L_4

Laboratory IV

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1 Details of Lab 4

Q. 1 **C**. Change the gate-delay of the AND gate to 0, 3, 5. Observe the output changes with respect to the changes of input x.

The output mimics the input x with an offset along the time axis associated with the time of the gate delay. E.g. a 3ns gate delay results in a 3ns shift between the input x and the output.

Q. 2 Draw the circuit to implement the Boolean function as follows

$$f(a, b, c, d) = (a' + b)'c + d(b' + ac) \tag{1}$$

according to the expression directly. Connect b, c and d to binary switches and make them to be 0, 1 and 0, respectively. Connect a to a clock.

Q. 2.1 According to your simulation, how much time does it take for the change of a to be reflected in the output f?

Five nanoseconds.

Q. 2.2 Change the gate delays of all the gates along the path from a to f to 0, 2 and 4. Verify that the total delays from a to f you observed are correct.

For a 0ns delay, a and f corresponded exactly. For a 2ns delay, a and f differed by a 10ns delay. For a 5ns delay, a and f differed by a 45ns delay.

Q. 3 Here follows the logical truth table (figure 1) of equation 1.

Using figure 1 we can express equation 1 as the sum of minterms shown in equation 2.

$$f_{\sum \text{minterms}}(a, b, c, d) = a'b'c'd + a'b'cd + ab'c'd + ab'cd' + ab'cd + abcd \tag{2}$$

Q. 4 Compare the circuits.

Testing all 16 possible input combinations resulted in identical outputs if the gate delay is set to 0ns.

a	b	c	d	$a'+b$	$(a'+b)'c$	ac	$b'+ac$	$d(b'+ac)$	$(a'+b)'c+d(b'+ac)$
0	0	0	0	1	0	0	1	0	0
0	0	0	1	1	0	0	1	1	1
0	0	1	0	1	0	0	1	0	0
0	0	1	1	1	0	0	1	1	1
0	1	0	0	1	0	0	0	0	0
0	1	0	1	1	0	0	0	0	0
0	1	1	0	1	0	0	0	0	0
0	1	1	1	1	0	0	0	0	0
1	0	0	0	0	0	0	1	0	0
1	0	0	1	0	0	0	1	1	1
1	0	1	0	0	1	1	1	0	1
1	0	1	1	0	1	1	1	1	1
1	1	0	0	1	0	0	0	0	0
1	1	0	1	1	0	0	0	0	0
1	1	1	0	1	0	1	1	0	0
1	1	1	1	1	0	1	1	1	1

Figure 1: Truth table for equation 1.

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

Figure 2: Karnaugh map of figure 1.

1.1 Extraneous Information Involving Question 3

Here follows the Karnaugh map (figure 2) and direct circuit implementation (figure 3) of said K. map for equation 1.

Which shows that equation 1 can be represented as the sum of minterms as follows:

$$f(a,b,c,d) = b'd + acd + ab'c \tag{3}$$

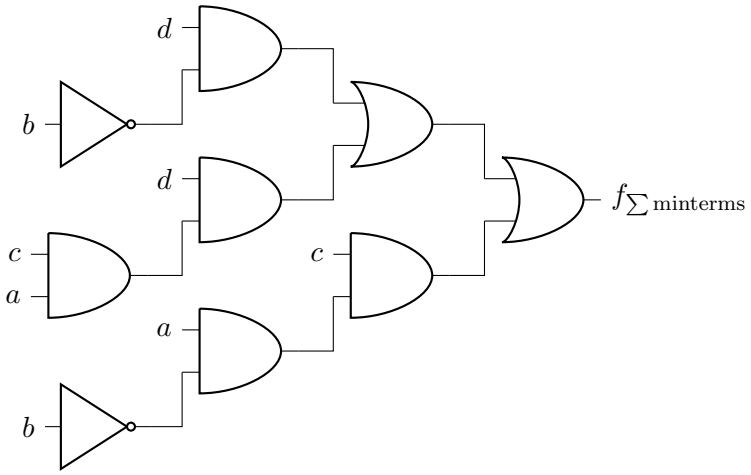

Figure 3: Circuit diagram for equation 1 after reduction to sum of midterms.