CS2100 Computer Organization

AY2024/25 Semester 1

Assignment 2

(Deadline: 14 October 2024, Monday, 1pm)

Instructions

1. There are **7** questions in this assignment, with a total of 40 marks.

2. This assignment is due on **Monday, 14 October 2024, 1 pm.** The submission folder will be closed at 1:10 pm, **after which no submission will be accepted and you will receive ZERO for this assignment.**

3. Download the template file **assign2_template** from Canvas and use it to create your submission file.

4. Submit a pdf file named after your Student Number (eg: A0123456X.pdf), with format identical to the template file, to the submission folder.

5. You should do these assignments on your own. Do not discuss the assignment questions with others.

6. Please post on QnA "Assignments" topic if you have any queries.

Part I: MIPS Datapath (20 marks)

Question 1. (15 marks)

Consider the MIPS single-cycle datapath covered in class, where you have the following latencies (ps=10^{-12} seconds). You only need to consider the instructions `lw`, `sw`, `beq`, and `addi`

Register File	ALU	Memory Read	Memory Write
2 ps	4 ps	5 ps	7 ps

Calculate the cycle time and clock frequency of the processor, and the time taken for the `beq` instruction.

Also consider an optimisation where a new Register File takes 1 ps and a new ALU takes 2 ps. Which one would you go for? Explain your answers.

Question 2. (5 marks)

Consider the MIPS data and control path that was covered in class. In this, you wish to add a new I-format instruction called `whatispc $R`, where `$R` is set to be the value of the current PC. What changes do you have to make to the MIPS datapath. Also, state the value of the control signals, including any new signal that you may have added/modified. Be mindful about using as little extra hardware as possible.

Part II. Boolean algebra, logic circuits and simplification (20 marks)

Note that in general, unless otherwise stated, complemented literals are not available. Constants 0 and 1 are always available.
Remember to write · for the AND operation, or mark will be deducted. If you are typing your answers, you may use the full stop (.) for AND and the single quote (') for complement. Do not use other alternative symbols (such as $\sim A$, $\neg A$, $\bar{A}$, etc. for the complement of A, write A' instead).

Unless otherwise stated, workings are not required.

The above instructions apply for subsequent assignment, midterm test and the final exam.

Question 3 (Total: 3 marks)
Given a 6-variable Boolean function $Y(A, B, C, D, E, F)$. Let $M31$ be maxterm 31 and $m29$ be minterm 29 of the function.

Write the simplified Sum-of-Products (SOP) expressions for (a) $M31$, and (b) $m29 \cdot M31$.

(Write your working on page 4 of the template answer file. Your working will not be graded, but it allows us to find out where you went wrong if your answer is incorrect. No working mark or partial credit will be given for incorrect answers.)

Question 4 (Total: 4 marks)
Given the following Boolean functions F, G, H on 4 variables a, b, c, d in sum-of-minterms ($\sum m$) notation or product-of-maxterms ($\prod M$) notation:

$$F(a, b, c, d) = \sum m(5,7,13,15)$$
$$G(a, b, c, d) = \sum m(0,1,4,5)$$
$$H(a, b, c, d) = \prod M(0,4,8,12)$$

Find (a) $F \cdot G'$; and (b) $G' \oplus H$, where $\oplus$ is the exclusive-or (XOR) operation. Write your answer in the $\sum m$ notation.

Question 5 (3 marks)
Given a Boolean function $R(A, B, C, D) = \sum m(2,7,8,13)$, implement R using the fewest number of logic gates. Draw your logic circuit clearly. Logic gates that are available are inverters (NOT gates), AND gates, OR gates, NAND gates, NOR gates, XOR gates and XNOR gates. Except for inverters, all gates have fan-in of 2 (i.e. two inputs).

Question 6 (Total: 7 marks)

Given the 4-variable Boolean function $Z(A,B,C,D) = \sum m(1,2,3,7,11,14) + \sum x(0,6,8,9,15)$ where m are the minterms and x the don't-cares. (You may draw the K-map on page 4 of the template answer file but no marks will be given to it.)

(a) How many prime implicants (PIs) are there on the K-map of Z? [1 mark]

(b) How many essential prime implicants (EPIs) are there on the K-map of Z? [1 mark]

(c) How many distinct simplified SOP expressions are there for Z? [1 mark]

(d) Write out one simplified SOP expression for Z. You are to (1) write the literals with a product term in alphabetical order (eg: $P \cdot Q' \cdot R$ instead of $R \cdot Q' \cdot P$ or $P \cdot R \cdot Q'$), and (2) write the essential prime implicants before the non-essential ones. The order among the essential prime implicants and the order among the non-essential prime implicants do not matter. [2 marks]

(e) Write out one simplified POS expression for Z. The order of literals in a sum term must be in alphabetical order (eg: $U + V' + W'$ instead of $W' + U + V'$ or $U + W' + V'$). [2 marks]

Question 7 (Total: 3 marks)

A mini ALU takes in two 2-bit 2's complement numbers AB and CD as inputs and it performs the subtraction operation $AB - CD$. One of the ALU's outputs is called $IsZero$ which is 1 if the subtraction yields a zero result, or 0 otherwise.

The inputs of the ALU AB and CD comes from the outputs of another device which could only generate the output values of -1, 0 or 1in decimal.

(a) Fill in the truth table in the template file. [1 mark]

(b) Write out the simplified SOP expression for $IsZero$. [2 marks]

=== END OF PAPER ===