ECE 6913, Computing Systems Architecture

Fall 2020 NYU ECE

Please fill in your name: ___________________________________

Quiz 1, October 9th 2020

<u>Maximum time:</u> 140 minutes : **2 PM AM** - **4:20 PM** [+ 10 minutes to assemble PDF and upload]

Closed Book, Closed Notes,

Calculators allowed.

Must show your work in steps – to get any credit

This is NOT a group project You may NOT discuss, share your Quiz solutions with anyone else.

You must stay logged in to Zoom throughout the Quiz, with Camera on

Instructor available online if you have questions on the Quiz, during the Quiz – enter question in Zoom chat box at any time during Quiz

This Test has 6 problems. Please attempt all of them. Please show **<u>all work</u>**. Please write **<u>legibly</u>**

1. Please be sure to have 5-10 sheets of white or ruled paper & a Pencil, Eraser
2. Write down your solutions on 8.5 x 11 sheets of white paper, single sided with your name printed in top right corner of each sheet and with **Page Number and Problem number identified clearly on each sheet**
3. **Stop working on your Quiz at 4:20 PM** – you have 10 minutes to scan/take pictures of each sheet and upload them as completed PDF assignment to NYU Classes – you may use any of several smartphone apps to integrate your scans/pictures of sheets into a PDF file
4. Take pictures of each sheet and **upload** the PDF of all sheets after checking you have all sheets in the right order **by 4:30 PM latest.**
5. You may use iPAD to write down your solutions directly rather than on paper
6. Portal **will close at 4:30 PM** not allowing upload of your quiz after 4:30 PM

Problem 1.

1a. A microprocessor manufacturer decides to advertise its newest chip based only on the metric IPC (Instructions per cycle). Is this a good metric? Why or why not?

`No, because the metric does not take into account frequency or number of executed instructions, both of which affect execution time.`

1b. If you were the chief architect for another company and were asked to design a chip to compete based solely on this metric, what important design decision would you make?

`Make the cycle time as long as possible and process many instructions per cycle.`

1c. p% of a program is perfectly parallelizable. We wish to run it on a multiprocessor. Assume we have an unlimited number of processing elements. If the maximum speedup achievable on this program is 100, what is p?

a) assuming p = 100x, $1/(1-p) = 100 \rightarrow p = 99\%$

b) assuming p = 100%, $1/(1-p) = 1 + 100\% = 2 \Rightarrow p = 50\%$

Problem 2.

Your job is to evaluate the potential performance of two processors, each implementing a different ISA. The evaluation is based on its performance on a particular benchmark. On the processor implementing ISA A, the best compiled code for this benchmark performs at the rate of 10 IPC. That processor has a 500 MHz clock. On the processor implementing ISA B, the best compiled code for this benchmark performs at the rate of 2 IPC. That processor has a 600 MHz clock.

2a. What is the performance in MIPS (millions of instructions per sec) of the processor implementing ISA A?

10 IPC x 500 MHz = 5000 MIPS

2b. What is the performance in MIPS (millions of instructions per sec) of the processor implementing ISA B?

2 IPC x 600 MHz = 1200 MIPS

2c. Which is the higher performance processor? A or B ? Explain

Not enough information provided. We don't know the number of instructions executed on each processor, so we can't compare performance. Processor A for example may have very simple instructions (or NOPs). Processor B could be faster if its instructions actually accomplish significantly more work than Processor A's. The MIPS metric does not take into account number of executed instructions, which also affects the performance (i.e. execution time) of each processor.

Problem 3.

What is 5CD4 −07DF when these values represent (i) unsigned 16-bit hexadecimal numbers stored in unsigned format (ii) signed 16-bit hexadecimal numbers stored in 2s complement format? The result should be written in hexadecimal. Show your work

(ii) **Signed representation:**

Range: $-2^{15} \rightarrow +2^{15} - 1 = -32768 \rightarrow +32767$

- A = $5CD4_{16} = 23764_{10} = 0101\ 1100\ 1101\ 0100_2$
- B = $07DF_{16} = 2015_{10} = 0000\ 0111\ 1101\ 1111_2$

A-B = $21749_{10} = 54F5_{16}$ = **0101 0100 1111 0101**

Problem 4.

