Queen Mary
University of London

Winter Examination Period 2021 — January — Semester A

ECS404U Computer Systems and Networks Duration: 3 hours

This is a 3-hour open-book exam, which must be started within a 24-hour period.

You MUST submit your answers within 3 hours of the time that you started the exam.

Follow all instructions on the download page.

You can refer to textbooks, notes and online materials to facilitate your working, but normal referencing and plagiarism rules apply, and you must cite any sources used.

You must upload a SINGLE PDF file containing your solutions. These can be typed or hand-written, or a combination of the two. Multiple submissions are not permitted, so be sure that you check your submission before uploading it.

Calculators are permitted in this examination.

Answer FOUR questions.

You MUST adhere to the word limits, where specified in the questions. Failure to do so will lead to those answers not being marked.

YOU MUST COMPLETE THE EXAM ON YOUR OWN, WITHOUT CONSULTING OTHERS.

Question:	1	2	3	4	Total
Points:	25	25	25	25	100
Score:					

Examiners:
Dr Arman Khouzani, Prof Edmund Robinson

Question 1

Digital Representation of Data

(a) This part of the question is based on the four right-most digits of **your own 9-digit student ID number**.

(i) Write down the four rightmost digits of your own 9-digit student ID number. For instance, if your student ID number is **`201234516`** then write down **`4516`**.

(ii) Replace any occurrences of **`0`** by **`a`**, **`1`** by **`b`**, and **`2`** by **`c`**. Give the result. For instance, if the last four digits of your student number are **`4516`**, then write down **`45b6`**.

(iii) Treat the expression you just wrote down as the hex encoding of a bit sequence. Write down the bit sequence represented by the first two characters (**`45`**) in our example, and the bit sequence represented by the last two characters (**`b6`**). Explain how you reach your answers.

[5 marks]

(b) Consider the two binary sequences you obtained in part (a-iii). Suppose each of them represents a signed integer in 8-bit two's complement, which we will refer to as x and y. What numbers are x and y (in base 10)? Show in detail how each bit pattern relates to the corresponding number.

Note that x and y could be negative or positive numbers depending on your particular case. **[5 marks]**

(c) Show that you understand binary addition by adding the two bit sequences. As well as showing the method, give the result, and the sequence of carries (including 0). Explain how your result relates to $x + y$.

[5 marks]

(d) For this part we treat your student number as a string of characters. Given that '0' is the 48*th* character in the ASCII character set, and 'a' is the 97*th*, how are the four characters you wrote down for part (a-iii) represented in UTF-8? Give the *hex* dump of this string and explain how you get the hex dump of a UTF-8 representation from knowing the decimal representation of ASCII characters.

[5 marks — word limit 100]

(e) This part is about floating point representation. Give the significand (mantissa) and exponent for the representation of 10.25 in binary. (Recall that the 10.25 in standard scientific notation would be $1.025 * 10^1$, you are being asked about the binary equivalent). Use this to explain why the representations of 10.25 and 5.125 are very similar. **[5 marks — word limit 60]**

Question 2

Computer Architecture

(a) The designer of the circuit in Figure 1 intended to produce a circuit containing an or gate followed by an inverter. But they have made a mistake. The circuit contains six CMOS transistors, labelled as T1 through T6. It has two inputs labelled A and B, and one output wire labelled C.

