BCD To Decimal Digit With 7-Segment Display

By Jake D. Karas

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10/28/2021

Objective:

The objective of this lab was to design a logic circuit that causes a 7-segment display to show all 10 single digit decimal numbers based on the binary-coded-decimal (BCD) input combination fed into the circuit. In software, this was completed using a common cathode 7-segment display and numerous logic gates, while in hardware, a common anode display and a decoder were used to build the same circuit with fewer individual components.

Equipment Used:

- 74LS08 quad 2-input AND TTL IC
- 74LS32 quad 2-input OR TTL IC
- 74LS86 2-input XOR TTL IC
- 74LS266 2-input XNOR TTL IC
- 74LS47 Common Anode 7 Segment Display Decoder
- 7-segment display (common anode)
- DC Voltmeter
- +5V Power supply
- Bread Board
- Light Emitting Diode
- Connecting Wires

Methodology:

As a general rule of thumb, the truth table of a logic function is found first when only given a circuit description. However, as there are seven outputs, being each segment on the 7-segment display, instead of just one or two output variables, seven of these were accounted for in the main truth table. To then find the simplified boolean equation for each output, seven K-Maps were constructed and solved, one for each output. Don't care terms were used in place of the combinations for decimal numbers 10 to 16, as these are illegal inputs for BCD. Once each equation was found, XOR/XNOR rules were applied to attempt to further simplify the equations.

With the seven boolean equations determined, the gate-level circuit was designed in Multisim utilizing many logic gates. To keep the circuit clean, the inputs and their rails were kept on the lefthand side of the workspace, the logic gates were placed in the center, and the 7-segment display itself was at the top-right corner. The gates that control each individual output were kept in clusters to make it easier to trace the sub-circuits for each output without the circuit appearing cross-wired.

For the tangible version of the BCD-controlled 7-segment display circuit, a simple decoder replaced the complex gate-level design from the software version. The 74LS47 IC chip, which served as the decoder itself, is a slightly longer IC chip than the ones for the individual logic gates, with one additional pin on each side of itself. Although the outputs were associated with completely random pins on this chip, this version of the circuit requires many fewer wires than the one designed on Multisim. The other major difference is that the 7-segment display was common anode, meaning that a logic '0' is required to light a particular segment rather than a ‘1’ used with a common cathode display.

Truth Table):

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

K-Maps:
Segment A:

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AB \ CD	00	01	11	10
00	1 0	0 1	1 3	1 2
01	0 4	1 5	1 7	0 6
11	X 12	X 13	X 15	X 14
10	1 8	1 9	X 11	X 10

$$a = A + CD + BD + B'D' = A + CD + (B \oplus D)'$$

Segment B:

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CD AB	00	01	11	10
00	1 0	1 1	1 3	1 2
01	1 4	0 5	1 7	0 6
11	X 12	X 13	X 15	X 14
10	1 8	1 9	X 11	X 10

$$b = A + B' + C'D' + CD = A + B' + (C \oplus D)'$$

Segment C:

