3
1.1	Алгебраические уравнения в СКНФ и СДНФ	3
1.2	Минимизация с помощью различных алгоритмов	4
1.2.1	Законы алгебры логики	4
1.2.2	Карты Карно	6
1.2.3	Метод Квайна	8
1.3	Перевод полученных выражений к базису 2И-НЕ/2ИЛИ-НЕ . .	11
1.3.1	2И-НЕ	12
1.3.2	2ИЛИ-НЕ	13
1.4	Цифровая схема	14
2	Счётчик с коэффициентом счёта 6.	20
2.1	Декодер номера билета.	20
2.2	Счётчик для 6 знаков.	22
2.3	Общая схема.	22
3	Преобразователь кода, на выходе которого формируется последовательность бинарных чисел соответствующая цифрам студенческого билета.	24

1 Реализация шифратора для вывода знака на ССИ.

На рисунке 1.1 пример семисегментного индикатора.

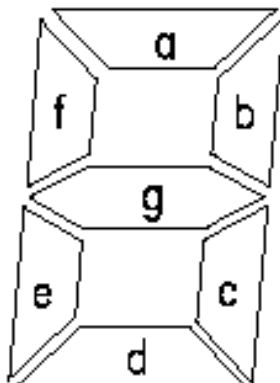


Рисунок 1.1 – Семисегментный индикатор

Кодировка

Символ	x_0	x_1	x_2	x_3	a	b	c	d	e	f	g
0	0	0	0	0	1	1	1	1	1	1	0
1	0	0	0	1	0	1	1	0	0	0	0
2	0	0	1	0	1	1	0	1	1	0	1
3	0	0	1	1	1	1	1	1	0	0	1
4	0	1	0	0	0	1	1	0	0	1	1
5	0	1	0	1	1	0	1	1	0	1	1
6	0	1	1	0	1	0	1	1	1	1	1
7	0	1	1	1	1	1	1	0	0	0	0
8	1	0	0	0	1	1	1	1	1	1	1
9	1	0	0	1	1	1	1	1	0	1	1
Л	1	0	1	0	1	1	1	0	1	1	0

1.1 Алгебраические уравнения в СКНФ и СДНФ

Определим СКНФ и СДНФ:

$$y_a^{\text{СКНФ}} = (x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee x_2 \vee x_3)$$

$$y_a^{\text{СДНФ}} = \bar{x}_0\bar{x}_1\bar{x}_2\bar{x}_3 \vee \bar{x}_0\bar{x}_1x_2\bar{x}_3 \vee \bar{x}_0\bar{x}_1x_2x_3 \vee \bar{x}_0x_1\bar{x}_2x_3 \vee \bar{x}_0x_1x_2\bar{x}_3 \vee \bar{x}_0x_1x_2x_3 \vee x_0\bar{x}_1\bar{x}_2\bar{x}_3 \vee x_0\bar{x}_1\bar{x}_2x_3 \vee x_0\bar{x}_1x_2\bar{x}_3$$

$$y_b^{\text{СКНФ}} = (x_0 \vee \bar{x}_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee x_3)$$

$$y_b^{\text{СДНФ}} = \bar{x}_0\bar{x}_1\bar{x}_2\bar{x}_3 \vee \bar{x}_0\bar{x}_1\bar{x}_2x_3 \vee \bar{x}_0\bar{x}_1x_2\bar{x}_3 \vee \bar{x}_0\bar{x}_1x_2x_3 \vee \bar{x}_0x_1\bar{x}_2\bar{x}_3 \vee \bar{x}_0x_1x_2x_3 \vee x_0\bar{x}_1\bar{x}_2\bar{x}_3 \vee x_0\bar{x}_1\bar{x}_2x_3 \vee x_0\bar{x}_1x_2\bar{x}_3$$

$$y_c^{\text{СКНФ}} = (x_0 \vee x_1 \vee \bar{x}_2 \vee x_3)$$

$$y_c^{\text{СДНФ}} = \bar{x}_0\bar{x}_1\bar{x}_2\bar{x}_3 \vee \bar{x}_0\bar{x}_1\bar{x}_2x_3 \vee \bar{x}_0\bar{x}_1x_2\bar{x}_3 \vee \bar{x}_0\bar{x}_1x_2x_3 \vee \bar{x}_0x_1\bar{x}_2\bar{x}_3 \vee \bar{x}_0x_1\bar{x}_2x_3 \vee \bar{x}_0x_1x_2\bar{x}_3 \vee \bar{x}_0x_1x_2x_3 \vee x_0\bar{x}_1\bar{x}_2\bar{x}_3 \vee x_0\bar{x}_1\bar{x}_2x_3 \vee x_0\bar{x}_1x_2\bar{x}_3 \vee x_0\bar{x}_1x_2x_3$$

$$y_d^{\text{СКНФ}} = (x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee x_2 \vee x_3) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (\bar{x}_0 \vee x_1 \vee \bar{x}_2 \vee x_3)$$

$$y_d^{\text{СДНФ}} = \bar{x}_0\bar{x}_1\bar{x}_2\bar{x}_3 \vee \bar{x}_0\bar{x}_1\bar{x}_2x_3 \vee \bar{x}_0\bar{x}_1x_2\bar{x}_3 \vee \bar{x}_0\bar{x}_1x_2x_3 \vee \bar{x}_0x_1\bar{x}_2\bar{x}_3 \vee \bar{x}_0x_1\bar{x}_2x_3 \vee \bar{x}_0x_1x_2\bar{x}_3 \vee \bar{x}_0x_1x_2x_3 \vee x_0\bar{x}_1\bar{x}_2\bar{x}_3 \vee x_0\bar{x}_1\bar{x}_2x_3 \vee x_0\bar{x}_1x_2\bar{x}_3 \vee x_0\bar{x}_1x_2x_3$$

$$y_e^{\text{СКНФ}} = (x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee x_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee x_2 \vee x_3) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (\bar{x}_0 \vee x_1 \vee x_2 \vee \bar{x}_3)$$

$$y_e^{\text{СДНФ}} = \bar{x}_0\bar{x}_1\bar{x}_2\bar{x}_3 \vee \bar{x}_0\bar{x}_1\bar{x}_2x_3 \vee \bar{x}_0\bar{x}_1x_2\bar{x}_3 \vee \bar{x}_0\bar{x}_1x_2x_3 \vee \bar{x}_0x_1\bar{x}_2\bar{x}_3 \vee \bar{x}_0x_1\bar{x}_2x_3 \vee \bar{x}_0x_1x_2\bar{x}_3 \vee \bar{x}_0x_1x_2x_3 \vee x_0\bar{x}_1\bar{x}_2\bar{x}_3 \vee x_0\bar{x}_1\bar{x}_2x_3 \vee x_0\bar{x}_1x_2\bar{x}_3 \vee x_0\bar{x}_1x_2x_3$$

$$y_f^{\text{СКНФ}} = (x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee x_1 \vee \bar{x}_2 \vee x_3) \cdot (x_0 \vee x_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3)$$

$$y_f^{\text{СДНФ}} = \bar{x}_0\bar{x}_1\bar{x}_2\bar{x}_3 \vee \bar{x}_0\bar{x}_1\bar{x}_2x_3 \vee \bar{x}_0\bar{x}_1x_2\bar{x}_3 \vee \bar{x}_0\bar{x}_1x_2x_3 \vee \bar{x}_0x_1\bar{x}_2\bar{x}_3 \vee \bar{x}_0x_1\bar{x}_2x_3 \vee \bar{x}_0x_1x_2\bar{x}_3 \vee \bar{x}_0x_1x_2x_3 \vee x_0\bar{x}_1\bar{x}_2\bar{x}_3 \vee x_0\bar{x}_1\bar{x}_2x_3 \vee x_0\bar{x}_1x_2\bar{x}_3 \vee x_0\bar{x}_1x_2x_3$$

$$y_g^{\text{СКНФ}} = (x_0 \vee x_1 \vee x_2 \vee x_3) \cdot (x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (\bar{x}_0 \vee x_1 \vee \bar{x}_2 \vee x_3)$$

$$y_g^{\text{СДНФ}} = \bar{x}_0\bar{x}_1x_2\bar{x}_3 \vee \bar{x}_0\bar{x}_1x_2x_3 \vee \bar{x}_0x_1\bar{x}_2\bar{x}_3 \vee \bar{x}_0x_1\bar{x}_2x_3 \vee \bar{x}_0x_1x_2\bar{x}_3 \vee \bar{x}_0x_1x_2x_3 \vee x_0\bar{x}_1\bar{x}_2\bar{x}_3 \vee x_0\bar{x}_1\bar{x}_2x_3 \vee x_0\bar{x}_1x_2\bar{x}_3 \vee x_0\bar{x}_1x_2x_3 \vee x_0x_1\bar{x}_2\bar{x}_3 \vee x_0x_1\bar{x}_2x_3 \vee x_0x_1x_2\bar{x}_3 \vee x_0x_1x_2x_3$$

1.2 Минимизация с помощью различных алгоритмов

1.2.1 Законы алгебры логики

Для начала сократим выражение с помощью законов алгебры логики:

$$\begin{aligned} y_a^{\text{СКНФ}} &= (x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee x_2 \vee x_3) = \\ &= ((x_0 \vee x_2) \vee (x_1 \vee \bar{x}_3)) \cdot ((x_0 \vee x_2) \vee (\bar{x}_1 \vee x_3)) = \\ &= (x_0 \vee x_2) \vee ((x_1 \vee \bar{x}_3) \cdot (\bar{x}_1 \vee x_3)) \end{aligned}$$

$$\begin{aligned} y_a^{\text{СДНФ}} &= \bar{x}_0\bar{x}_1\bar{x}_2\bar{x}_3 \vee \bar{x}_0\bar{x}_1\bar{x}_2x_3 \vee \bar{x}_0\bar{x}_1x_2\bar{x}_3 \vee \bar{x}_0\bar{x}_1x_2x_3 \vee \bar{x}_0x_1\bar{x}_2\bar{x}_3 \vee \bar{x}_0x_1\bar{x}_2x_3 \vee \bar{x}_0x_1x_2\bar{x}_3 \vee \bar{x}_0x_1x_2x_3 \vee \\ &\quad \underline{\underline{x_0\bar{x}_1\bar{x}_2\bar{x}_3}} \vee \underline{\underline{x_0\bar{x}_1\bar{x}_2x_3}} \vee \underline{\underline{x_0\bar{x}_1x_2\bar{x}_3}} = \\ &= \bar{x}_0\bar{x}_1\bar{x}_2\bar{x}_3 \vee \bar{x}_0\bar{x}_1\bar{x}_2x_3 \vee \bar{x}_0\bar{x}_1x_2\bar{x}_3 \vee \bar{x}_0\bar{x}_1x_2x_3 \vee x_0\bar{x}_1\bar{x}_2 \vee x_0\bar{x}_1x_2 \end{aligned}$$

Используем закон дистрибутивности

$$\boxed{x \vee (y \cdot z) = (x \vee y) \cdot (x \vee z)}$$

$$\begin{aligned} y_b^{\text{СКНФ}} &= (x_0 \vee \bar{x}_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee x_3) = \\ &\quad \bar{x}_1 \vee x_0 \vee (x_2 \vee \bar{x}_3 \cdot (\bar{x}_2 \vee x_3)) \\ y_b^{\text{СДНФ}} &= \underline{\bar{x}_0 \bar{x}_1 \bar{x}_2 \bar{x}_3} \vee \underline{\bar{x}_0 \bar{x}_1 \bar{x}_2 x_3} \vee \underline{\bar{x}_0 \bar{x}_1 x_2 \bar{x}_3} \vee \underline{\bar{x}_0 \bar{x}_1 x_2 x_3} \vee \bar{x}_0 x_1 \bar{x}_2 \bar{x}_3 \vee \bar{x}_0 x_1 x_2 x_3 \vee \\ &\quad \underline{\underline{x_0 \bar{x}_1 \bar{x}_2 \bar{x}_3}} \vee \underline{\underline{x_0 \bar{x}_1 \bar{x}_2 x_3}} \vee \underline{\underline{x_0 \bar{x}_1 x_2 \bar{x}_3}} = \\ &\quad \underline{\bar{x}_0 \bar{x}_1 \bar{x}_2} \vee \underline{\bar{x}_0 \bar{x}_1 x_2} \vee \bar{x}_0 x_1 \bar{x}_2 \bar{x}_3 \vee \bar{x}_0 x_1 x_2 x_3 \vee x_0 \bar{x}_1 \bar{x}_2 x_3 \vee x_0 \bar{x}_1 \bar{x}_3 = \\ &\quad \bar{x}_0 \bar{x}_1 \vee \bar{x}_0 x_1 \bar{x}_2 \bar{x}_3 \vee \bar{x}_0 x_1 x_2 x_3 \vee x_0 \bar{x}_1 \bar{x}_2 x_3 \vee x_0 \bar{x}_1 \bar{x}_3 \end{aligned}$$

