2016 EXAMINATIONS

Lancaster University

Part I (First Year)

SCHOOL OF COMPUTING AND COMMUNICATIONS

SCC.150 Digital Systems (1 hour & 30 Minutes)

- **Answer any <u>THREE</u> out of the four questions.**
- **Use a <u>separate</u> answer book for <u>each</u> question.**

Question 1

1.a Draw an empty template of a 4-variable Karnaugh Map, ensuring that you label the axes correctly.

[3 marks]

1.b i) Use your Karnaugh Map template to simplify the following Boolean expression:

F = A'BC'D + ABC'D + ABCD + AB'CD (note: X' means "not X")

Show all working and give your answer as a (simplified) sum-of-products Boolean expression.

[4 marks]

ii) Using de Morgan's law, manipulate your simplified sum-of-products expression from 1.b.i to generate an equivalent product-of-products expression that is ready to map to a logic circuit implementation that uses only NAND gates.

[4 marks]

iii) Finally, draw the corresponding circuit using 3-input NAND gates.

[4 marks]

1.c i) Write down the truth table for the XOR function in terms of two inputs, A and B.

[2 marks]

ii) Write down the corresponding sum-of-products Boolean function.

[2 marks]

iii) Manipulate your Boolean function to generate an equivalent sum-of-sums expression that is ready to map to a logic circuit implementation that uses only NOR gates.

[3 marks]

iv) Finally, draw the corresponding circuit using 2-input NOR gates.

[3 marks]

[Total 25 Marks]

Question 2

2.a What does the term RISC stand for? What is the characteristic of a RISC architecture? What does MIPS stand for?

[3 marks]

2.b Write a MIPS instruction that initializes $s0 to contain the value 10.

[2 marks]

2.c Convert the instruction below to its MIPS machine language representation (32 bits).

```
sltiu $s1, $t0, 10
```

i) Give the decimal value for each of the four fields of the instruction.

[4 marks]

ii) Then, give the full 32-bit representation in binary.

[4 marks]

iii) Convert the binary representation obtained in question (ii) to hexadecimal.

[2 marks]

Set less than unsigned immediate

sltiu rt, rs, imm

0xb	rs	rt	imm
6	5	5	16

Set register rt to 1 if register rs is less than the sign-extended immediate, and to 0 otherwise.

Name	Register number
$zero	0
$v0–$v1	2–3
$a0–$a3	4–7
$t0–$t7	8–15
$s0–$s7	16–23
$t8–$t9	24–25
$gp	28
$sp	29
$fp	30
$ra	31

Question 2 continues on the next page…

2.d Given the following MIPS assembly code:

i) Describe what the purpose of the program is.

[5 marks]

ii) What will the values be at addresses 0x10010000 to 0x10010010 when the program finishes?

[5 marks]

```
      lui  $t0,0x1001
      add  $t1,$zero,$zero
      addi $t2,$zero,5

loop: sll  $t3,$t1,2
      add  $t3,$t3,$t0
      sw   $t1,0($t3)
      addi $t1,$t1,1
      bne  $t1,$t2,loop
```

[Total 25 Marks]

Question 3

3.a A function **strlen** is required which accepts as input a c string terminated with a NUL character ('\0'). The **strlen** function should return the number of characters that precede the terminating NUL character. Provide the implementation of **strlen**.

```
int strlen(const char* s) {
    << YOUR CODE >>>
}
```

[8 marks]

3.b What is the difference of a struct and a union? Given below is a struct and a union. Give the size in byte for each of the two constructs allocated in memory.

```
struct student {
   char *name;
   int id;
};

union student {
   char *name;
   int id;
};
```

[5 marks]

3.c Memory is organized in regions called Text, Data, Stack and Heap. The program below defines the variables s and t. In which memory region does the content of each variable reside? In which region is memory allocated with **malloc**?

```
#include <stdio.h>
#include <stdlib.h>
int s = 5;
main {
   int t = 6;
   return 0;
}
```

[6 marks]

Question 3 continues on the next page…

3.d State the output of the program below. Please explain the difference between the operators &, &&, | and ||.

```
#include <stdio.h>
char x=0x01;
char y=0x02;
main () {
   printf("Result 1: %d\n",x &  y);
   printf("Result 2: %d\n",x && y);
   printf("Result 3: %d\n",x |  y);
   printf("Result 4: %d\n",x || y);
}
```

[6 marks]

[Total 25 Marks]

Question 4

4.a i) Define the term cache memory and briefly outline the role of cache memory in computer architecture. You may illustrate your answer with diagrams.

[3 marks]

ii) Explain the difference between combinational and sequential logic. You may illustrate your answer with diagrams.

[2 marks]

ii) Briefly explain the concept of instruction pipelining. You may illustrate your answer with diagrams.

[2 marks]

4.b i) Explain when it is necessary to spill registers when calling procedures.

[1 marks]

ii) Explain what the stack pointer is used for.

[1 marks]

iii) Below is a procedure which spills registers on the stack and performs a calculation. Complete the code of the procedure (moving the computation result from $s0 into an appropriate register, restoring registers, returning from the procedure).

```
leaf_example:
     addi $sp,$sp,-12     #grow stack by 3 words
     sw $s2,8($sp)        #save register $s2
     sw $s1,4($sp)        #save register $s1
     sw $s0,0($sp)        #save register $s0
     add $s1,$a0,$a1      #$s1 contains g+h
     add $s2,$a2,$a3      #$s2 contains i+j
     sub $s0,$s1,$s2      #f = $s1 - $s2
     << YOUR CODE >>
```

[8 marks]

Question 4 continues on the next page…

4.c A program should be written which sets the Flag SCC_150_A in the variable flags. Then a test should be carried out if flag SCC_150_A is set. If this is the case the sentence "Match A" should be printed on screen. Then a test should be carried out if flag SCC_150_A and flag SCC_150_B is set.

If this is the case the sentence "Match B C" should be printed on screen. Please complete the program given below.

```
#include <stdio.h>
#define SCC_150_A 0x01
#define SCC_150_B 0x02
unsigned int flags = 0;
main () {
    << YOUR CODE GOES HERE >>
}
```

[8 marks]

[Total 25 Marks]

END OF PAPER