

# EE709 End-semester exam.

## To be submitted by 8 May, 2021 2355

This is a take-home exam. You are expected to solve it *by yourself*, using reference material provided in class.

1. You are asked to implement a *majority* function on 5 input variables. The output of the function is 1 if and only if at least 3 of the inputs are 1.
  - (a) Implement the function using only 2-input NAND gates (3 marks).
  - (b) Implement the function using only 2-input NOR gates (3 marks).
  - (c) Implement the function using only 2-to-1 multiplexors (4 marks).

In each case, you are expected to draw the final circuit diagram.

2. Consider the following system of boolean functions:

$$\begin{aligned}y_1 &= x_1 \oplus x_2 \oplus x_3 \oplus x_4 \\y_2 &= (x_1.x_2) \oplus (x_2.x_3) \oplus (x_3.x_4) \oplus (x_1.x_4) \\y_3 &= (x_1.x_2.x_3) \oplus (x_2.x_3.x_4) \oplus (x_1.x_3.x_4)\end{aligned}$$

This describes a function from  $\mathbf{B}_2^4$  to  $\mathbf{B}_2^3$ .

- (a) Let  $A$  be the set defined by the formula  $(x_1.x_2) + (x_3.x_4)$ . Using the BDD package, find the image of  $A$  under this function. (5 marks)
- (b) Let  $B$  be the set defined by the formula  $(y_1.y_2) + (y_2.y_3)$ . Using the BDD package, find the pre-image of  $B$  under this function. (5 marks)

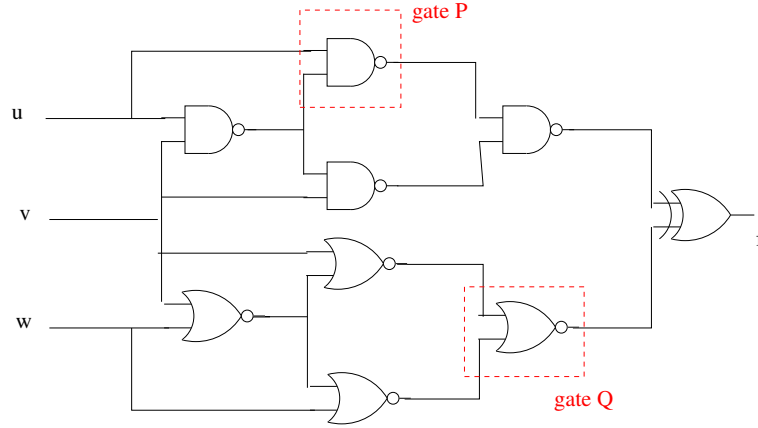


Figure 1: Test generation.

In each case, submit you code together with the generated output.

3. Consider the circuit shown in Figure 1. In this circuit, there are two possible faults that can occur. In the first fault, the NAND gate P can behave like a NOR gate. In the second fault, the NOR gate Q can behave like a NAND gate. Using the MINISAT package, find tests to detect each of these faults. Submit your code and run logs. (5 + 5).
4. Consider the Mealy state machine described by the following equations:

$$\begin{aligned}
 q_0(k+1) &= x_1(k) \oplus x_2(k) \oplus q_1(k) \\
 q_1(k+1) &= x_2(k) \oplus q_0(k) \\
 y(k) &= x_1(k) + (q_0(k) \oplus q_1(k))
 \end{aligned}$$

Assume that  $q_0(0) = q_1(0) = 0$ .

- (a) Find (using the BDD package) the set of reachable states starting from this initial state. (5 marks)
- (b) Using the MINISAT package, determine if the following sequence of output values (at  $y$ ) can occur in this state machine? If yes, find an input sequence (at  $x_1$  and  $x_2$ ) which creates this output sequence. (5 marks)

0, 1, 1, 0, 1, 0

In each case, submit your code and run logs.

5. Write a short essay (300 words) outlining the concepts of defects, fault models and errors in CMOS circuits. (10)