Для $y_c^{\text{СКНФ}}$ сокращать нечего $y_c^{\text{СКНФ}} = (x_0 \vee x_1 \vee \bar{x}_2 \vee x_3)$.

$$\begin{aligned} y_c^{\text{СДНФ}} &= \underline{\bar{x}_0 \bar{x}_1 \bar{x}_2 \bar{x}_3} \vee \underline{\bar{x}_0 \bar{x}_1 \bar{x}_2 x_3} \vee \bar{x}_0 \bar{x}_1 x_2 x_3 \vee \underline{\bar{x}_0 x_1 \bar{x}_2 \bar{x}_3} \vee \underline{\bar{x}_0 x_1 \bar{x}_2 x_3} \vee \underline{\bar{x}_0 x_1 x_2 \bar{x}_3} \vee \\ &\quad \underline{\bar{x}_0 x_1 x_2 x_3} \vee \underline{\underline{x_0 \bar{x}_1 \bar{x}_2 \bar{x}_3}} \vee \underline{\underline{x_0 \bar{x}_1 \bar{x}_2 x_3}} \vee \underline{\underline{x_0 \bar{x}_1 x_2 \bar{x}_3}} = \\ &\quad \underline{\bar{x}_0 \bar{x}_1 \bar{x}_2} \vee \bar{x}_0 \bar{x}_1 x_2 x_3 \vee \underline{\bar{x}_0 x_1 \bar{x}_2} \vee \underline{\bar{x}_0 x_1 x_2} \vee \underline{x_0 \bar{x}_1 \bar{x}_2} \vee x_0 \bar{x}_1 x_2 \bar{x}_3 = \\ &\quad \bar{x}_1 \bar{x}_2 \vee \bar{x}_0 \bar{x}_1 x_2 x_3 \vee \bar{x}_0 x_1 \vee x_0 \bar{x}_1 x_2 \bar{x}_3 \end{aligned}$$

$$\begin{aligned} y_d^{\text{СКНФ}} &= (x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee x_2 \vee x_3) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (\bar{x}_0 \vee x_1 \vee \bar{x}_2 \vee x_3) = \\ &\quad (x_0 \vee (x_1 \vee x_2 \vee \bar{x}_3) \cdot (\bar{x}_1 \vee x_2 \vee x_3) \cdot (\bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3)) \cdot (\bar{x}_0 \vee x_1 \vee \bar{x}_2 \vee x_3) \\ y_d^{\text{СДНФ}} &= \underline{\bar{x}_0 \bar{x}_1 \bar{x}_2 \bar{x}_3} \vee \underline{\bar{x}_0 \bar{x}_1 x_2 \bar{x}_3} \vee \bar{x}_0 \bar{x}_1 x_2 x_3 \vee \bar{x}_0 x_1 \bar{x}_2 x_3 \vee \bar{x}_0 x_1 x_2 \bar{x}_3 \vee \\ &\quad \underline{\underline{x_0 \bar{x}_1 \bar{x}_2 \bar{x}_3}} \vee \underline{\underline{x_0 \bar{x}_1 \bar{x}_2 x_3}} = \\ &\quad \bar{x}_0 \bar{x}_1 \bar{x}_3 \vee \bar{x}_0 \bar{x}_1 x_2 x_3 \vee \bar{x}_0 x_1 \bar{x}_2 x_3 \vee \bar{x}_0 x_1 x_2 \bar{x}_3 \vee x_0 \bar{x}_1 \bar{x}_2 \end{aligned}$$

$$\begin{aligned} y_e^{\text{СКНФ}} &= \underline{(x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee x_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee x_2 \vee x_3)} \cdot \\ &\quad \underline{(x_0 \vee \bar{x}_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (\bar{x}_0 \vee x_1 \vee x_2 \vee \bar{x}_3)} = \\ &\quad (x_0 \vee x_1 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee x_2) \cdot ((x_0 \vee \bar{x}_1 \vee \bar{x}_2) \cdot (\bar{x}_0 \vee x_1 \vee x_2)) \vee \bar{x}_3 \\ y_e^{\text{СДНФ}} &= \underline{\bar{x}_0 \bar{x}_1 \bar{x}_2 \bar{x}_3} \vee \underline{\bar{x}_0 \bar{x}_1 x_2 \bar{x}_3} \vee \bar{x}_0 x_1 x_2 \bar{x}_3 \vee \underline{\underline{x_0 \bar{x}_1 \bar{x}_2 \bar{x}_3}} \vee \underline{\underline{x_0 \bar{x}_1 x_2 \bar{x}_3}} = \\ &\quad \underline{\bar{x}_0 \bar{x}_1 \bar{x}_3} \vee \bar{x}_0 x_1 x_2 \bar{x}_3 \vee \underline{x_0 \bar{x}_1 \bar{x}_3} = \\ &\quad \bar{x}_1 \bar{x}_3 \vee \bar{x}_0 x_1 x_2 \bar{x}_3 \end{aligned}$$

$$\begin{aligned} y_f^{\text{СКНФ}} &= (x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee x_1 \vee \bar{x}_2 \vee x_3) \cdot (x_0 \vee x_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3) = \\ &\quad (x_0 \vee x_1 \vee (x_2 \vee \bar{x}_3) \cdot (\bar{x}_2 \vee x_3)) \cdot (x_0 \vee \bar{x}_2 \bar{x}_3) \\ y_f^{\text{СДНФ}} &= \underline{\bar{x}_0 \bar{x}_1 \bar{x}_2 \bar{x}_3} \vee \underline{\bar{x}_0 \bar{x}_1 \bar{x}_2 x_3} \vee \bar{x}_0 x_1 \bar{x}_2 x_3 \vee \bar{x}_0 x_1 x_2 \bar{x}_3 \vee \underline{\underline{x_0 \bar{x}_1 \bar{x}_2 \bar{x}_3}} \vee \\ &\quad \underline{\underline{x_0 \bar{x}_1 \bar{x}_2 x_3}} \vee x_0 \bar{x}_1 x_2 \bar{x}_3 = \\ &\quad \bar{x}_0 \bar{x}_2 \bar{x}_3 \vee \bar{x}_0 \bar{x}_1 \bar{x}_2 x_3 \vee \bar{x}_0 x_1 x_2 \bar{x}_3 \vee x_0 \bar{x}_1 \bar{x}_2 \vee x_0 \bar{x}_1 x_2 \bar{x}_3 \end{aligned}$$

$$\begin{aligned}
y_g^{\text{СКНФ}} &= (x_0 \vee x_1 \vee x_2 \vee x_3) \cdot (x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (\bar{x}_0 \vee x_1 \vee \bar{x}_2 \vee x_3) = \\
&= (x_0 \vee x_1 \vee x_2) \cdot ((x_0 \vee \bar{x}_1 \vee \bar{x}_3) \cdot (\bar{x}_0 \vee x_1 \vee x_3) \vee \bar{x}_2) \\
y_g^{\text{СДНФ}} &= \underline{\bar{x}_0 \bar{x}_1 x_2 \bar{x}_3} \vee \underline{\bar{x}_0 \bar{x}_1 x_2 x_3} \vee \underline{\bar{x}_0 x_1 \bar{x}_2 \bar{x}_3} \vee \underline{\bar{x}_0 x_1 \bar{x}_2 x_3} \vee \underline{\bar{x}_0 x_1 x_2 \bar{x}_3} \vee \underline{\underline{x_0 \bar{x}_1 \bar{x}_2 x_3}} \vee \\
&= \underline{\underline{x_0 \bar{x}_1 \bar{x}_2 x_3}} = \\
&= \bar{x}_0 \bar{x}_1 x_2 \vee \bar{x}_0 x_1 \bar{x}_2 \vee \bar{x}_0 x_1 x_2 \bar{x}_3 \vee x_0 \bar{x}_1 \bar{x}_2
\end{aligned}$$

1.2.2 Карты Карно

$a^{\text{СДНФ}}$

		x_0, x_1			
		00	01	11	10
x_2, x_3	00	0	0	1	1
	01	0	1	1	1
	11	0	1	1	0
	10	0	1	0	1

$a^{\text{СКНФ}}$

		x_0, x_1			
		00	01	11	10
x_2, x_3	00	1	0	1	1
	01	1	1	1	1
	11	1	1	1	1
	10	0	1	1	1

$$y_a^{\text{СДНФ}} = x_2 \bar{x}_0 \vee \bar{x}_1 \bar{x}_3 \vee x_0 \bar{x}_1 \bar{x}_2 \vee \bar{x}_0 x_1 x_3$$

$$y_a^{\text{СКНФ}} = (x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee x_2 \vee x_3)$$

$b^{\text{СДНФ}}$

		x_0, x_1			
		00	01	11	10
x_2, x_3	00	0	0	1	1
	01	0	1	1	0
	11	0	1	1	1
	10	0	1	1	0

$b^{\text{СКНФ}}$

		x_0, x_1			
		00	01	11	10
x_2, x_3	00	1	1	1	1
	01	1	0	1	1
	11	1	1	1	1
	10	1	0	1	1

$$y_b^{\text{СДНФ}} = \bar{x}_1 x_2 \bar{x}_3 \vee \bar{x}_0 x_2 x_3 \vee \bar{x}_0 \bar{x}_1 x_3 \vee \bar{x}_0 \bar{x}_2 \bar{x}_3 \vee x_0 \bar{x}_1 \bar{x}_3$$

$$y_b^{\text{СКНФ}} = (x_0 \vee \bar{x}_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee x_3)$$

$c^{\text{СДНФ}}$

		x_0, x_1			
		00	01	11	10
x_2, x_3	00	0	0	1	1
	01	0	1	0	1
	11	0	1	1	1
	10	0	1	1	1

$c^{\text{СКНФ}}$

		x_0, x_1			
		00	01	11	10
x_2, x_3	00	1	1	1	1
	01	0	1	1	1
	11	1	1	1	1
	10	1	1	1	1

$$y_c^{\text{СДНФ}} = \bar{x}_0 \bar{x}_2 \vee x_0 \bar{x}_1 \bar{x}_2 \vee x_0 \bar{x}_1 \bar{x}_3 \vee \bar{x}_0 x_2 x_3 \vee \bar{x}_0 x_1 x_2$$

$$y_c^{\text{СКНФ}} = (x_0 \vee x_1 \vee \bar{x}_2 \vee x_3)$$

$d^{\text{CDH}\Phi}$

		x_0, x_1			
		00	01	11	10
x_2, x_3	00	0	0	1	0
	01	0	0	1	1
	11	0	1	1	0
	10	0	1	0	1

 $d^{\text{CKH}\Phi}$

		x_0, x_1			
		00	01	11	10
x_2, x_3	00	1	0	1	1
	01	1	1	1	0
	11	1	0	1	1
	10	0	1	1	1

$$y_d^{\text{CDH}\Phi} = x_0 \bar{x}_1 \bar{x}_2 \vee \bar{x}_0 \bar{x}_1 x_2 \vee \bar{x}_0 x_2 \bar{x}_3 \vee \bar{x}_0 \bar{x}_1 \bar{x}_3 \vee \bar{x}_0 x_1 \bar{x}_2 x_3$$

$$y_d^{\text{CKH}\Phi} = (x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee x_2 \vee x_3) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (\bar{x}_0 \vee x_1 \vee \bar{x}_2 \vee x_3)$$

 $e^{\text{CDH}\Phi}$

		x_0, x_1			
		00	01	11	10
x_2, x_3	00	0	0	0	0
	01	0	1	1	1
	11	0	1	1	0
	10	0	0	0	0

 $e^{\text{CKH}\Phi}$

		x_0, x_1			
		00	01	11	10
x_2, x_3	00	1	0	1	1
	01	1	1	1	1
	11	0	0	1	1
	10	0	0	1	0

$$y_e^{\text{CDH}\Phi} = \bar{x}_1 \bar{x}_3 \vee \bar{x}_0 x_2 \bar{x}_3$$

$$y_e^{\text{CKH}\Phi} = (x_0 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee x_2) \cdot (x_1 \vee x_2 \vee \bar{x}_3)$$

 $f^{\text{CDH}\Phi}$

		x_0, x_1			
		00	01	11	10
x_2, x_3	00	0	0	0	0
	01	0	1	0	1
	11	0	1	1	1
	10	0	1	0	1