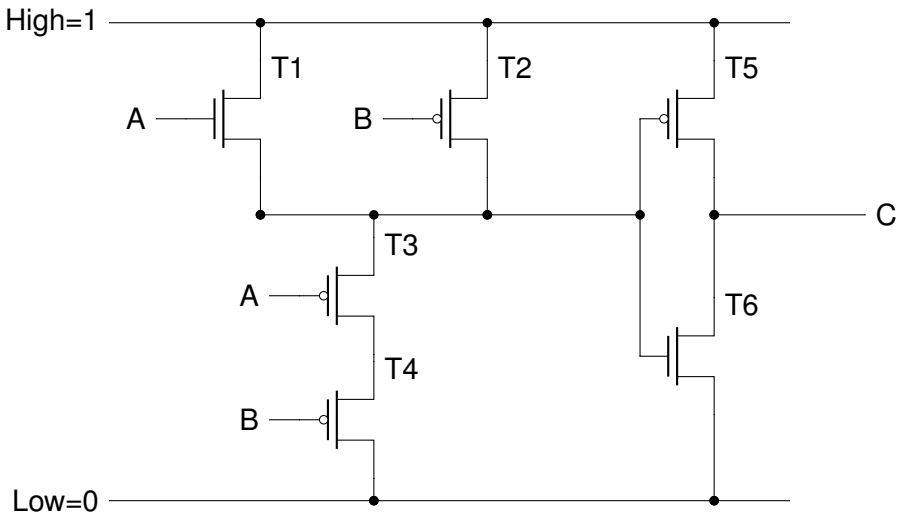

Figure 1: CMOS circuit

(i) List the transistors that are supposed to be part of the or gate, and the transistors that are supposed to be part of the inverter. Describe how the two gates are connected.

(ii) Specify the state of each of the 6 transistors T1 through T4 when both input wires A and B are at Low electric potentials (voltages), that is, when A=0 B=0. What is the resulting behaviour of the circuit? Provide brief explanations with your answers.

(iii) Describe how to fix the design so that this is indeed an or-gate followed by an inverter. Explain why your correction works.

[10 marks — word limit 150]

(b) The diagrams in Figure 2 show a single SRAM cell and a single DRAM cell. Concentrating on the structure and/or the components used in these cells, explain why:

(i) The SRAM design (rather than DRAM) is (generally) used for memory internal to a cpu.

(ii) You would expect DRAM to be slower than SRAM.

[5 marks — word limit 60]

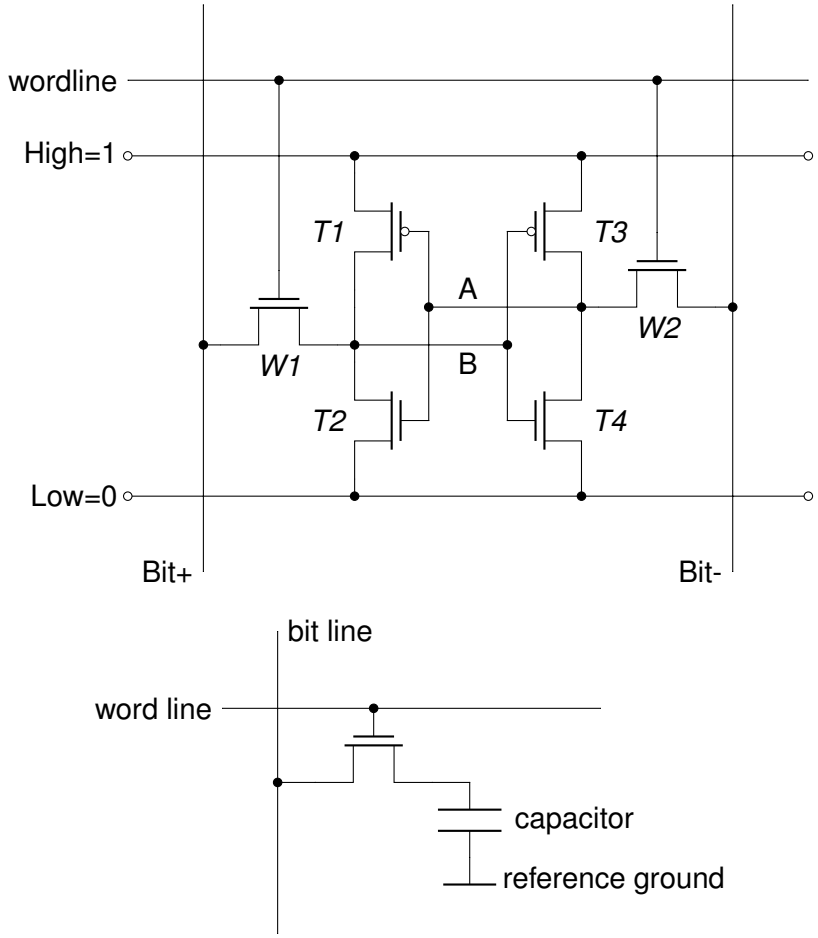

Figure 2: SRAM and DRAM

(c) Briefly describe how “Cache memory” (e.g., L1/L2) improves the efficiency of a processor. **[5 marks — word limit 50]**

(d) This part is about interrupts.

(i) Explain the problem that was solved by the introduction of interrupts.

(ii) In broad outline, what happens when the cpu receives an interrupt?