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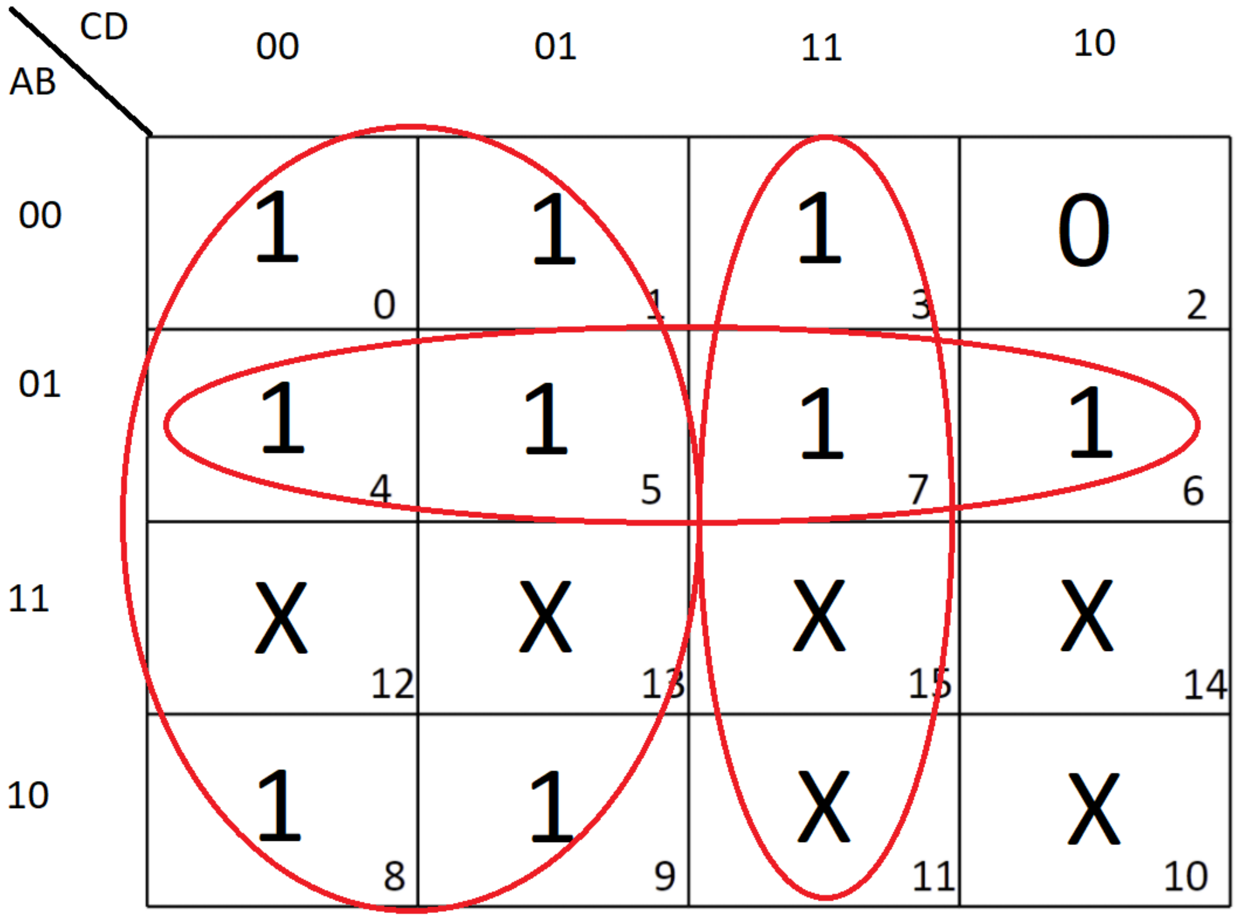

$c = C' + CD + A'B$

Segment D:

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AB \ CD	00	01	11	10
00	1 (0)	0 (1)	1 (3)	1 (2)
01	0 (4)	1 (5)	0 (7)	1 (6)
11	X (12)	X (13)	X (15)	X (14)
10	1 (8)	0 (9)	X (11)	X (10)

$$d = B'D' + CD' + A'B'C + BC'D$$

Segment E:

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AB \ CD	00	01	11	10
00	1 0	0 1	0 3	1 2
01	0 4	0 5	0 7	1 6
11	X 12	X 13	X 15	X 14
10	1 8	0 9	X 11	X 10

$$e = B'D' + CD'$$

Segment F:

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AB \ CD	00	01	11	10
00	1_{0}	0_{1}	0_{3}	0_{2}
01	1_{4}	1_{5}	0_{7}	1_{6}
11	X_{12}	X_{13}	X_{15}	X_{14}
10	1_{8}	1_{9}	X_{11}	X_{10}

$$f = A + BC' + BD' + C'D'$$

Segment G:

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AB \ CD	00	01	11	10
00	0 (0)	0 (1)	1 (3)	1 (2)
01	1 (4)	1 (5)	0 (7)	1 (6)
11	X (12)	X (13)	X (15)	X (14)
10	1 (8)	1 (9)	X (11)	X (10)

$$g = A + CD' + BC' + B'C = A + CD' + (B \oplus C)$$

Multisim Circuit Diagram:

Complete Circuit:

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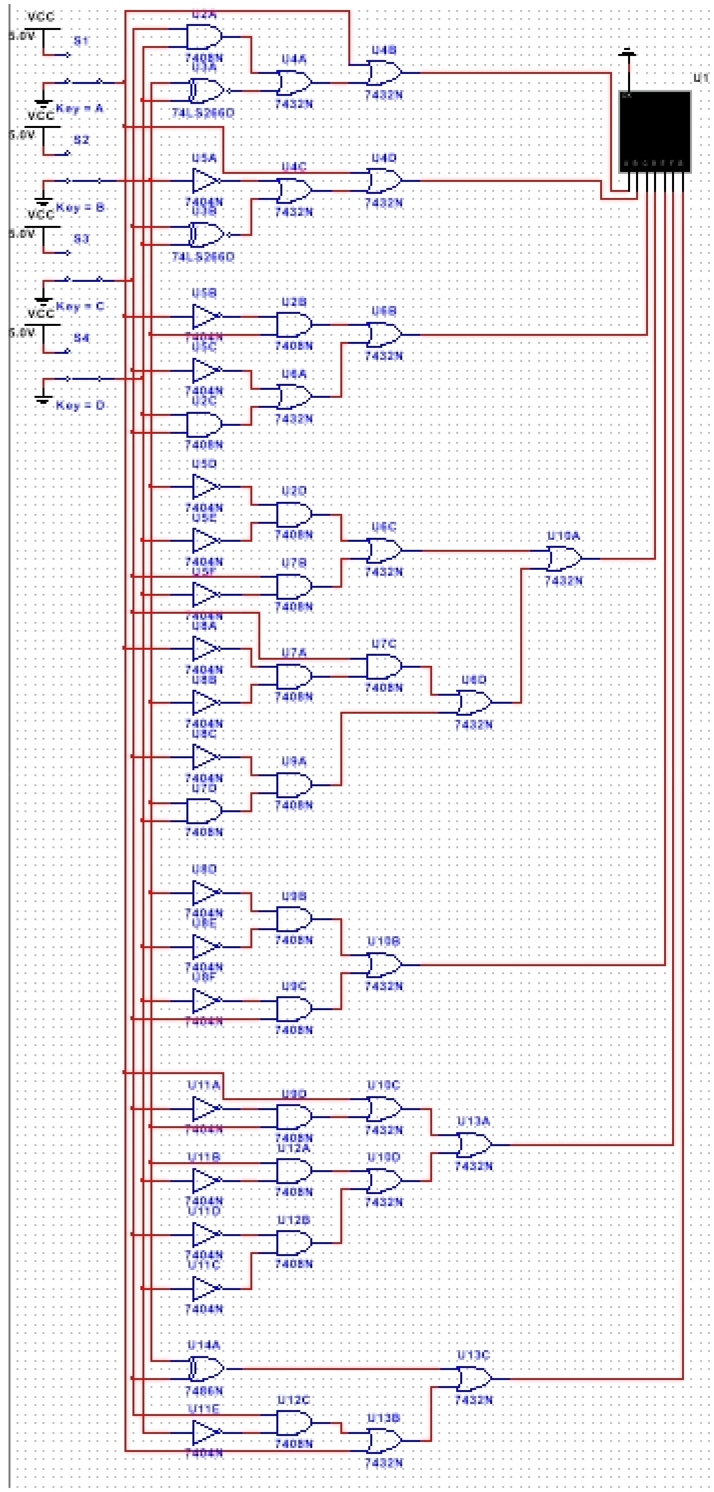

Close-Ups:
*Note: Rail Order (Left To Right) - ACDB
Segment A:

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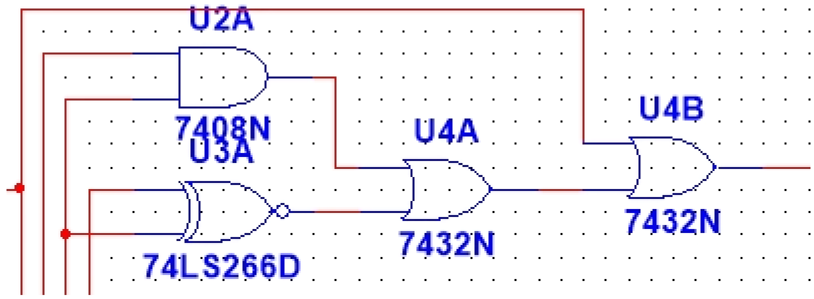
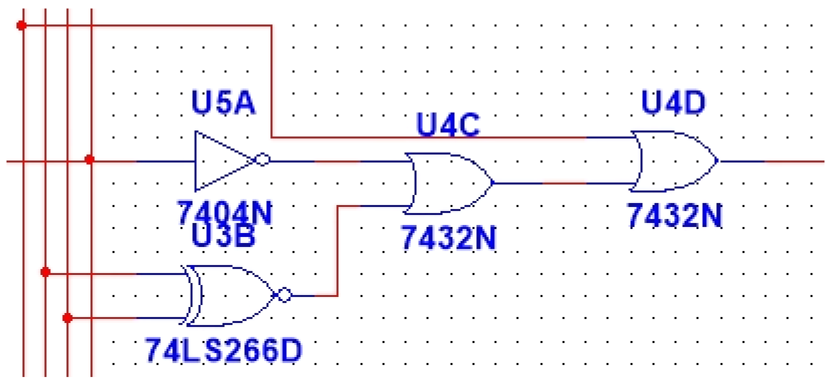


Segment B:



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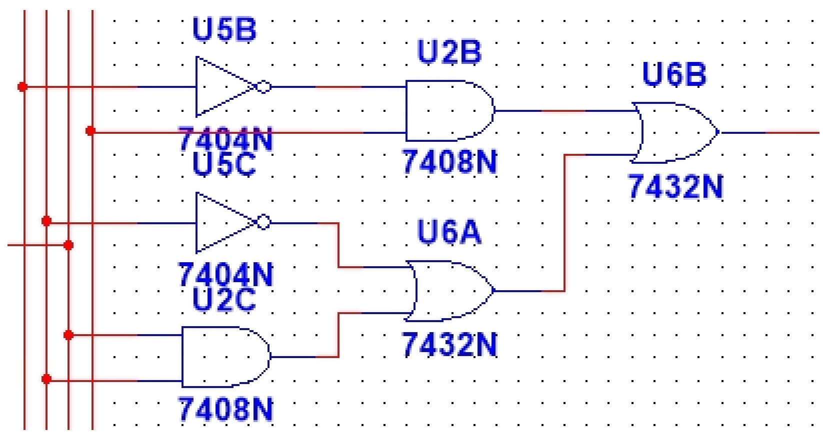

Segment D:

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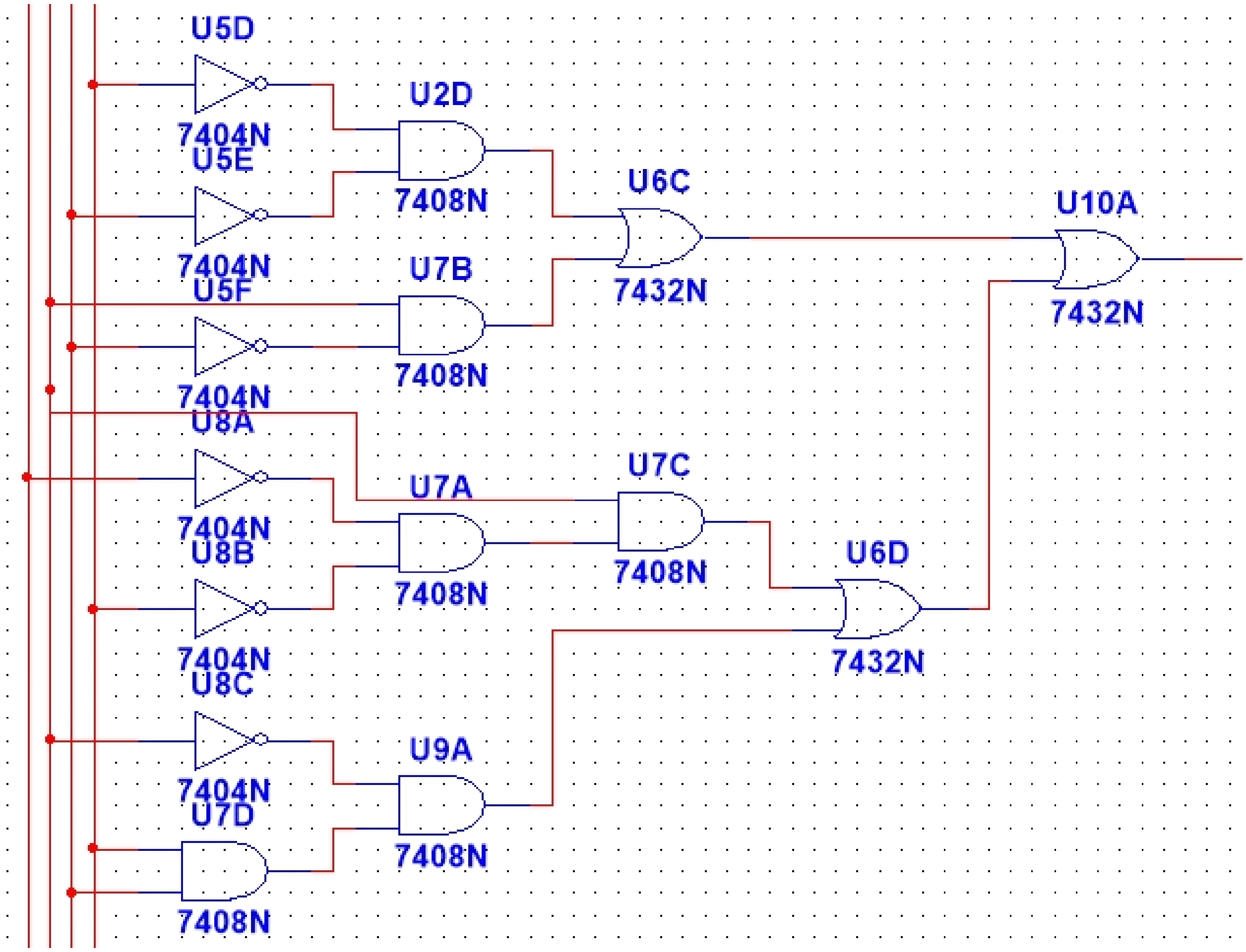
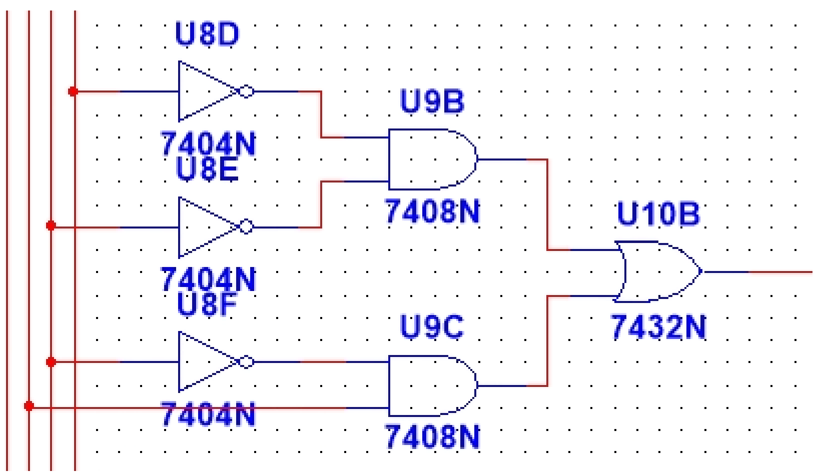