 $f^{\text{CKH}\Phi}$

		x_0, x_1			
		00	01	11	10
x_2, x_3	00	1	1	1	1
	01	0	1	1	1
	11	0	0	1	1
	10	0	1	1	1

$$y_f^{\text{CDH}\Phi} = x_0 \bar{x}_1 \bar{x}_3 \vee x_0 \bar{x}_1 \bar{x}_2 \vee \bar{x}_0 \bar{x}_2 \bar{x}_3 \vee \bar{x}_0 x_1 x_3 \vee \bar{x}_0 x_1 \bar{x}_2$$

$$y_f^{\text{CKH}\Phi} = (x_0 \vee x_1 \vee \bar{x}_2) \cdot (x_0 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (x_0 \vee x_1 \vee \bar{x}_3)$$

 $g^{\text{CDH}\Phi}$

		x_0, x_1			
		00	01	11	10
x_2, x_3	00	0	0	1	0
	01	0	1	1	1
	11	0	1	0	1
	10	0	0	0	1

 $g^{\text{CKH}\Phi}$

		x_0, x_1			
		00	01	11	10
x_2, x_3	00	0	1	1	1
	01	1	1	1	0
	11	1	0	1	1
	10	0	1	1	1

$$y_g^{\text{CDH}\Phi} = x_0 \bar{x}_1 \bar{x}_3 \vee \bar{x}_0 \bar{x}_1 x_2 \vee \bar{x}_0 x_1 \bar{x}_3 \vee \bar{x}_0 x_1 \bar{x}_2$$

$$y_g^{\text{СКНФ}} = (x_0 \vee x_1 \vee x_2) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (\bar{x}_0 \vee x_1 \vee \bar{x}_2 \vee x_3)$$

1.2.3 Метод Квайна

СДНФ

$\bar{x}_0\bar{x}_1\bar{x}_2\bar{x}_3$ 0	$0 + 1 = \bar{x}_0\bar{x}_1\bar{x}_3$ 0'	$0' + 9' = \bar{x}_1\bar{x}_3$ 0''	$\bar{x}_0x_1x_3$
$\bar{x}_0\bar{x}_1x_2\bar{x}_3$ 1	$0 + 6 = \bar{x}_1\bar{x}_2\bar{x}_3$ 1'	$1' + 4' = \bar{x}_1\bar{x}_3$ 1''	\bar{x}_0x_2
$\bar{x}_0\bar{x}_1x_2x_3$ 2	$1 + 2 = \bar{x}_0\bar{x}_1x_2$ 2'	$2' + 7' = \bar{x}_0x_2$ 2''	$\bar{x}_1\bar{x}_3$
$\bar{x}_0x_1\bar{x}_2x_3$ 3	$1 + 4 = \bar{x}_0x_2\bar{x}_3$ 3'	$3' + 5' = \bar{x}_0x_2$ 3''	$x_0\bar{x}_1\bar{x}_2$
$\bar{x}_0x_1x_2\bar{x}_3$ 4	$1 + 8 = \bar{x}_1x_2\bar{x}_3$ 4'		
$\bar{x}_0x_1x_2x_3$ 5	$2 + 5 = \bar{x}_0x_2x_3$ 5'		
$x_0\bar{x}_1\bar{x}_2\bar{x}_3$ 6	$3 + 5 = \bar{x}_0x_1x_3$ 6'		
$x_0\bar{x}_1\bar{x}_2x_3$ 7	$4 + 5 = \bar{x}_0x_1x_2$ 7'		
$x_0\bar{x}_1x_2\bar{x}_3$ 8	$6 + 7 = x_0\bar{x}_1\bar{x}_2$ 8'		
	$6 + 8 = x_0\bar{x}_1\bar{x}_3$ 9'		

$$y_a = \bar{x}_0x_1x_3 + \bar{x}_0x_2 + \bar{x}_1\bar{x}_3 + x_0\bar{x}_1\bar{x}_2$$

$\bar{x}_0\bar{x}_1\bar{x}_2\bar{x}_3$ 0	$0 + 1 = \bar{x}_0\bar{x}_1\bar{x}_2$ 0'	$0' + 6' = \bar{x}_0\bar{x}_1$ 0''	$\bar{x}_0\bar{x}_1$
$\bar{x}_0\bar{x}_1\bar{x}_2x_3$ 1	$0 + 2 = \bar{x}_0\bar{x}_1\bar{x}_3$ 1'	$0' + 9' = \bar{x}_1\bar{x}_2$ 1''	$\bar{x}_0\bar{x}_2\bar{x}_3$
$\bar{x}_0\bar{x}_1x_2\bar{x}_3$ 2	$0 + 4 = \bar{x}_0\bar{x}_2\bar{x}_3$ 2'	$1' + 4' = \bar{x}_0\bar{x}_1$ 2''	$\bar{x}_0x_2x_3$
$\bar{x}_0\bar{x}_1x_2x_3$ 3	$0 + 6 = \bar{x}_1\bar{x}_2\bar{x}_3$ 3'	$1' + 10' = \bar{x}_1\bar{x}_3$ 3''	$\bar{x}_1\bar{x}_2$
$\bar{x}_0x_1\bar{x}_2\bar{x}_3$ 4	$1 + 3 = \bar{x}_0\bar{x}_1x_3$ 4'	$3' + 5' = \bar{x}_1\bar{x}_2$ 4''	$\bar{x}_1\bar{x}_3$
$\bar{x}_0x_1x_2\bar{x}_3$ 5	$1 + 7 = \bar{x}_1\bar{x}_2x_3$ 5'	$3' + 7' = \bar{x}_1\bar{x}_3$ 5''	
$x_0\bar{x}_1\bar{x}_2\bar{x}_3$ 6	$2 + 3 = \bar{x}_0\bar{x}_1x_2$ 6'		
$x_0\bar{x}_1\bar{x}_2x_3$ 7	$2 + 8 = \bar{x}_1x_2\bar{x}_3$ 7'		
$x_0\bar{x}_1x_2\bar{x}_3$ 8	$3 + 5 = \bar{x}_0x_2x_3$ 8'		
	$6 + 7 = x_0\bar{x}_1\bar{x}_2$ 9'		
	$6 + 8 = x_0\bar{x}_1\bar{x}_3$ 10'		

$$y_b = \bar{x}_0\bar{x}_1 + \bar{x}_0\bar{x}_2\bar{x}_3 + \bar{x}_0x_2x_3 + \bar{x}_1\bar{x}_2 + \bar{x}_1\bar{x}_3$$

$\bar{x}_0\bar{x}_1\bar{x}_2\bar{x}_3$ 0	$0 + 1 = \bar{x}_0\bar{x}_1\bar{x}_2$ 0'	$0' + 7' = \bar{x}_0\bar{x}_2$ 0''	$\bar{x}_0\bar{x}_2$
$\bar{x}_0\bar{x}_1\bar{x}_2x_3$ 1	$0 + 3 = \bar{x}_0\bar{x}_2\bar{x}_3$ 1'	$0' + 11' = \bar{x}_1\bar{x}_2$ 1''	\bar{x}_0x_1
$\bar{x}_0\bar{x}_1x_2x_3$ 2	$0 + 7 = \bar{x}_1\bar{x}_2\bar{x}_3$ 2'	$1' + 4' = \bar{x}_0\bar{x}_2$ 2''	\bar{x}_0x_3
$\bar{x}_0x_1\bar{x}_2\bar{x}_3$ 3	$1 + 2 = \bar{x}_0\bar{x}_1x_3$ 3'	$2' + 5' = \bar{x}_1\bar{x}_2$ 3''	$\bar{x}_1\bar{x}_2$
$\bar{x}_0x_1\bar{x}_2x_3$ 4	$1 + 4 = \bar{x}_0\bar{x}_2x_3$ 4'	$3' + 9' = \bar{x}_0x_3$ 4''	$x_0\bar{x}_1\bar{x}_3$
$\bar{x}_0x_1x_2\bar{x}_3$ 5	$1 + 8 = \bar{x}_1\bar{x}_2x_3$ 5'	$4' + 6' = \bar{x}_0x_3$ 5''	
$\bar{x}_0x_1x_2x_3$ 6	$2 + 6 = \bar{x}_0x_2x_3$ 6'	$7' + 10' = \bar{x}_0x_1$ 6''	
$x_0\bar{x}_1\bar{x}_2\bar{x}_3$ 7	$3 + 4 = \bar{x}_0x_1\bar{x}_2$ 7'	$8' + 9' = \bar{x}_0x_1$ 7''	
$x_0\bar{x}_1\bar{x}_2x_3$ 8	$3 + 5 = \bar{x}_0x_1\bar{x}_3$ 8'		
$x_0\bar{x}_1x_2\bar{x}_3$ 9	$4 + 6 = \bar{x}_0x_1x_3$ 9'		
	$5 + 6 = \bar{x}_0x_1x_2$ 10'		
	$7 + 8 = x_0\bar{x}_1\bar{x}_2$ 11'		
	$7 + 9 = x_0\bar{x}_1\bar{x}_3$ 12'		

$$y_c = \bar{x}_0\bar{x}_2 + \bar{x}_0x_1 + \bar{x}_0x_3 + \bar{x}_1\bar{x}_2 + x_0\bar{x}_1\bar{x}_3$$

$\bar{x}_0\bar{x}_1\bar{x}_2\bar{x}_3$ 0	$0 + 1 = \bar{x}_0\bar{x}_1\bar{x}_3$ 0'	$\bar{x}_0\bar{x}_1\bar{x}_3$
$\bar{x}_0\bar{x}_1x_2\bar{x}_3$ 1	$0 + 5 = \bar{x}_1\bar{x}_2\bar{x}_3$ 1'	$\bar{x}_0\bar{x}_1x_2$
$\bar{x}_0\bar{x}_1x_2x_3$ 2	$1 + 2 = \bar{x}_0\bar{x}_1x_2$ 2'	$\bar{x}_0x_2\bar{x}_3$
$\bar{x}_0x_1\bar{x}_2x_3$ 3	$1 + 4 = \bar{x}_0x_2\bar{x}_3$ 3'	$\bar{x}_1\bar{x}_2\bar{x}_3$
$\bar{x}_0x_1x_2\bar{x}_3$ 4	$5 + 6 = x_0\bar{x}_1\bar{x}_2$ 4'	$x_0\bar{x}_1\bar{x}_2$
$x_0\bar{x}_1\bar{x}_2\bar{x}_3$ 5		
$x_0\bar{x}_1x_2x_3$ 6		

$$y_d = \bar{x}_0\bar{x}_1\bar{x}_3 + \bar{x}_0\bar{x}_1x_2 + \bar{x}_0x_2\bar{x}_3 + \bar{x}_1\bar{x}_2\bar{x}_3 + x_0\bar{x}_1\bar{x}_2$$

$\bar{x}_0\bar{x}_1\bar{x}_2\bar{x}_3$ 0	$0 + 1 = \bar{x}_0\bar{x}_1\bar{x}_3$ 0'	$0' + 4' = \bar{x}_1\bar{x}_3$ 0''	$\bar{x}_0x_2\bar{x}_3$
$\bar{x}_0\bar{x}_1x_2\bar{x}_3$ 1	$0 + 3 = \bar{x}_1\bar{x}_2\bar{x}_3$ 1'	$1' + 3' = \bar{x}_1\bar{x}_3$ 1''	$\bar{x}_1\bar{x}_3$
$\bar{x}_0x_1x_2\bar{x}_3$ 2	$1 + 2 = \bar{x}_0x_2\bar{x}_3$ 2'		
$x_0\bar{x}_1\bar{x}_2\bar{x}_3$ 3	$1 + 4 = \bar{x}_1x_2\bar{x}_3$ 3'		
$x_0\bar{x}_1x_2\bar{x}_3$ 4	$3 + 4 = x_0\bar{x}_1\bar{x}_3$ 4'		

$$y_e = \bar{x}_0x_2\bar{x}_3 + \bar{x}_1\bar{x}_3$$

$\bar{x}_0\bar{x}_1\bar{x}_2\bar{x}_3$ 0	$0 + 1 = \bar{x}_0\bar{x}_2\bar{x}_3$ 0'	$\bar{x}_0\bar{x}_2\bar{x}_3$
$\bar{x}_0x_1\bar{x}_2\bar{x}_3$ 1	$0 + 4 = \bar{x}_1\bar{x}_2\bar{x}_3$ 1'	$\bar{x}_0x_1\bar{x}_2$
$\bar{x}_0x_1x_2\bar{x}_3$ 2	$1 + 2 = \bar{x}_0x_1\bar{x}_2$ 2'	$\bar{x}_0x_1\bar{x}_3$
$\bar{x}_0x_1x_2x_3$ 3	$1 + 3 = \bar{x}_0x_1\bar{x}_3$ 3'	$\bar{x}_1\bar{x}_2\bar{x}_3$
$x_0\bar{x}_1\bar{x}_2\bar{x}_3$ 4	$4 + 5 = x_0\bar{x}_1\bar{x}_2$ 4'	$x_0\bar{x}_1\bar{x}_2$
$x_0\bar{x}_1x_2\bar{x}_3$ 5	$4 + 6 = x_0\bar{x}_1\bar{x}_3$ 5'	$x_0\bar{x}_1\bar{x}_3$
$x_0\bar{x}_1x_2x_3$ 6		

$$y_f = \bar{x}_0\bar{x}_2\bar{x}_3 + \bar{x}_0x_1\bar{x}_2 + \bar{x}_0x_1\bar{x}_3 + \bar{x}_1\bar{x}_2\bar{x}_3 + x_0\bar{x}_1\bar{x}_2 + x_0\bar{x}_1\bar{x}_3$$

