CS2100 Assignment #2
AY2024/25 Semester 1
Deadline: Monday, 14 October 2024, 1:00pm
TEMPLATE FOR SUBMISSION (ANSWERS)

Full name: | Tutorial grp: **T**

Q1. (Total: 15 marks)

Cycle time: **18** ps [4 marks]

Clock frequency: **55** GHz [3 marks]

Time taken for `beq` instruction: **11** ps [3 marks]

Optimization: new **ALU** [5 marks]

Explain your answers below.

Cycle time is based on the slowest instruction. That is `sw` and `lw` in this case.

`sw` ➔ Fetch (5 ps) + RegFile (2 ps) + ALU (4 ps) + MemWrite (7 ps) = 18 ps
`lw` ➔ Fetch (5 ps) + RegFile (2 ps) + ALU (4 ps) + MemRead (5 ps) + RegFile (2 ps) = 18 ps

Clock frequency = (1/18) * 10^{12} Hz = **55 GHz**

`beq` ➔ Fetch (5 ps) + RegFile (2 ps) + ALU (4 ps) = **11 ps**

For optimisation, we only look at the slowest instructions.

For `lw`, RegFile reduces by 2 ps and ALU by 2 ps, so max reduction is 2 ps using either.

For `sw`, RegFile reduces by 1 (no write back) and ALU by 2 ps, so max reduction is 2 ps using ALU.

Hence, going with a new ALU is overall better.

Q2. (Total: 5 marks)

Easiest would be to take a line from the PC value and then send it to MemToReg, but this would need changes to MemToReg to take a 3rd input line. This would mean that we would have the following control signals:

RegDst = 0
RegWrite = 1
ALUSrc = X
PCSrc = 0
ALUop = X
MemRead and MemWrite are both 0
MemToReg = 2

Q3. (Total: 3 marks)

(a) $M31 =$ $\boldsymbol{A + B' + C' + D' + E' + F'}$ [1 mark]

(b) $m29 \cdot M31 =$ $\boldsymbol{A' \cdot B \cdot C \cdot D \cdot E' \cdot F}$ [2 marks]

Note that given a minterm mx and a maxterm My on a function with the same n variables, where $x, y \in \{0,1,2,3,4,5, \cdots, 2^n - 1\}$, if $x = y$, then $mx \cdot My = 0$, otherwise $mx \cdot My = mx$. Exercise: prove this.

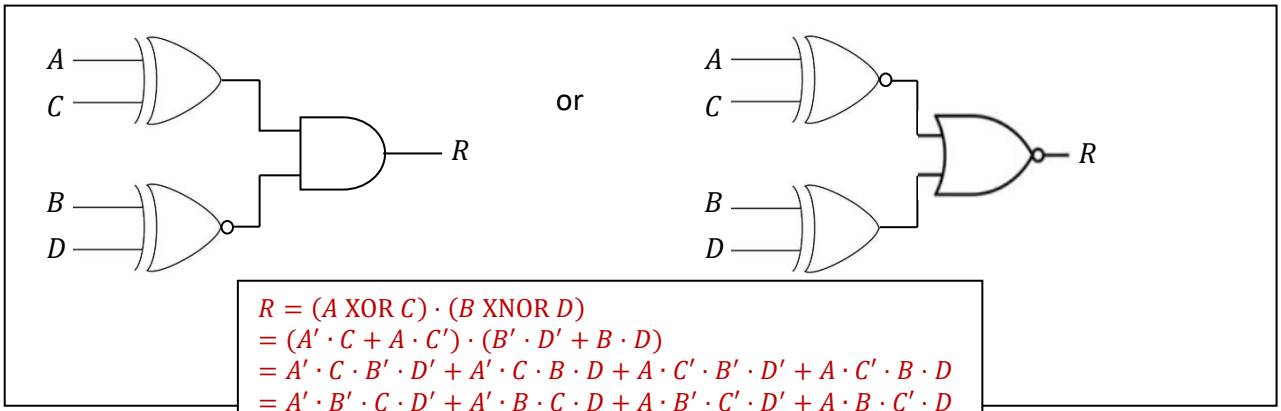
Q4. (Total: 4 marks)

(a) $F \cdot G' = \sum m($ $\boldsymbol{7, 13, 15}$) [2 marks]

(b) $G' \oplus H = \sum m($ $\boldsymbol{1, 5, 8, 12}$) [2 marks]

Q5. (Total: 3 marks)

Draw your circuit below.