[5 marks — word limit 100]

Question 3

Instruction Set Architecture, Assembly Language

(a) This part is about comparison of "RISC" (Reduced Instruction Set Computer) versus "CISC" (Complex Instruction Set Computer) instruction set architectures.

Suppose you have written some complicated code in a high-level programming language like Fortran, Rust, or C. You then compile your code using two different compilers. First you use a compiler that produces machine code for a 32-bit RISC architecture (e.g. ARM or MIPS). Then you use a compiler that produces code for a 32-bit CISC architecture (e.g. an x86 family). So you now have two executable files, one produced by the RISC compiler and one produced by the CISC compiler. Which of these two executables is expected to be a larger file? Support your answer with a brief explanation.

[8 marks — word limit 50]

(b) The following shows a snippet of a programme in 32-bit MIPS Assembler:

```
1  .text
2  addi  $t1, $zero, ? # where ? is the last digit of your student ID
3
4  LOOP:
5  slt $t2, $zero, $t1
6  beq $t2, $zero, DONE
7  addi $t1, $t1, -3  # $t1 <- $t1 - 3
8  j LOOP
9  DONE:
10 slt $s0, $t1, $zero
11
12 # some code to exit
```

Suppose at the beginning of the programme (before entering the LOOP), you put the rightmost digit of your own student ID in register **`$t1`**. That is, you replace the question mark in line 2 of the code with the last digit of your student ID.

What will be the value stored in **`$s0`** when the programme finishes? Support your answer by providing the full trace of the programme. That is, write down the values in registers **`$t1`**, **`$t2`** and **`$s0`** (depending on whichever one changes) each time there is a change in any of them as you step through the programme until it finishes execution (and exits).

[7 marks]

(c) The following is a programme in 32-bit MIPS Assembler.

```
1  .text
2
3      addi  $s0, $zero, 6
4      addi  $t0, $zero, 0
5
6      addi  $t1, $zero, ?? # ?? is the next to last digit of your student ID
7      addi  $t2, $zero, ?  # ? is the last digit of your student ID
8
9      LOOP:
10     addi $t0, $t0, 1
11
12     addi $v0, $zero, 1    # syscall code to print an integer
13     add $a0, $zero, $t1
14     syscall
15
16     beq $t0, $s0, DONE
17
18     add $t3, $t2, $t2
19     addi $t3, $t3, 1
20     add $t4, $t1, $t3
21     add $t1, $zero, $t2
22     add $t2, $zero, $t4
23
24     addi  $v0, $zero, 4   # syscall code to print a string
25     la  $a0, COMMA_FOR_SEPARATION
26     syscall
27
28     j LOOP
29
30     DONE:
31     addi $v0, $zero, 10     # syscall code to exit
32     syscall
33
34 .data
35     COMMA_FOR_SEPARATION:   .asciiz ", " # comma (and space) string
```

Codes/Q3_c.asm

Suppose you load the rightmost two digits of your own student ID in registers **`$t1`** and **`$t2`** respectively. That is, in line 6 of the code, you replace **`??`** with the next to last digit of your student ID, and in line 7, you replace **`?`** with the last digit of your student ID. So for instance, if your student ID is **`200123456`** then **`$t1`** is initialised to 5 and **`$t2`** is initialised to 6.

Write down what is printed to the console when this programme is run until it finishes.

[10 marks]

Question 4

Computer Networks

(a) What is the purpose of each of the following?

(i) MAC address

(ii) IP address

(iii) TCP port number

(iv) TCP Sequence number

[10 marks — word limit 150 (overall)]

(b) Recall that when communicating data over a network, we first break it up into packets. There is a decision to be made about the size of the packets. Provide your thoughts on pros and cons of choosing a smaller packet size versus a larger packet size.

[5 marks — word limit 100]

(c) For each of the following statements, determine whether it is correct or incorrect. Support each of your answers with a brief explanation.

(i) A router needs to also do modulation and demodulation.

(ii) A router typically changes the source and destination MAC addresses of the dataframes that traverse it.

(iii) At the physical layer, you can encode data in electric or electromagnetic waves but not sound waves.

(iv) All packets of the same TCP session between a source and a destination traverse the same intermediate hops (that is, the same path) from the source to the destination.

(v) HTTP is an application layer protocol that can be used for communication of HTML files, but not multimedia.

[10 marks — word limit 150 (overall)]

End of questions