$\bar{x}_0\bar{x}_1x_2\bar{x}_3$ 0	$0 + 1 = \bar{x}_0\bar{x}_1x_2$ 0'	$\bar{x}_0\bar{x}_1x_2$
$\bar{x}_0\bar{x}_1x_2x_3$ 1	$0 + 4 = \bar{x}_0x_2\bar{x}_3$ 1'	$\bar{x}_0x_1\bar{x}_2$
$\bar{x}_0x_1\bar{x}_2\bar{x}_3$ 2	$2 + 3 = \bar{x}_0x_1\bar{x}_2$ 2'	$\bar{x}_0x_1\bar{x}_3$
$\bar{x}_0x_1\bar{x}_2x_3$ 3	$2 + 4 = \bar{x}_0x_1\bar{x}_3$ 3'	$\bar{x}_0x_2\bar{x}_3$
$\bar{x}_0x_1x_2\bar{x}_3$ 4	$5 + 6 = x_0\bar{x}_1\bar{x}_2$ 4'	$x_0\bar{x}_1\bar{x}_2$
$x_0\bar{x}_1\bar{x}_2\bar{x}_3$ 5		
$x_0\bar{x}_1\bar{x}_2x_3$ 6		

$$y_g = \bar{x}_0\bar{x}_1x_2 + \bar{x}_0x_1\bar{x}_2 + \bar{x}_0x_1\bar{x}_3 + \bar{x}_0x_2\bar{x}_3 + x_0\bar{x}_1\bar{x}_2$$

СКНФ

Корректно сократить возможно только СКНФ для е, f и g.

$(x_0 \vee x_1 \vee x_2 \vee \bar{x}_3)$ 0	$0+1=(x_0 \vee x_1 \vee \bar{x}_3)$ 0'	$0'+5'=(x_0 \vee \bar{x}_3)$ 0''	$(x_0 \vee \bar{x}_1 \vee x_2)$
$(x_0 \vee x_1 \vee \bar{x}_2 \vee \bar{x}_3)$ 1	$0+3=(x_0 \vee x_2 \vee \bar{x}_3)$ 1'	$1'+3'=(x_0 \vee \bar{x}_3)$ 1''	$(x_0 \vee \bar{x}_3)$
$(x_0 \vee \bar{x}_1 \vee x_2 \vee x_3)$ 2	$0+5=(x_1 \vee x_2 \vee \bar{x}_3)$ 2'		$(x_1 \vee x_2 \vee \bar{x}_3)$
$(x_0 \vee \bar{x}_1 \vee x_2 \vee \bar{x}_3)$ 3	$1+4=(x_0 \vee \bar{x}_2 \vee \bar{x}_3)$ 3'		
$(x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3)$ 4	$2+3=(x_0 \vee \bar{x}_1 \vee x_2)$ 4'		
$(\bar{x}_0 \vee x_1 \vee x_2 \vee \bar{x}_3)$ 5	$3+4=(x_0 \vee \bar{x}_1 \vee \bar{x}_3)$ 5'		

$$y_e = (x_0 \vee \bar{x}_1 \vee x_2) \cdot (x_0 \vee \bar{x}_3) \cdot (x_1 \vee x_2 \vee \bar{x}_3)$$

$(x_0 \vee x_1 \vee x_2 \vee \bar{x}_3)$ 0	$0+2=(x_0 \vee x_1 \vee \bar{x}_3)$ 0'	$(x_0 \vee \bar{x}_2 \vee \bar{x}_3)$
$(x_0 \vee x_1 \vee \bar{x}_2 \vee x_3)$ 1	$1+2=(x_0 \vee x_1 \vee \bar{x}_2)$ 1'	$(x_0 \vee x_1 \vee \bar{x}_2)$
$(x_0 \vee x_1 \vee \bar{x}_2 \vee \bar{x}_3)$ 2	$2+3=(x_0 \vee \bar{x}_2 \vee \bar{x}_3)$ 2'	$(x_0 \vee x_1 \vee \bar{x}_3)$
$(x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3)$ 3		

$$y_f = (x_0 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (x_0 \vee x_1 \vee \bar{x}_2) \cdot (x_0 \vee x_1 \vee \bar{x}_3)$$

$(x_0 \vee x_1 \vee x_2 \vee x_3) \ 0$	$0+1=(x_0 \vee x_1 \vee x_2) \ 0'$	$(x_0 \vee x_1 \vee x_2)$
$(x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \ 1$		$(x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3)$
$(x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3) \ 2$		$(\bar{x}_0 \vee x_1 \vee \bar{x}_2 \vee x_3)$
$(\bar{x}_0 \vee x_1 \vee \bar{x}_2 \vee x_3) \ 3$		

$$y_g = (x_0 \vee x_1 \vee x_2) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (\bar{x}_0 \vee x_1 \vee \bar{x}_2 \vee x_3)$$

1.3 Перевод полученных выражений к базису 2И-НЕ/2ИЛИ-НЕ

При переводе в базис к изначальному алгебраическому уравнению применяется двойное отрицание, после чего используются законы де

Моргана:

$$\begin{aligned}\overline{a \cdot b} &= \bar{a} \vee \bar{b} \\ \overline{a \vee b} &= \bar{a} \cdot \bar{b}\end{aligned}$$

Чтобы не загромождать запись двойными отрицаниями, они будут опускаться после того, как будет показано их применение, то есть:

$$\begin{aligned}\overline{\overline{A \vee B \vee C \vee D}} &= \overline{\bar{A} \cdot \bar{B} \cdot \bar{C} \cdot \bar{D}} \\ A \vee B \vee C \vee D &= \overline{\overline{\bar{A} \vee \bar{B} \vee \bar{C} \vee \bar{D}}}\end{aligned}$$

1.3.1 2И-HE

$$\begin{aligned}
y_a^{\text{ДНФ}} &= \overline{\overline{x_0 x_2 \vee \bar{x}_1 \bar{x}_3 \vee x_0 \bar{x}_1 x_2 \vee x_0 x_1 x_2}} = \\
&= \overline{\overline{\bar{x}_0 x_2} \cdot \overline{\bar{x}_0 \bar{x}_3} \cdot \overline{x_0 \bar{x}_1 \bar{x}_2} \cdot \overline{x_0 x_1 x_2}} \\
y_a^{\text{КНФ}} &= \overline{(x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee x_2 \vee x_3)} = \\
&= \overline{(x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee x_2 \vee x_3)} = \\
&= \overline{\bar{x}_0 \bar{x}_1 \bar{x}_2 x_3 \cdot \bar{x}_0 x_1 \bar{x}_2 \bar{x}_3} \\
y_b^{\text{ДНФ}} &= \overline{\overline{\bar{x}_1 x_2 \bar{x}_3 \vee \bar{x}_0 x_2 x_3 \vee \bar{x}_0 \bar{x}_1 x_3 \vee \bar{x}_0 \bar{x}_2 \bar{x}_3 \vee x_0 \bar{x}_1 \bar{x}_3}} = \\
&= \overline{\bar{x}_1 x_2 \bar{x}_3 \cdot \bar{x}_0 x_2 x_3 \cdot \bar{x}_0 \bar{x}_1 x_3 \cdot \bar{x}_0 \bar{x}_2 \bar{x}_3 \cdot x_0 \bar{x}_1 \bar{x}_3} \\
y_b^{\text{КНФ}} &= \overline{(x_0 \vee \bar{x}_1 \vee x_2 \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee x_3)} = \\
&= \overline{(x_0 \vee \bar{x}_1 \vee x_2 \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee x_3)} = \\
&= \overline{\bar{x}_0 x_1 \bar{x}_2 x_3 \cdot \bar{x}_0 x_1 x_2 \bar{x}_3} \\
y_c^{\text{ДНФ}} &= \overline{\overline{\bar{x}_0 \bar{x}_2 \vee x_0 \bar{x}_1 \bar{x}_2 \vee x_0 \bar{x}_1 \bar{x}_3 \vee \bar{x}_0 x_2 x_3 \vee \bar{x}_0 x_1 x_2}} = \\
&= \overline{\bar{x}_0 \bar{x}_2 \cdot x_0 \bar{x}_1 \bar{x}_2 \cdot x_0 \bar{x}_1 \bar{x}_3 \cdot \bar{x}_0 x_2 x_3 \cdot \bar{x}_0 x_1 x_2} \\
y_c^{\text{КНФ}} &= \overline{(x_0 \vee x_1 \vee \bar{x}_2 \vee x_3)} = \overline{\bar{x}_0 \bar{x}_1 x_2 \bar{x}_3} \\
y_d^{\text{ДНФ}} &= \overline{\overline{x_0 \bar{x}_1 \bar{x}_2 \vee \bar{x}_0 \bar{x}_1 x_2 \vee \bar{x}_0 x_2 \bar{x}_3 \vee \bar{x}_0 \bar{x}_1 \bar{x}_3 \vee \bar{x}_0 x_1 \bar{x}_2 x_3}} = \\
&= \overline{x_0 \bar{x}_1 \bar{x}_2 \cdot \bar{x}_0 \bar{x}_1 x_2 \cdot \bar{x}_0 x_2 \bar{x}_3 \cdot \bar{x}_0 \bar{x}_1 \bar{x}_3 \cdot \bar{x}_0 x_1 \bar{x}_2 x_3} \\
y_d^{\text{КНФ}} &= \\
&= \overline{(x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee x_2 \vee x_3) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (\bar{x}_0 \vee x_1 \vee \bar{x}_2 \vee x_3)} \\
&= \overline{(x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee x_2 \vee x_3) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (\bar{x}_0 \vee x_1 \vee \bar{x}_2 \vee x_3)} \\
&= \overline{\bar{x}_0 \bar{x}_1 \bar{x}_2 x_3 \cdot \bar{x}_0 x_1 \bar{x}_2 \bar{x}_3 \cdot \bar{x}_0 x_1 x_2 x_3 \cdot x_0 \bar{x}_1 x_2 \bar{x}_3} \\
y_e^{\text{ДНФ}} &= \overline{\overline{\bar{x}_1 \bar{x}_3 \vee \bar{x}_0 x_2 \bar{x}_3}} = \overline{\bar{x}_1 \bar{x}_3 \cdot \bar{x}_0 x_2 \bar{x}_3} \\
y_e^{\text{КНФ}} &= \overline{(x_0 \vee \bar{x}_3) \vee (x_0 \vee \bar{x}_1 \vee x_2) \cdot (x_1 \vee x_2 \vee \bar{x}_3)} = \\
&= \overline{(x_0 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee x_2) \cdot (x_1 \vee x_2 \vee \bar{x}_3)} = \\
&= \overline{\bar{x}_0 x_3 \cdot \bar{x}_0 x_1 \bar{x}_2 \cdot \bar{x}_1 x_2 x_3} \\
y_f^{\text{ДНФ}} &= \overline{\overline{x_0 \bar{x}_1 \bar{x}_3 \vee x_0 \bar{x}_1 \bar{x}_2 \vee \bar{x}_0 \bar{x}_2 \bar{x}_3 \vee \bar{x}_0 x_1 x_2 \vee \bar{x}_0 x_1 \bar{x}_2}} = \\
&= \overline{x_0 \bar{x}_1 \bar{x}_3 \cdot x_0 \bar{x}_1 \bar{x}_2 \cdot \bar{x}_0 \bar{x}_2 \bar{x}_3 \cdot \bar{x}_0 x_1 x_3 \cdot \bar{x}_0 x_1 \bar{x}_2} \\
y_f^{\text{КНФ}} &= \overline{(x_0 \vee x_1 \vee \bar{x}_2) \cdot (x_0 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (x_0 \vee x_1 \vee \bar{x}_3)} = \\
&= \overline{(x_0 \vee x_1 \vee \bar{x}_2) \cdot (x_0 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (x_0 \vee x_1 \vee \bar{x}_3)} = \overline{\bar{x}_0 \bar{x}_1 x_2 \cdot \bar{x}_0 x_2 x_3 \cdot \bar{x}_0 \bar{x}_1 x_3} \\
y_g^{\text{ДНФ}} &= \overline{\overline{x_0 \bar{x}_1 \bar{x}_3 \vee \bar{x}_0 \bar{x}_1 x_2 \vee \bar{x}_0 x_1 \bar{x}_3 \vee \bar{x}_0 x_1 \bar{x}_2}} = \overline{x_0 \bar{x}_1 \bar{x}_3 \cdot \bar{x}_0 \bar{x}_1 x_2 \cdot \bar{x}_0 x_1 \bar{x}_3 \cdot \bar{x}_0 x_1 \bar{x}_2} \\
y_g^{\text{КНФ}} &= \overline{(x_0 \vee x_1 \vee x_2) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (\bar{x}_0 \vee x_1 \vee \bar{x}_2 \vee x_3)} = \\
&= \overline{(x_0 \vee x_1 \vee x_2) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (\bar{x}_0 \vee x_1 \vee \bar{x}_2 \vee x_3)} = \\
&= \overline{\bar{x}_0 \bar{x}_1 \bar{x}_2 \cdot \bar{x}_0 x_1 x_2 x_3 \cdot x_0 \bar{x}_1 x_2 \bar{x}_3}
\end{aligned}$$