$R = (A \text{ XOR } C) \cdot (B \text{ XNOR } D)$
$= (A' \cdot C + A \cdot C') \cdot (B' \cdot D' + B \cdot D)$
$= A' \cdot C \cdot B' \cdot D' + A' \cdot C \cdot B \cdot D + A \cdot C' \cdot B' \cdot D' + A \cdot C' \cdot B \cdot D$
$= A' \cdot B' \cdot C \cdot D' + A' \cdot B \cdot C \cdot D + A \cdot B' \cdot C' \cdot D' + A \cdot B \cdot C' \cdot D$
$= m2 + m7 + m8 + m13$

Q6. (Total: 7 marks)

(a) Number of PIs in the K-map of Z: **6** ($B \cdot C$, $A' \cdot B'$, $B' \cdot C'$, $B' \cdot D$, $A' \cdot C$ and $C \cdot D$.) [1 mark]

(b) Number of EPIs in the K-map of Z: **1** ($B \cdot C$) [1 mark]

(c) Number of distinct simplified SOP expressions for Z: **3** [1 mark]

(d) One simplified SOP expression for Z: [2 marks]

$\boldsymbol{B \cdot C + A' \cdot B' + B' \cdot D}$ or $\boldsymbol{B \cdot C + A' \cdot B' + C \cdot D}$ or $\boldsymbol{B \cdot C + B' \cdot D + A' \cdot C}$

(e) One simplified POS expression for Z: [2 marks]

$\boldsymbol{(B' + C) \cdot (A' + B + D)}$

Q7. (Total:3 marks)

(a) [1 mark]

A	B	C	D	$IsZero$
0	0	0	0	**1**
0	0	0	1	**0**
0	0	1	0	**X**
0	0	1	1	**0**
0	1	0	0	**0**
0	1	0	1	**1**
0	1	1	0	**X**
0	1	1	1	**0**
1	0	0	0	**X**
1	0	0	1	**X**
1	0	1	0	**X**
1	0	1	1	**X**
1	1	0	0	**0**
1	1	0	1	**0**
1	1	1	0	**X**
1	1	1	1	**1**

(b) Simplified SOP expression [2 marks]

$IsZero =$ $\boldsymbol{A \cdot C + B' \cdot D' + A' \cdot B \cdot C' \cdot D}$

Workings

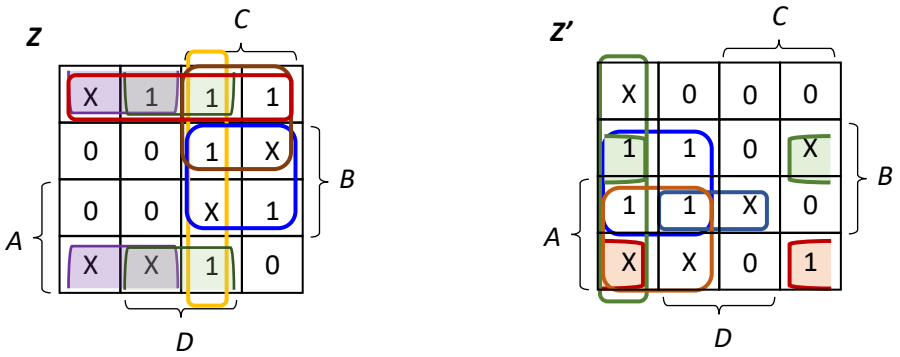
Write your workings here. They will not be graded, but the grader might look at it to figure out where you went wrong.

Workings for Q3

(b)

$m29 \cdot M31 = M31 \cdot m29$ (commutative law)
$= (A + B' + C' + D' + E' + F') \cdot (A' \cdot B \cdot C \cdot D \cdot E' \cdot F)$
$= A \cdot (A' \cdot B \cdot C \cdot D \cdot E' \cdot F) + B' \cdot (A' \cdot B \cdot C \cdot D \cdot E' \cdot F)$
$+C' \cdot (A' \cdot B \cdot C \cdot D \cdot E' \cdot F) + D' \cdot (A' \cdot B \cdot C \cdot D \cdot E' \cdot F)$
$+E' \cdot (A' \cdot B \cdot C \cdot D \cdot E' \cdot F) + F' \cdot (A' \cdot B \cdot C \cdot D \cdot E' \cdot F)$ (distributive law)
$= 0 + 0 + 0 + 0$ (complement law $X \cdot X' = 0$)
$+E' \cdot (A' \cdot B \cdot C \cdot D \cdot E' \cdot F) + F' \cdot (A' \cdot B \cdot C \cdot D \cdot E' \cdot F)$ (
$= (A' \cdot B \cdot C \cdot D \cdot E' \cdot F) + (A' \cdot B \cdot C \cdot D \cdot E' \cdot F)$ (idempotent)
$= (A' \cdot B \cdot C \cdot D \cdot E' \cdot F)$ (idempotent)

K-map for Q6



Working: SOP expression for Z' is $B \cdot C' + A \cdot B' \cdot D'$ (see K-map of Z' above.)

$Z' = B \cdot C' + A \cdot B' \cdot D'$
$Z = (B \cdot C' + A \cdot B' \cdot D')' = (B \cdot C')' \cdot (A \cdot B' \cdot D')' = (B' + C) \cdot (A' + B + D).$