BBM233: LOGIC DESIGN LAB
2023 FALL
EXPERIMENT 3:
BCD-TO-7 SEGMENT DISPLAY DECODERS

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1 Purpose

In this experiment a BCD-to-7 segment display decoder will be designed and constructed.

2 Introduction

A 7-segment display consists of seven LEDs arranged in a rectangular fashion. Each of the seven LEDs is called a segment because when illuminated the segment forms part of a numerical digit to be displayed. Each one of the seven LEDs in the display is given a positional segment with one of its connection pins being brought straight out of the rectangular plastic package. These individually LED pins are labelled from a through to g representing each individual LED. The other LED pins are connected together and wired to form a common pin.[1]

The displays common pin is generally used to identify which type of 7-segment display it is. As each LED has two connecting pins, one called the “Anode” and the other called the “Cathode”, there are therefore two types of LED 7-segment display called: Common Cathode (CC) and Common Anode (CA). The difference between the two displays, is that the common cathode has all the cathodes of the 7-segments connected directly together and the common anode has all the anodes of the 7-segments connected together and is illuminated as follows. In a common cathode display, all LED segment cathodes connect to ground (logic "0"), and each segment lights up with a "HIGH" (logic "1") signal and a current-limiting resistor applied to its anode terminals (a-g), while in a common anode display, all LED segment anodes connect to logic "1," and individual segments (a-g) light up with a ground (logic "0" or "LOW") signal applied to their cathodes through a suitable current-limiting resistor.[2] [1]

To use a 7-segment display with ease, a 7-segment display decoder is needed. The primary function of a 7-segment display decoder is to convert the input data into the appropriate signals that can drive the display. To achieve this, the decoder analyzes the input data and maps it to a specific combination of segment control signals. This mapping process can be implemented using combinational logic circuits. For example, consider a BCD to 7-segment display decoder. The BCD input consists of four binary digits, representing a decimal number between 0 and 9. The decoder's task is to convert this BCD input into the appropriate segment control signals. This can be achieved by designing a combinational logic circuit that generates the correct combination of signals for each BCD input.[3] [2]

3 Procedure

1 - We will start by creating a truth table for each display segment, with a focus on the common cathode configuration. It's important to understand that the common cathode and common anode truth table setups differ significantly.

In common cathode displays, we use a "HIGH" signal to light up a specific segment, whereas common anode displays operate in the opposite way, as we discussed earlier. This contrast means that the truth tables for common cathode and common anode setups will have complementary patterns.[4] Furthermore, as we are only dealing with numerical digits (0-9), any additional logical combinations beyond this range will

[1] Answer to "What is a 7-segment display and how it works?"

[2] Answer to "How many types of 7-segment display are there and what sets them apart?"

[3] Answer to "Why do we need a decoder to use 7-segment displays?"

[4] Answer to "If you used a common anode instead of common cathode, would there be any change in truth table, and if so, how?"

not be taken into account and will be classified as "don't cares" (X) in the truth table. This designation implies that for these specific inputs, the LED output is undefined and the led behavior may appear random, which is not intentional.[5]

2 - For each output (a-g), we will simplify the function using a Karnaugh Map to obtain a minimized Boolean function in sum-of-products form.

3 - Lastly we will implement a circuit diagram for the 7448 BCD-to-7 segment display decoder for common cathode displays from scratch.[3]

4 Results

4.1 Truth Table

Referring to the procedure, we can create the 7448 decoder's truth table as follows:

A	B	C	D	a	b	c	d	e	f	g
0	0	0	0	1	1	1	1	1	1	0
0	0	0	1	0	1	1	0	0	0	0
0	0	1	0	1	1	0	1	1	0	1
0	0	1	1	1	1	1	1	0	0	1
0	1	0	0	0	1	1	0	0	1	1
0	1	0	1	1	0	1	1	0	1	1
0	1	1	0	0	0	1	1	1	1	1
0	1	1	1	1	1	1	0	0	0	0
1	0	0	0	1	1	1	1	1	1	1
1	0	0	1	1	1	1	0	0	1	1
1	0	1	0	X	X	X	X	X	X	X
1	0	1	1	X	X	X	X	X	X	X
1	1	0	0	X	X	X	X	X	X	X
1	1	0	1	X	X	X	X	X	X	X
1	1	1	0	X	X	X	X	X	X	X
1	1	1	1	X	X	X	X	X	X	X

Table 1: Truth table of a 7448 decoder

4.2 Karnaugh Maps

Referring to the procedure and the truth table, we can obtain minimized Boolean functions in sum-of-products form for each output (a-g) using Karnaugh Maps. The

[5] Answer to "What happens if you apply inputs for which you used don't cares?"

Karnaugh Maps will be on the left-hand side and the minimized Boolean functions will be on the right-hand side for the next subsections.