1.3.2 2ИЛИ-НЕ

$$\begin{aligned}
y_a^{\text{ДНФ}} &= \overline{\overline{\overline{x_0 x_2 \vee \bar{x}_1 \bar{x}_3 \vee x_0 \bar{x}_1 \bar{x}_2 \vee x_0 x_1 x_3}}} = \overline{\overline{x_0 x_2 \vee \bar{x}_1 \bar{x}_3 \vee x_0 \bar{x}_1 \bar{x}_2 \vee x_0 x_1 x_3}} = \\
&= \overline{x_0 \vee \bar{x}_2 \vee \bar{x}_1 \vee x_3 \vee \bar{x}_0 \vee x_1 \vee x_2 \vee x_0 \vee \bar{x}_1 \vee \bar{x}_3} \\
y_a^{\text{КНФ}} &= \overline{(x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee x_2 \vee x_3)} = \\
&= \overline{x_0 \vee x_1 \vee x_2 \vee \bar{x}_3 \vee x_0 \vee \bar{x}_1 \vee x_2 \vee x_3} \\
y_b^{\text{ДНФ}} &= \overline{\overline{\overline{\bar{x}_1 x_2 \bar{x}_3 \vee \bar{x}_0 x_2 x_3 \vee \bar{x}_0 \bar{x}_1 x_3 \vee \bar{x}_0 \bar{x}_2 \bar{x}_3 \vee x_0 \bar{x}_1 \bar{x}_3}}} = \\
&= \overline{\bar{x}_1 x_2 x_3 \vee \bar{x}_0 x_2 x_3 \vee \bar{x}_0 \bar{x}_1 x_3 \vee \bar{x}_0 \bar{x}_2 \bar{x}_3 \vee x_0 \bar{x}_1 \bar{x}_3} = \\
&= \overline{x_1 \vee \bar{x}_2 \vee x_3 \vee x_0 \vee \bar{x}_2 \vee \bar{x}_3 \vee x_0 \vee x_1 \vee \bar{x}_3 \vee x_0 \vee x_2 \vee x_3 \vee \bar{x}_0 \vee x_1 \vee x_3} \\
y_b^{\text{КНФ}} &= \overline{(x_0 \vee \bar{x}_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee x_3)} = \\
&= \overline{x_0 \vee \bar{x}_1 \vee x_2 \vee \bar{x}_3 \vee x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee x_3} \\
y_c^{\text{ДНФ}} &= \overline{\overline{\overline{\bar{x}_0 \bar{x}_2 \vee x_0 \bar{x}_1 \bar{x}_2 \vee x_0 \bar{x}_1 \bar{x}_3 \vee \bar{x}_0 x_2 x_3 \vee \bar{x}_0 x_1 x_2}}} = \\
&= \overline{\bar{x}_0 \bar{x}_2 \vee x_0 \bar{x}_1 \bar{x}_2 \vee x_0 \bar{x}_1 \bar{x}_3 \vee \bar{x}_0 x_2 x_3 \vee \bar{x}_0 x_1 x_2} = \\
&= \overline{x_0 \vee x_2 \vee \bar{x}_0 \vee x_1 \vee x_2 \vee \bar{x}_0 \vee x_1 \vee x_3 \vee x_0 \vee \bar{x}_2 \vee \bar{x}_3 \vee x_0 \vee \bar{x}_1 \vee \bar{x}_2} \\
y_c^{\text{КНФ}} &= \overline{x_0 \vee x_1 \vee \bar{x}_2 \vee x_3} \\
y_d^{\text{ДНФ}} &= \overline{\overline{\overline{x_0 \bar{x}_1 \bar{x}_2 \vee \bar{x}_0 \bar{x}_1 x_2 \vee \bar{x}_0 x_2 \bar{x}_3 \vee \bar{x}_0 \bar{x}_1 \bar{x}_3 \vee \bar{x}_0 x_1 \bar{x}_2 x_3}}} = \\
&= \overline{x_0 \bar{x}_1 \bar{x}_2 \vee \bar{x}_0 \bar{x}_1 x_2 \vee \bar{x}_0 x_2 \bar{x}_3 \vee \bar{x}_0 \bar{x}_1 \bar{x}_3 \vee \bar{x}_0 x_1 \bar{x}_2 x_3} = \\
&= \overline{\bar{x}_0 \vee x_1 \vee x_2 \vee x_0 \vee x_1 \vee \bar{x}_2 \vee x_0 \vee \bar{x}_2 \vee x_3 \vee x_0 \vee x_1 \vee x_3 \vee x_0 \vee \bar{x}_1 \vee x_2 \vee \bar{x}_3} \\
y_d^{\text{КНФ}} &= \overline{(x_0 \vee x_1 \vee x_2 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee x_2 \vee x_3) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (\bar{x}_0 \vee x_1 \vee \bar{x}_2 \vee x_3)} = \\
&= \overline{x_0 \vee x_1 \vee x_2 \vee \bar{x}_3 \vee x_0 \vee \bar{x}_1 \vee x_2 \vee x_3 \vee x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3 \vee \bar{x}_0 \vee x_1 \vee \bar{x}_2 \vee x_3} \\
y_e^{\text{ДНФ}} &= \overline{\bar{x}_1 \bar{x}_3 \vee \bar{x}_0 x_2 \bar{x}_3} = \overline{\bar{x}_1 \bar{x}_3 \vee \bar{x}_0 x_2 \bar{x}_3} = \overline{x_1 \vee x_3 \vee x_0 \vee \bar{x}_2 \vee x_3} \\
y_e^{\text{КНФ}} &= \overline{(x_0 \vee \bar{x}_3) \cdot (x_0 \vee \bar{x}_1 \vee x_2) \cdot (x_1 \vee x_2 \vee \bar{x}_3)} = \\
&= \overline{x_0 \vee \bar{x}_3 \vee x_0 \vee \bar{x}_1 \vee x_2 \vee x_1 \vee x_2 \vee \bar{x}_3} \\
y_f^{\text{ДНФ}} &= \overline{\overline{\overline{x_0 \bar{x}_1 \bar{x}_3 \vee x_0 \bar{x}_1 \bar{x}_2 \vee \bar{x}_0 \bar{x}_2 \bar{x}_3 \vee \bar{x}_0 x_1 x_3 \vee \bar{x}_0 x_1 \bar{x}_2}}} = \\
&= \overline{x_0 \bar{x}_1 \bar{x}_3 \vee x_0 \bar{x}_1 \bar{x}_2 \vee \bar{x}_0 \bar{x}_2 \bar{x}_3 \vee \bar{x}_0 x_1 x_3 \vee \bar{x}_0 x_1 \bar{x}_2} = \\
&= \overline{\bar{x}_0 \vee x_1 \vee x_3 \vee \bar{x}_0 \vee x_1 \vee x_2 \vee x_0 \vee x_2 \vee x_3 \vee x_0 \vee \bar{x}_1 \vee \bar{x}_3 \vee x_0 \vee \bar{x}_1 \vee x_2} \\
y_f^{\text{КНФ}} &= \overline{(x_0 \vee x_1 \vee \bar{x}_2) \cdot (x_0 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (x_0 \vee x_1 \vee \bar{x}_3)} = \\
&= \overline{x_0 \vee x_1 \vee \bar{x}_2 \vee x_0 \vee \bar{x}_2 \vee \bar{x}_3 \vee x_0 \vee x_1 \vee \bar{x}_3} \\
y_g^{\text{ДНФ}} &= \overline{\overline{\overline{\bar{x}_0 \bar{x}_1 \bar{x}_3 \vee \bar{x}_0 \bar{x}_1 x_2 \vee \bar{x}_0 x_1 \bar{x}_3 \vee \bar{x}_0 x_1 \bar{x}_2}}} = \overline{\bar{x}_0 \bar{x}_1 \bar{x}_3 \vee \bar{x}_0 \bar{x}_1 x_2 \vee \bar{x}_0 x_1 \bar{x}_3 \vee \bar{x}_0 x_1 \bar{x}_2} = \\
&= \overline{x_0 \vee x_1 \vee x_3 \vee x_0 \vee x_1 \vee \bar{x}_2 \vee x_0 \vee \bar{x}_1 \vee x_3 \vee x_0 \vee \bar{x}_1 \vee x_2} \\
y_g^{\text{КНФ}} &= \overline{(x_0 \vee x_1 \vee x_2) \cdot (x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3) \cdot (\bar{x}_0 \vee x_1 \vee \bar{x}_2 \vee x_3)} = \\
&= \overline{x_0 \vee x_1 \vee x_2 \vee x_0 \vee \bar{x}_1 \vee \bar{x}_2 \vee \bar{x}_3 \vee \bar{x}_0 \vee x_1 \vee \bar{x}_2 \vee x_3}
\end{aligned}$$

1.4 Цифровая схема

Все схемы строились через КНФ.

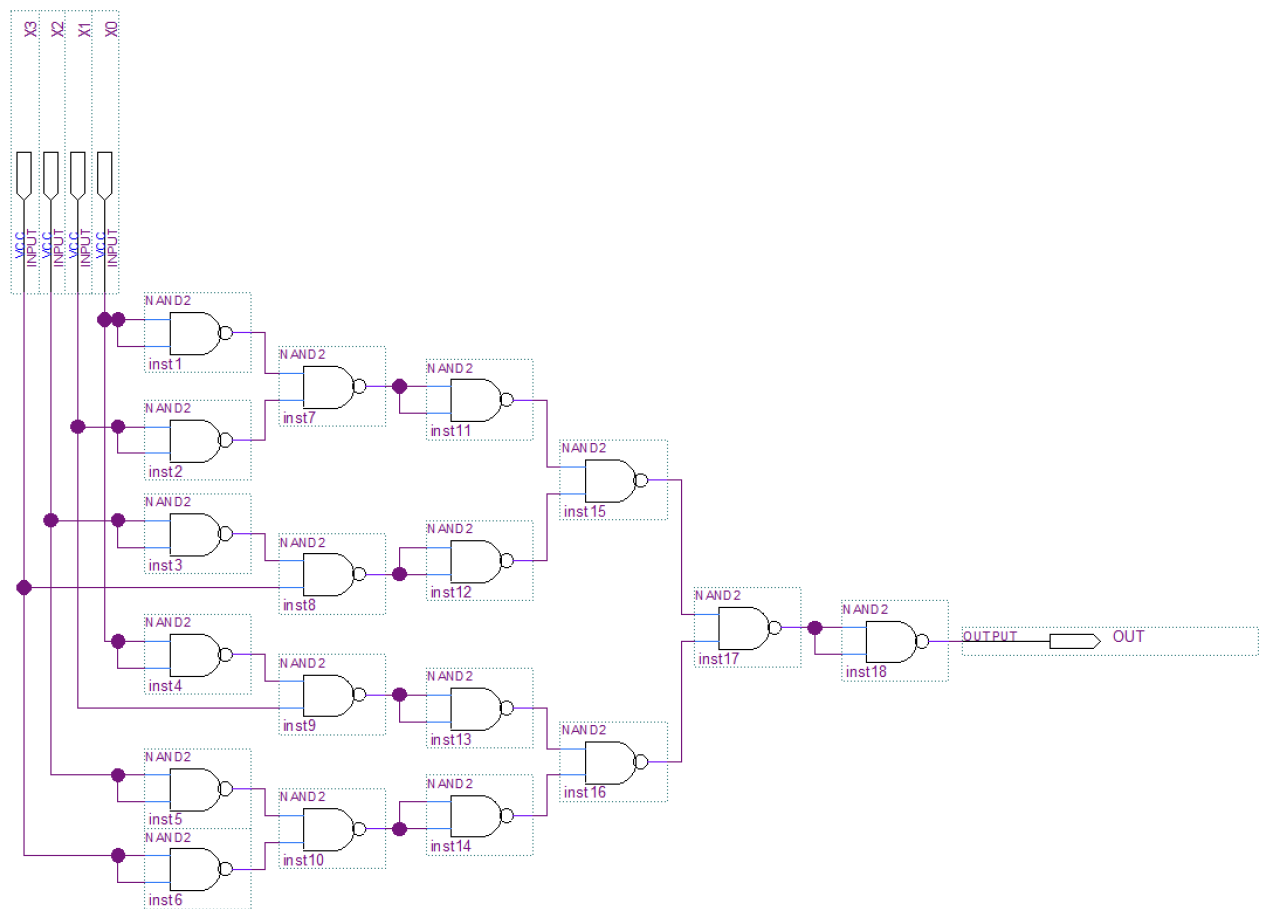


Рисунок 1.2 – Схема для светодиода А.