Write down the RISC V code for the following tasks:

(1) Load Register `x3` *with content* of `A[32]`

(2) Store contents of Register `x3` into `A[22]`

(3) Add contents of register `x3` and `x10` and place the result in register `x5`

(4) Copy contents at one memory location to another: `C[g] = A[i-5j+32]`

(5) implement in RISC V these line of code in C:

(i) `f = g - A[B[C[64]]]`

(ii) `f = g - A[C[16] + B[32]]`

(iii) `A[i] = 4B[8i-81] + 4C[32i+32]`

Problem 5.

NVIDIA has a “half” format, which is similar to IEEE 754 except that it is only 16 bits wide. The leftmost bit is still the sign bit, the exponent is 5 bits wide and the Fraction field is 10 bits long. A hidden 1 is assumed.

REPRESENTATION RANGE OF THE NVIDIA ‘HALF FORMAT’

For each of the following, write the *binary value* and *the* ***corresponding*** *decimal value* of the 16-bit floating point number that is the closest available representation of the requested number. If rounding is necess2ary use round-to-nearest. Give the decimal values either as whole numbers or fractions. Show your work.

Number	Binary	Decimal
0	00000 0000000000	0
Charge of an electron: -1.6×10^{-19} (C)	1 00000 0000000000	0
Smallest positive normalized number	0 00001 0000000000	$6.103515625 \times 10^{-5}$
Smallest positive **denormalized** number > 0	0 00000 0000000001	$5.960464477 \times 10^{-8}$
Largest positive **denormalized** number > 0	0 00000 1111111111	$\sim 6.103515625 \times 10^{-5}$
Largest positive number < infinity	0 11110 1111111111	= 65536
Average distance b/w proton and neutron in Hydrogen atom = 0.8751×10^{-15} m	0 00000 0000000000	0
Distance between Earth and Neptune in inches = 171,072,000,000,000	0 11111 0000000000	overflow

Smallest normalized number > 0: 0 00001 0000000000; bias = 15; val of exponent = 1-bias = -14, Significand = $1.000\ldots0_2$ = 1, Value in decimal ~ $1.00 \times 2^{-14} = 6.103515625 \times 10^{-5}$

Smallest positive denormalized number > 0: 0 00000 0000000001; value of exponent = -14; significand = 0.0000000001 = 1×2^{-10}; so smallest denormalized number = $1 \times 2^{-10} \times 2^{-14} = 2^{-24} = 5.960464477 \times 10^{-8}$

Largest possible denormalized number > 0: 0 00000 1111111111; value of exponent = 1-15 = -14; significand = 0.1111…1 ~ 1.0; so largest denormalized number = $1 \times 2^{-14} \sim 6.103515625 \times 10^{-5}$

Largest positive number < inf: 0: 0 11110 1111111111; value of exponent = 30 – 15 = 15; Significand = $1.11…1_2$ = ~ 2; value in decimal ~ 2 x 2^{15} = 2^{16} = 65536

Overflow: represented by +infinity: 0 11111 0000000000

Problem 6. This problem explores energy efficiency and its relationship with performance. The parts of this problem assume the following energy consumption for activity in Instruction memory, Registers, and Data memory. You can assume that the other components of the datapath consume a negligible amount of energy. ("Register Read" and "Register Write" refer to the register file only.)

I-Mem	1 Register Read	Register Write	D-Mem Read	D-Mem Write
140pJ	70pJ	60pJ	140pJ	120pJ

Assume that components in the datapath have the following latencies. You can assume that the other components of the datapath have negligible latencies.

I-Mem	Control	Register Read or Write	ALU	D-Mem Read or Write
200 ps	150 ps	90 ps	90 ps	250 ps

6.1 How much energy is spent to execute a **sub** instruction in a single-cycle design and in the five-stage pipelined design

Instruction-Memory is read, two registers are read, and a register is written

Energy consumed: 140pJ + 2*70pJ + 60pJ = **340pJ**

6.2 How much energy is spent to execute a **sw** instruction in a single-cycle design

Instruction-Memory is read, two registers are read (one with Data to be written, the other with the address in Data memory to be written into) and Data-Memory is written into

Energy consumed: 140pJ + 2*70pJ + 120pJ = **400pJ**

6.3 How much energy is spent to execute a **beq** instruction in a single-cycle design

I-Mem + 2 registers = 140pJ + 2 * 70pJ = **280pJ**