Segment E:



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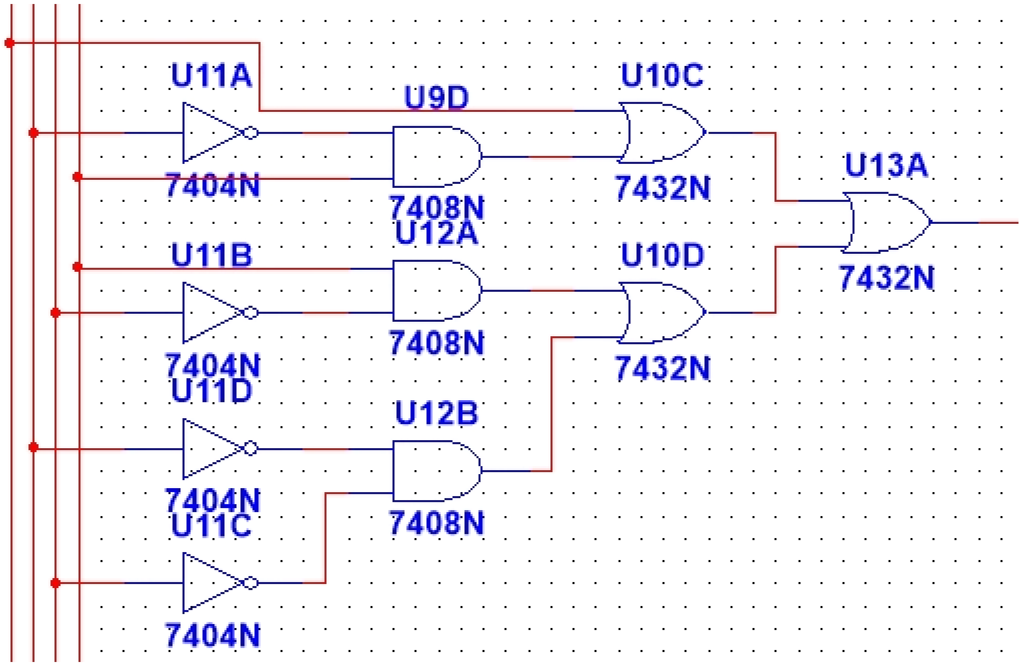
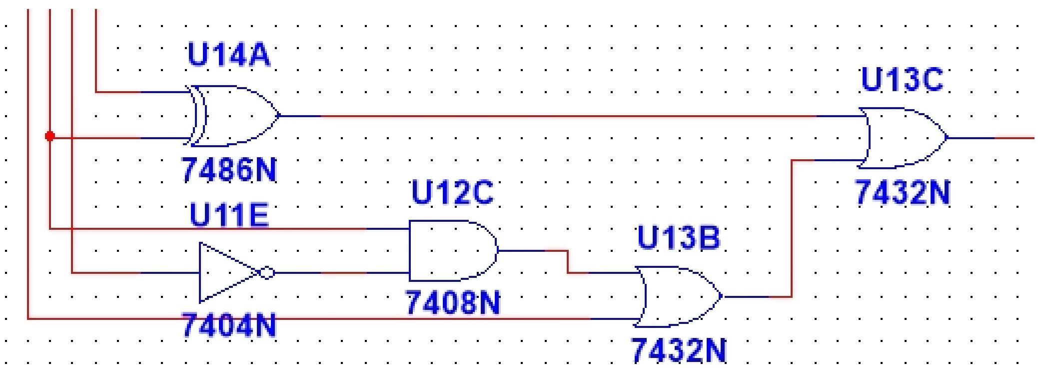


Segment G:



Conclusion:

7-segment displays are a component with 7 individual outputs that can light up to display a particular number or character by turning on particular combinations of the seven segments. This lab demonstrated that there are multiple devices and methods to make one display the decimal number associated with the BCD input combination it is fed. Both gate-level and block-level modeling yield the same outputs, although designing at block-level is much easier than doing so at gate-level.