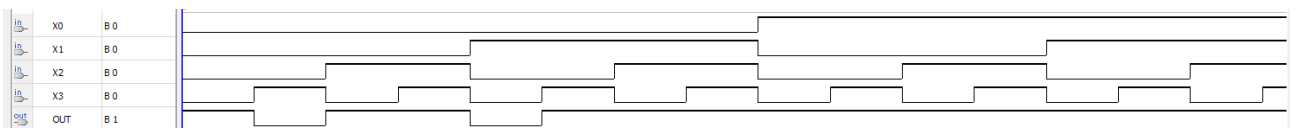


Рисунок 1.3 – Сигнал на светодиоде А.

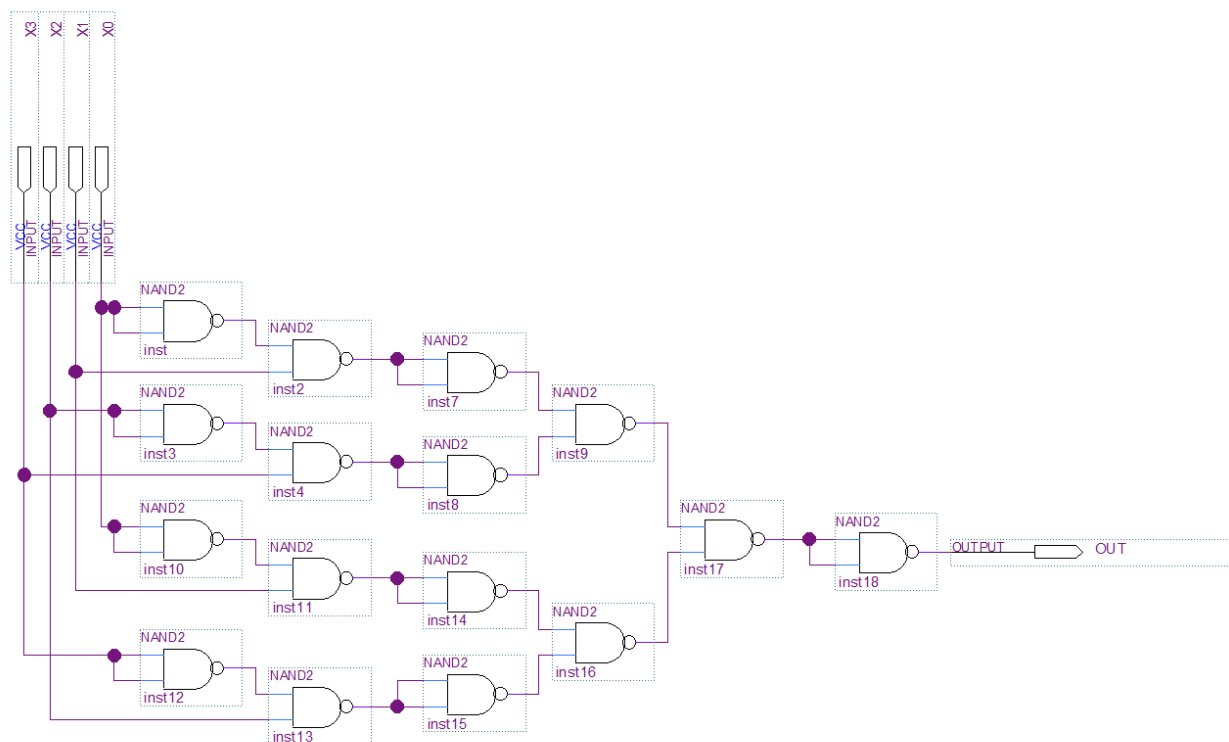


Рисунок 1.4 – Схема для светодиода В.

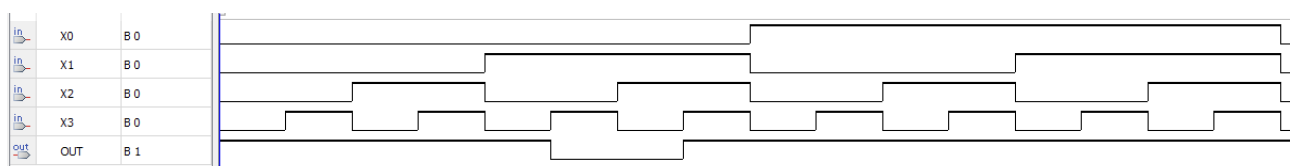


Рисунок 1.5 – Сигнал на светодиоде В.

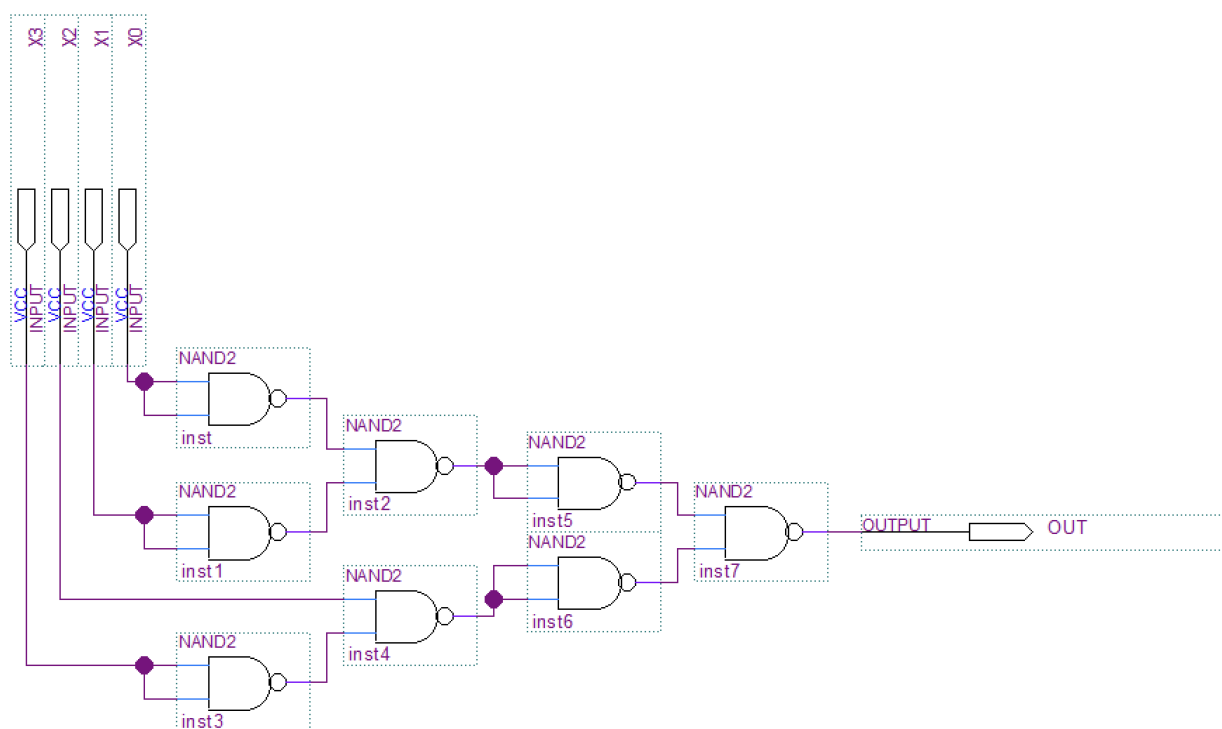


Рисунок 1.6 – Схема для светодиода С.

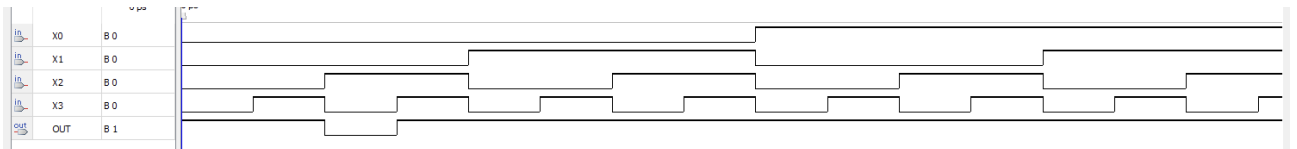


Рисунок 1.7 – Сигнал на светодиоде С.

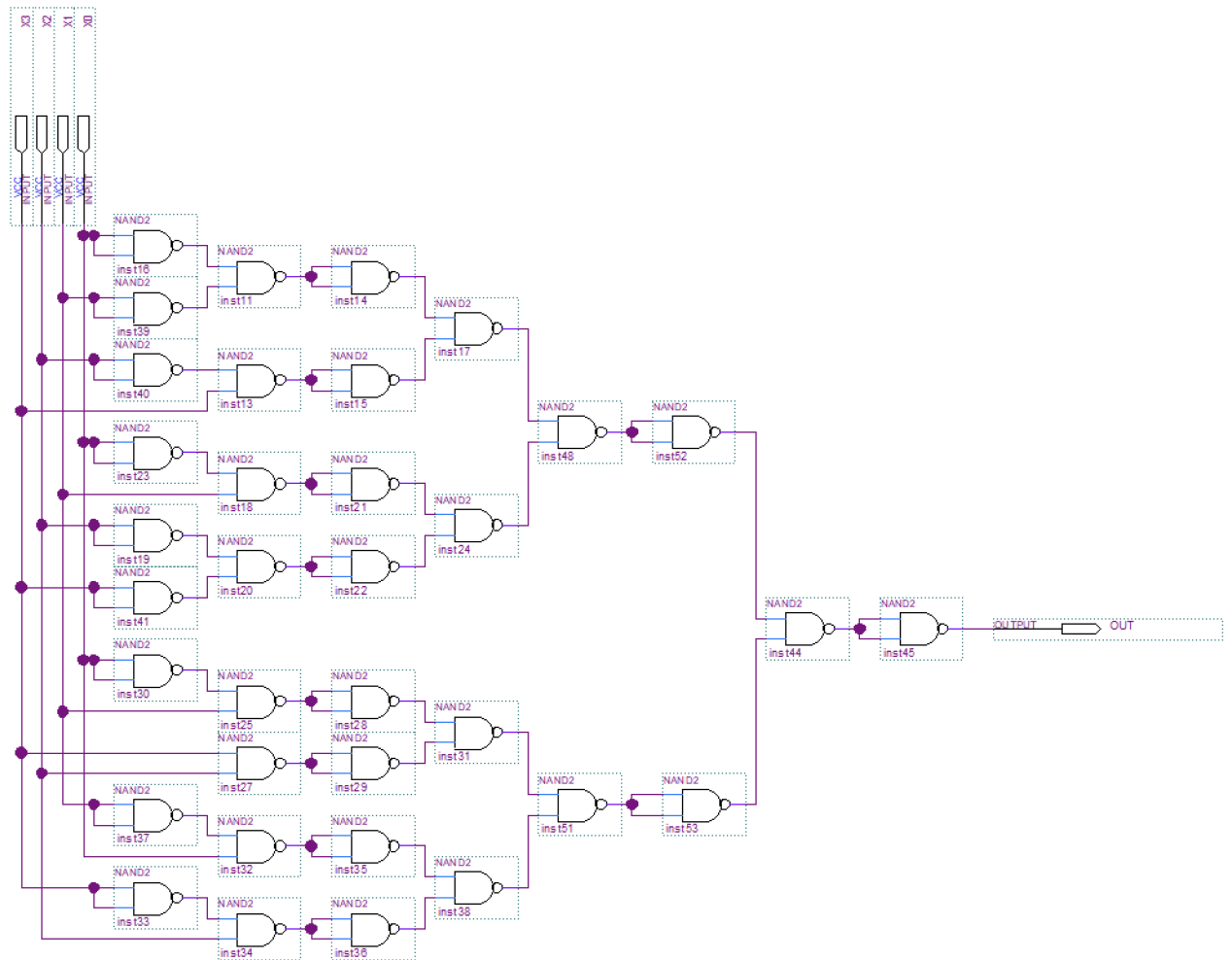


Рисунок 1.8 – Схема для светодиода D.