4.2.1 Output: a

AB \ CD	00	01	11	10
00	1	0	1	1
01	0	1	1	0
11	X	X	X	X
10	1	1	X	X

Simplified function in sum-of-products:

$$a(A,B,C,D) = A + BD + \bar{B}\bar{D} + CD$$

4.2.2 Output: b

AB \ CD	00	01	11	10
00	1	1	1	1
01	1	0	1	0
11	X	X	X	X
10	1	1	X	X

Simplified function in sum-of-products:

$$b(B,C,D) = \bar{B} + CD + \bar{C}\bar{D}$$

4.2.3 Output: c

AB \ CD	00	01	11	10
00	1	1	1	0
01	1	1	1	1
11	X	X	X	X
10	1	1	X	X

Simplified function in sum-of-products:

$$c(B,C,D) = B + \bar{C} + D$$

4.2.4 Output: d

AB \ CD	00	01	11	10
00	1	0	1	1
01	0	1	0	1
11	X	X	X	X
10	1	0	X	X

Simplified function in sum-of-products:

$$d(B,C,D) = \bar{B}\bar{D} + \bar{B}C + C\bar{D} + B\bar{C}D$$

4.2.5 Output: e

AB \ CD	00	01	11	10
00	1	0	0	1
01	0	0	0	1
11	X	X	X	X
10	1	0	X	X

Simplified function in sum-of-products:

$$e(B,C,D) = \bar{B}\bar{D} + C\bar{D}$$

4.2.6 Output: f

AB \ CD	00	01	11	10
00	1	0	0	0
01	1	1	0	1
11	X	X	X	X
10	1	1	X	X

Simplified function in sum-of-products:

$$f(A,B,C,D) = A + B\bar{C} + B\bar{D} + \bar{C}\bar{D}$$

4.2.7 Output: g

AB \ CD	00	01	11	10
00	0	0	1	1
01	1	1	0	1
11	X	X	X	X
10	1	1	X	X

Simplified function in sum-of-products:

$$g(A,B,C,D) = A + B\bar{C} + \bar{B}C + C\bar{D}$$

4.3 Circuit Implementation

Referring to the simplified functions, we can implement the 7448 decoder as:

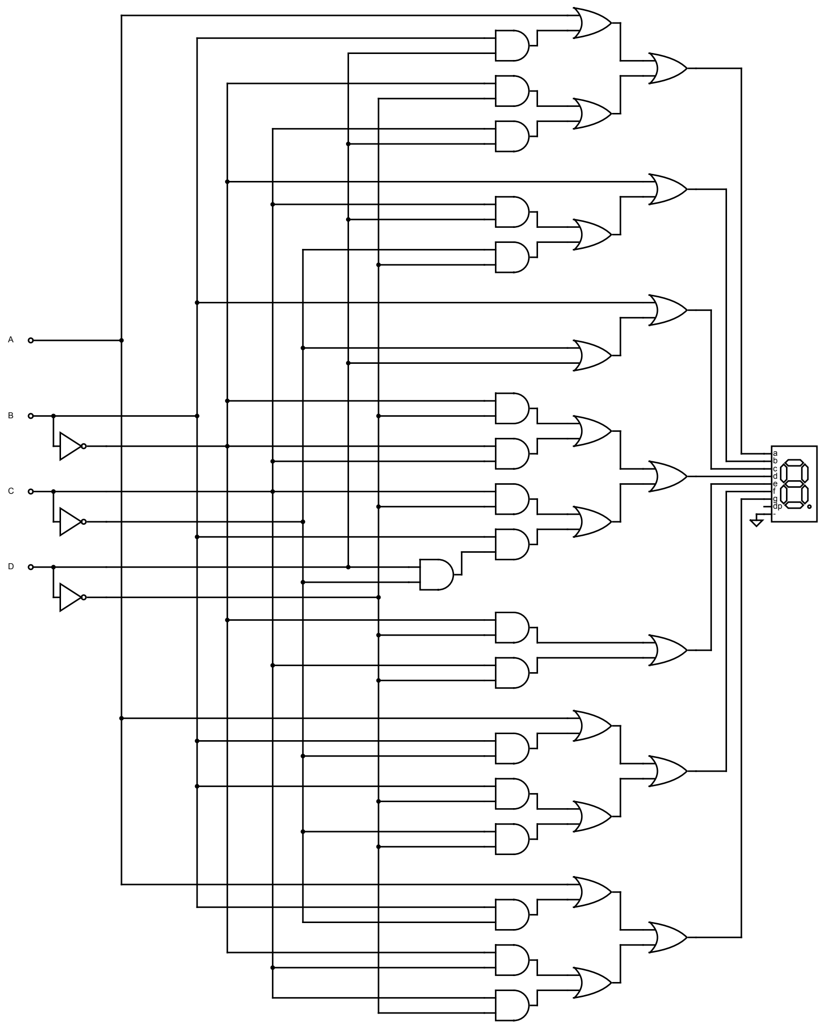

Figure 1: Circuit diagram of a 7448 decoder

References

[1] Electronics Tutorials. *7-segment Display*. Accessed on December 5, 2023. URL: `https://www.electronics-tutorials.ws/blog/7-segment-display-tutorial.html`.

[2] Electricity – Magnetism. *7-segment Display Decoder*. Accessed on December 5, 2023. URL: `https://www.electricity-magnetism.org/7-segment-display-decoder`.

[3] Hacettepe University. *BBM233 Digital Design Lab Experiment 1 - Basic Logic Gates*. 2023.