An Exercise in Circuit Design

Numbers are often displayed on small LCD (Liquid Crystal Display) screens such as those found on digital watches and car odometers.

For each number there are seven bars that can be bright or dim; which combination of bars that is lit up determines what number is displayed (see figure 1).

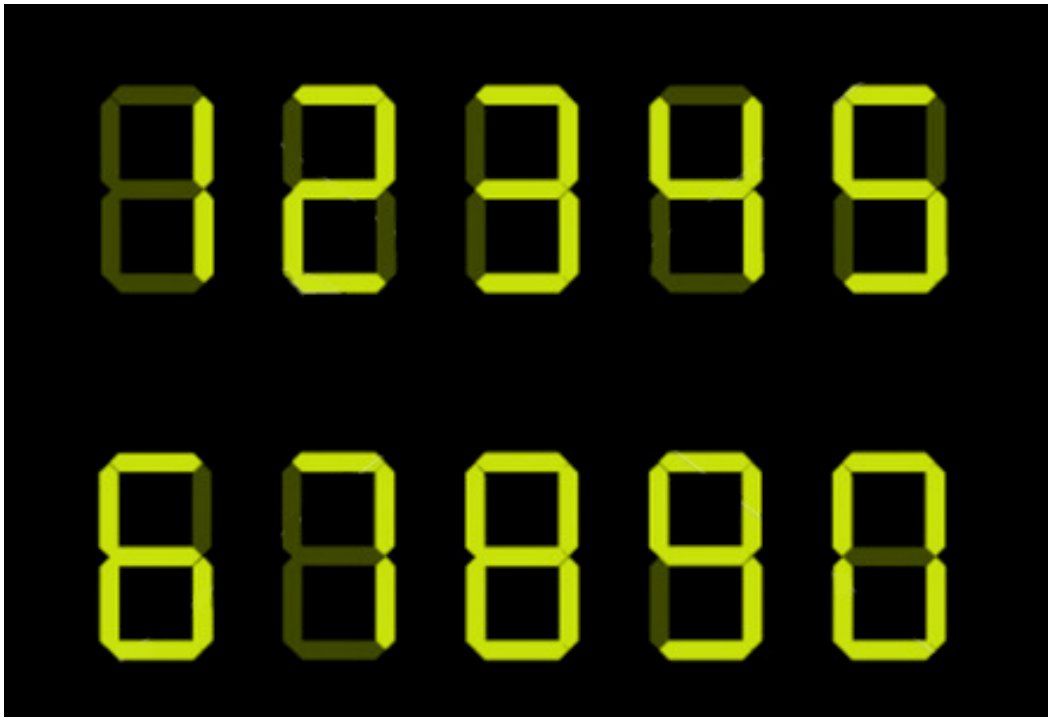


figure 1

In order to make an LCD number reflect the value of a four-bit Boolean number, we need a circuit with four inputs (one for each bit of the Boolean number) and seven outputs (one for each bar in the LCD number). To design such a circuit, we need a Karnaugh map and its associated Boolean expression for each output.

For example, let's create the K-map for the middle bar of the LCD number. It is lit up (the output is 1) for numbers 2, 3, 4, 5, 6, 8, and 9, and not lit up (the output is 0) for numbers 1, 7, and 0. Figure 2 shows the truth table for the middle bar.

A	B	C	D	output
0	0	0	0	0
0	0	0	1	0
0	0	1	0	1
0	0	1	1	1
0	1	0	0	1
0	1	0	1	1
0	1	1	0	1
0	1	1	1	0
1	0	0	0	1
1	0	0	1	1

figure 2

© Billingsley 2012-2018

What should the output be for 1010 through 1111? In theory, anyway, the inputs A, B, C, and D will never indicate a number above nine (1001), so we don't care what the output would be if they did. In those situations, we use a *don't care* in the truth table and its associated Karnaugh map., as shown in figures 3 and 4.

A	B	C	D	output
0	0	0	0	0
0	0	0	1	0
0	0	1	0	1
0	0	1	1	1
0	1	0	0	1
0	1	0	1	1
0	1	1	0	1
0	1	1	1	0
1	0	0	0	1
1	0	0	1	1
1	0	1	0	d
1	0	1	1	d
1	1	0	0	d
1	1	0	1	d
1	1	1	0	d
1	1	1	1	d

figure 3

	AB	AB'	A'B'	A'B
CD	d	d	1	0
CD'	d	d	1	1
C'D'	d	1	0	1
C'D	d	1	0	1

figure 4

The concept of *don't cares* is very useful; each don't care can be treated as either a 0 or a 1 when grouping cells in the K-map. This is helpful if it allows us to form a larger group than would otherwise be possible without the don't cares. There is no requirement to group all or any of the don't cares. Only use them in a group if it simplifies the logic. From figure 5 we can see that the sum-of-products expression for the middle bar of the LCD number is A + B'C + CD' + BC'. This is much simpler than if we had tried to avoid the don't cares.