Рисунок 1.9 – Сигнал на светодиоде D.

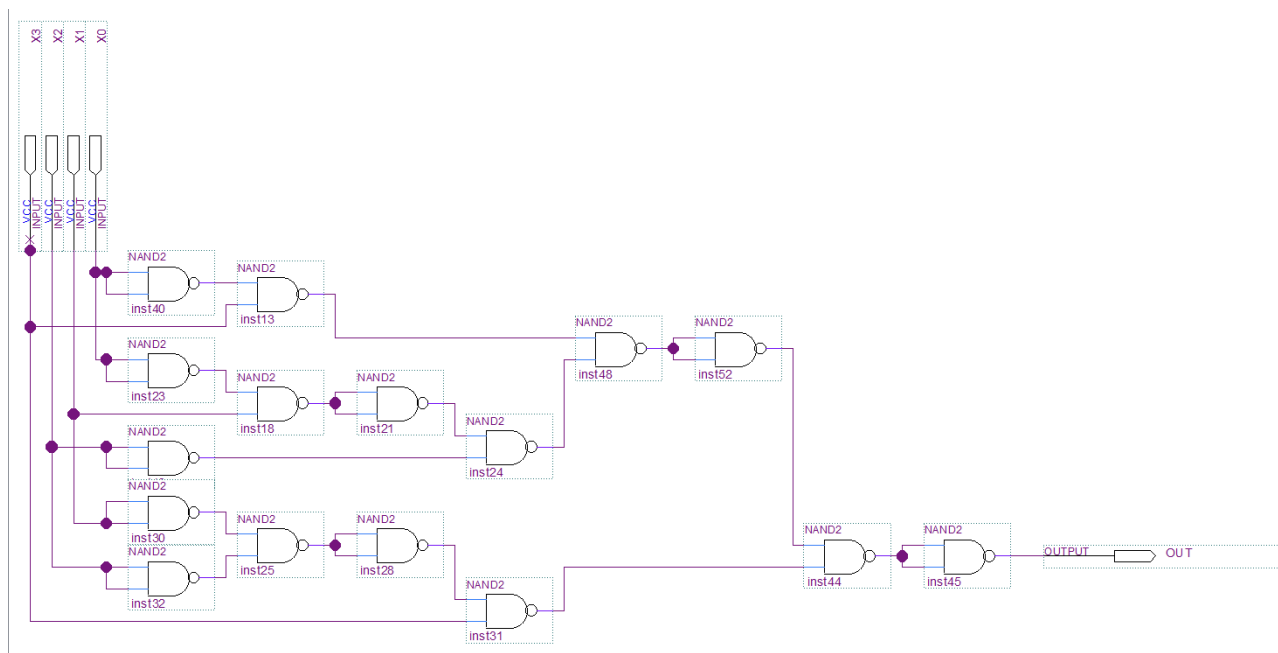


Рисунок 1.10 – Схема для светодиода Е.

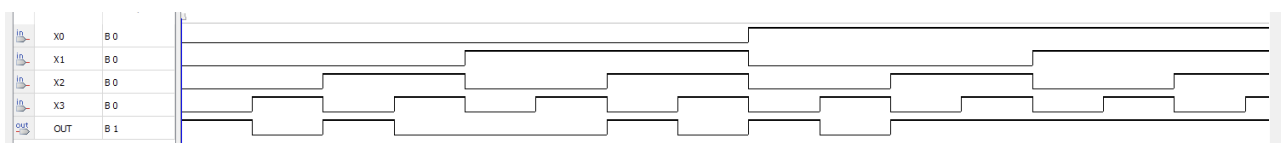


Рисунок 1.11 – Сигнал на светодиоде Е.

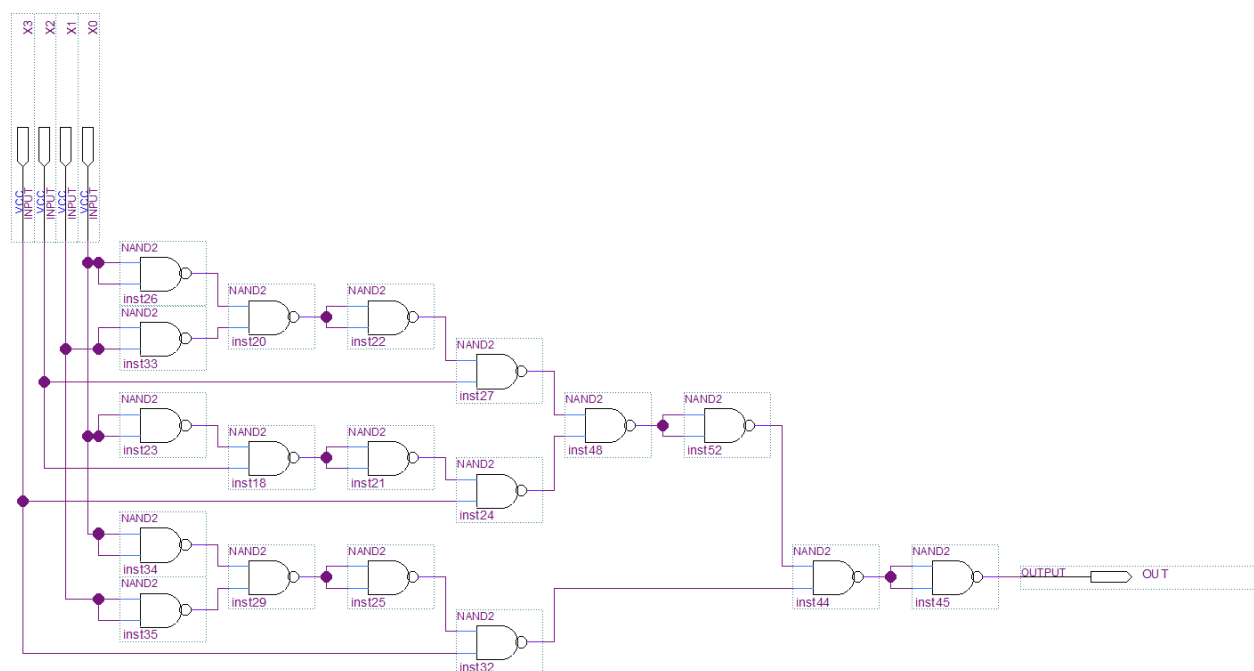


Рисунок 1.12 – Схема для светодиода F.

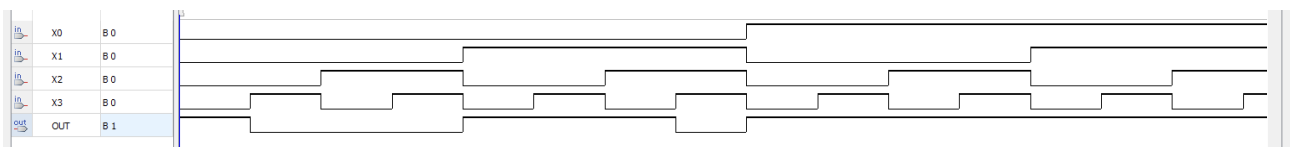


Рисунок 1.13 – Сигнал на светодиоде F.

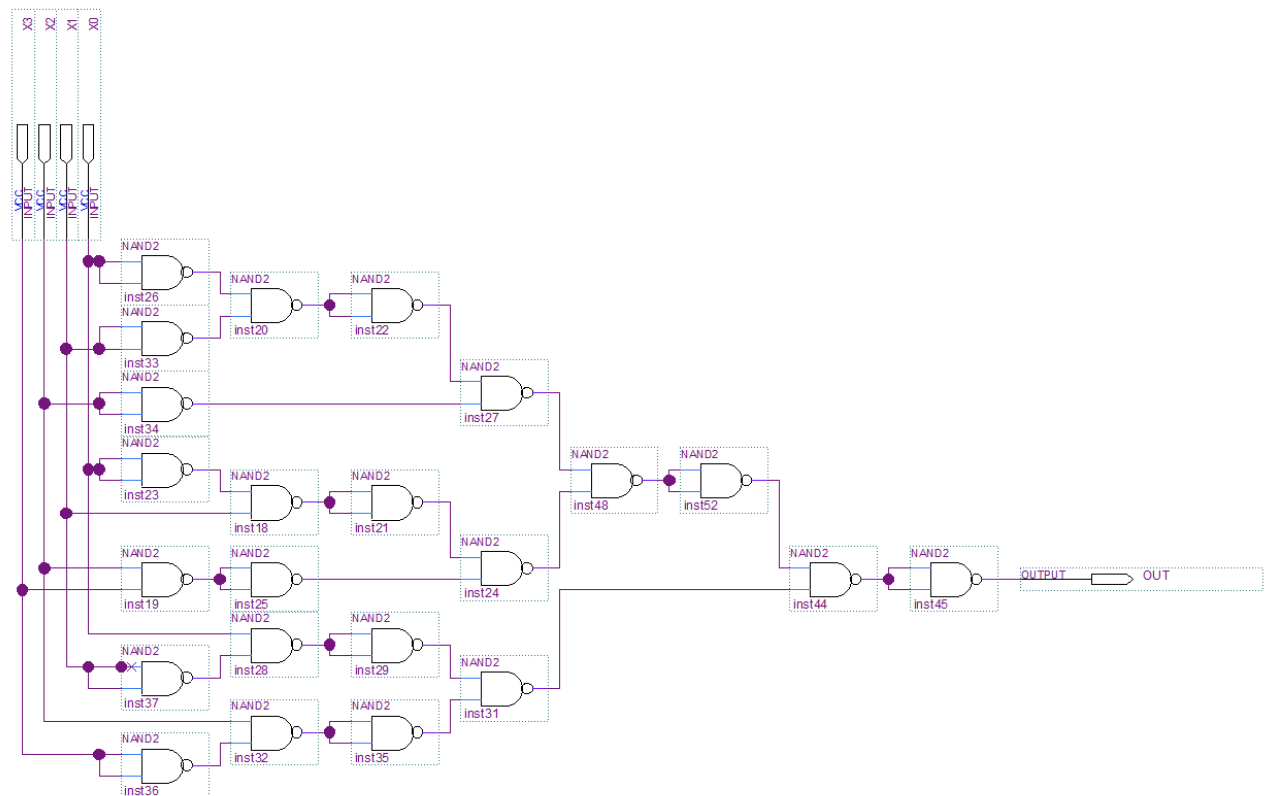


Рисунок 1.14 – Схема для светодиода G.



Рисунок 1.15 – Сигнал на светодиоде G.

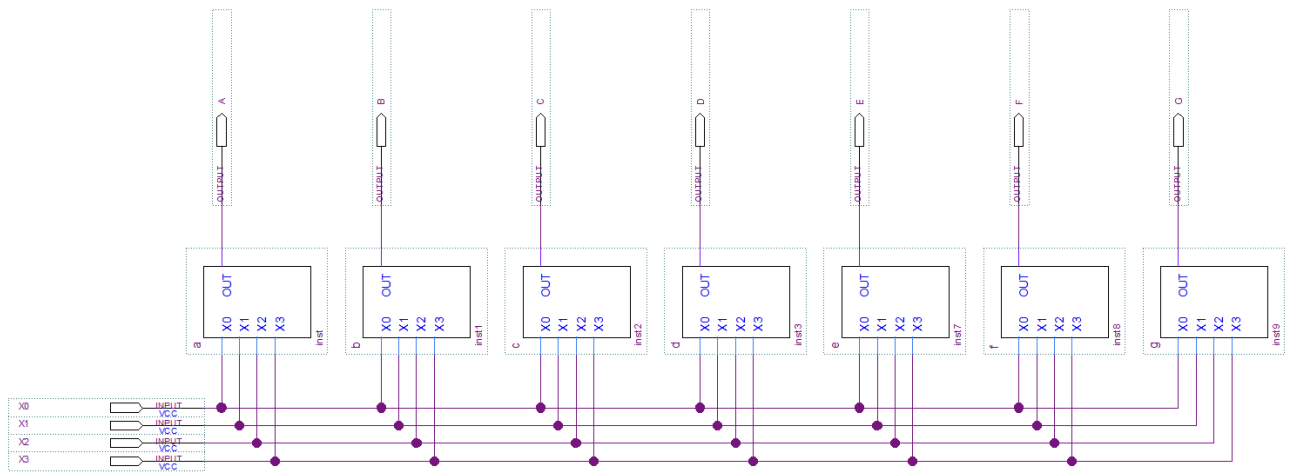


Рисунок 1.16 – Схема для светодиода BSD.

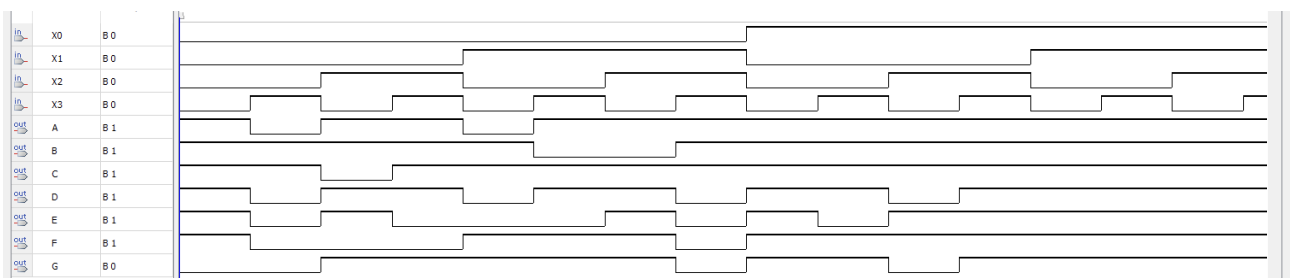


Рисунок 1.17 – Сигнал на BSD.

2 Счётчик с коэффициентом счёта 6.

2.1 Декодер номера билета.

Для начала построим декодер для билет под номером 20L274.

Символ	a_0	a_1	a_2	x_0	x_1	x_2	x_3
2	0	0	0	0	0	1	0
0	0	0	1	0	0	0	0
Л	0	1	0	1	0	1	0
2	0	1	1	0	0	1	0
7	1	0	0	0	1	1	1
4	1	0	1	0	1	0	0

$$\begin{aligned}x_0^{\text{СДНФ}} &= \bar{a}_0 a_1 \bar{a}_2 \\x_1^{\text{СДНФ}} &= a_0 \bar{a}_1 \bar{a}_2 \vee a_0 \bar{a}_1 a_2 \\x_2^{\text{СДНФ}} &= \bar{a}_0 \bar{a}_1 \bar{a}_2 \vee \bar{a}_0 a_1 \bar{a}_2 \vee \bar{a}_0 a_1 a_2 \vee a_0 \bar{a}_1 \bar{a}_2 \\x_3^{\text{СДНФ}} &= a_0 \bar{a}_1 \bar{a}_2\end{aligned}$$

Переведем в 2И-НЕ:

$$\begin{aligned}x_0^{\text{ДНФ}} &= \overline{\bar{a}_0 a_1 \bar{a}_2} \\x_1^{\text{ДНФ}} &= \overline{a_0 \bar{a}_1 \bar{a}_2 \vee a_0 \bar{a}_1 a_2} = \overline{a_0 \bar{a}_1 \bar{a}_2} \cdot \overline{a_0 \bar{a}_1 a_2} \\x_2^{\text{ДНФ}} &= \overline{\bar{a}_0 \bar{a}_1 \bar{a}_2 \vee \bar{a}_0 a_1 \bar{a}_2 \vee \bar{a}_0 a_1 a_2 \vee a_0 \bar{a}_1 \bar{a}_2} = \overline{\bar{a}_0 \bar{a}_1 \bar{a}_2} \cdot \overline{\bar{a}_0 a_1 \bar{a}_2} \cdot \overline{\bar{a}_0 a_1 a_2} \cdot \overline{a_0 \bar{a}_1 \bar{a}_2} \\x_3^{\text{ДНФ}} &= \overline{a_0 \bar{a}_1 \bar{a}_2}\end{aligned}$$

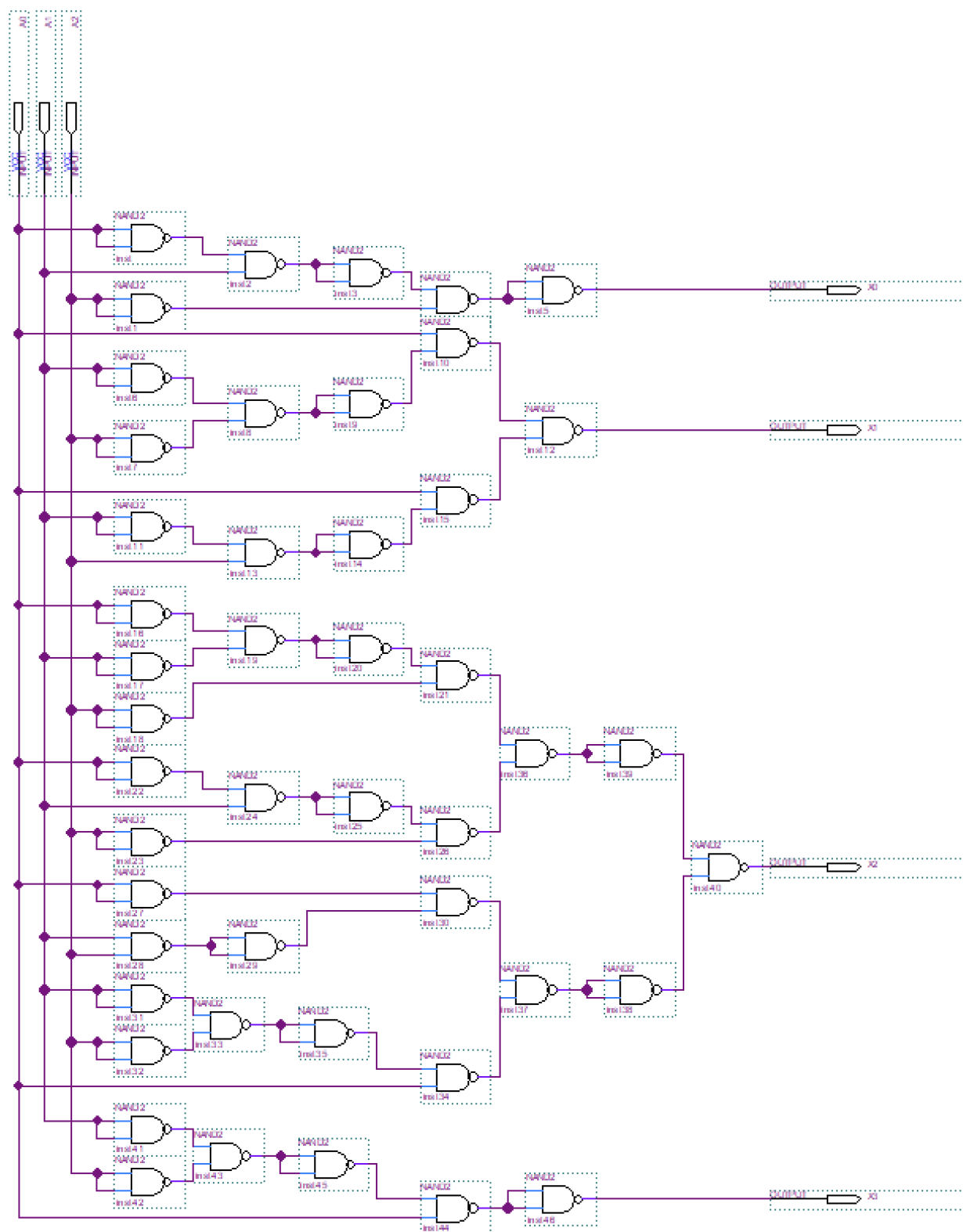


Рисунок 2.1 – Схема декодера для студенческого билета 20L274.

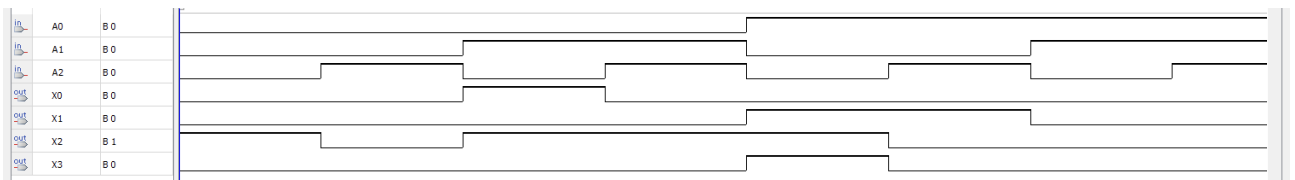


Рисунок 2.2 – Вывод декодера для студенческого билета 20L274.

2.2 Счётчик для 6 знаков.

Построим счётчик для 6 знаков.

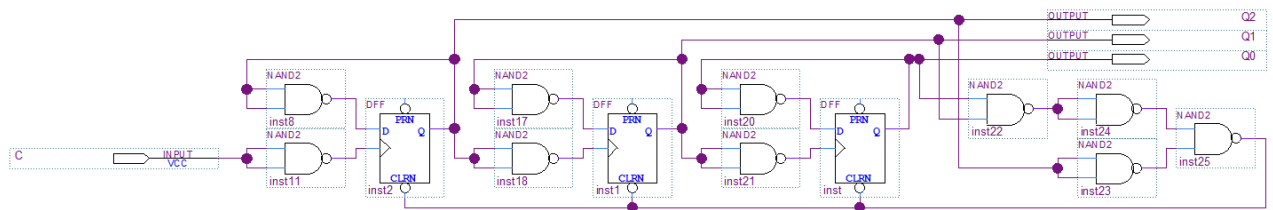


Рисунок 2.3 – Схема счётчика на D-триггерах для 6 знаков.

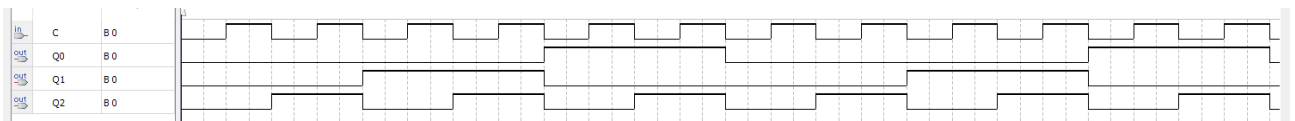


Рисунок 2.4 – Вывод счётчика на D-триггерах для 6 знаков.

Как видно из графика 2.4, как только значение доходит до 1 1 0 происходит сброс значений. Пострим финальную схему для вывода номера билета.

2.3 Общая схема.

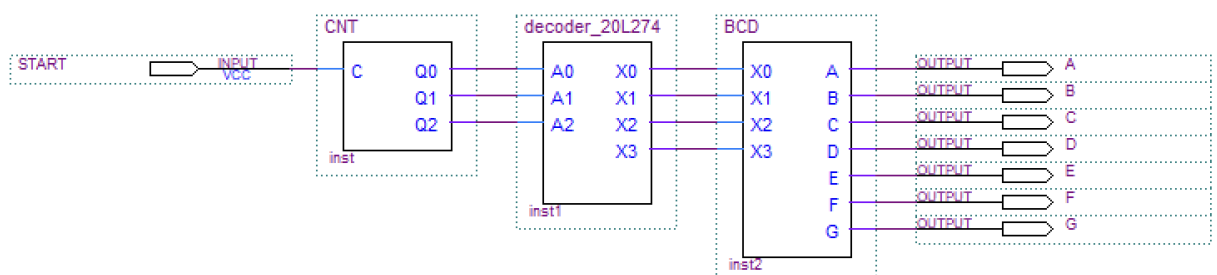


Рисунок 2.5 – Схема вывода билета.

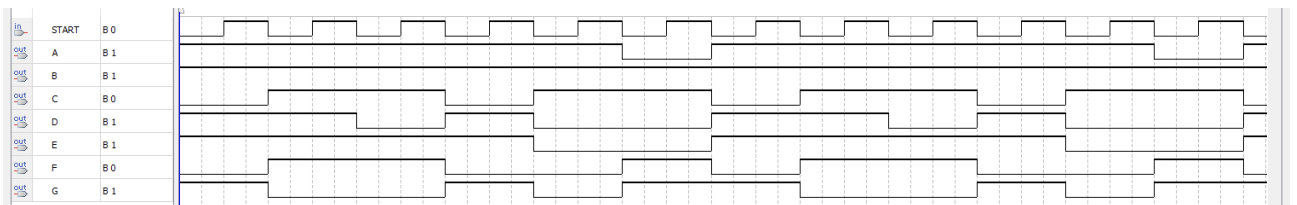


Рисунок 2.6 – Вывод вывода билета.

3 Преобразователь кода, на выходе которого формируется последовательность бинарных чисел соответствующая цифрам студенческого билета.