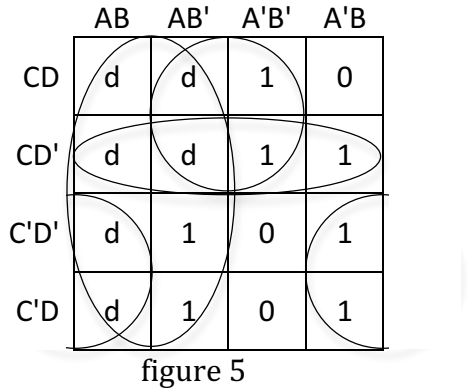


figure 5

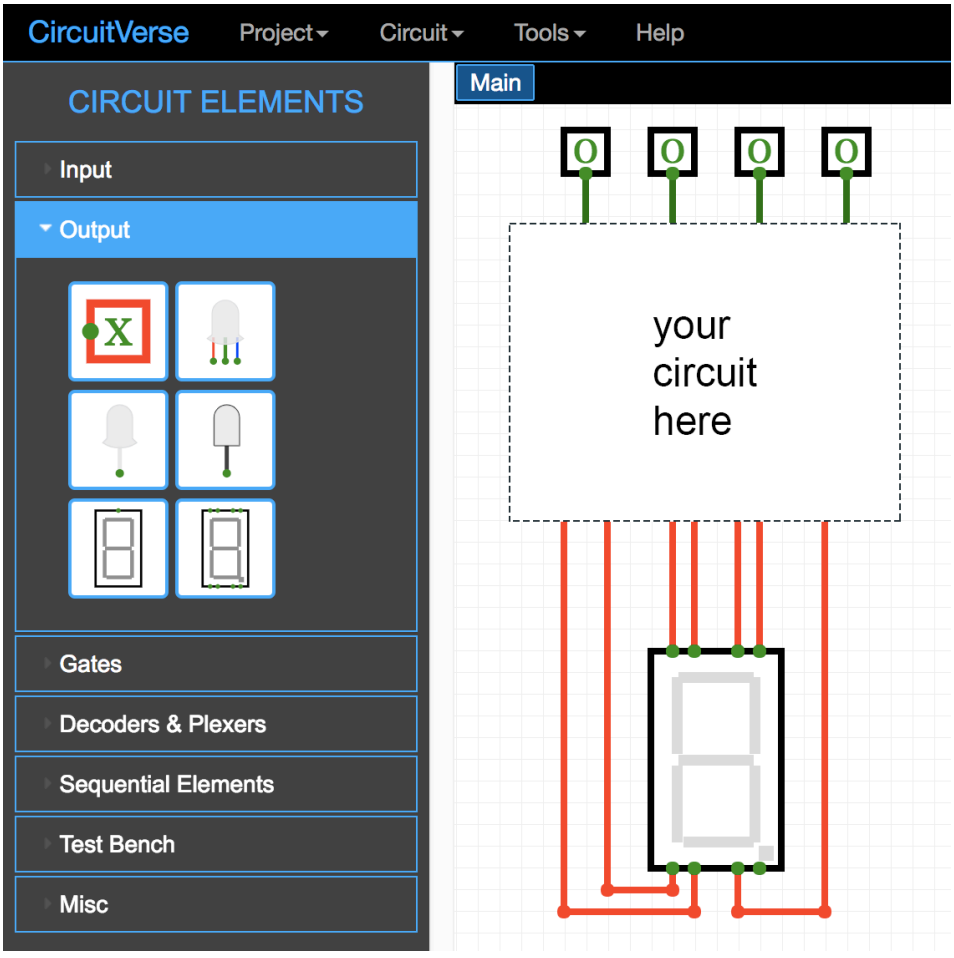
© Billingsley 2012-2018

Exercise:

a. Create truth tables and Karnaugh maps for the other six bars of the LCD digit.

b. Compare the Boolean expressions for each of the seven outputs. Are there any terms that two or more expressions have in common? Note these; there is no sense in duplicating these when generating the circuit.

c. Use CircuitVerse to design a circuit based on the seven Boolean expressions you generated for the LCD digit. CircuitVerse provides a 7-Segment Display; connect this to the seven outputs from your circuit. Test your circuit thoroughly.



Reflection questions: What happens when you set the input to be 1010? Or 1011, 1100, 1101, 1110, or 1111? Do you care? Why or why not?

This will be automatically turned in on CircuitVerse if you create your circuit in the correct group. *(no need to turn in your K-maps or answers to the reflection questions)*

© Billingsley 2012-2018