CIS 314 Computer Organization - Fall 2015
Problem Set 2

General guidelines: Always state your assumptions and clearly explain your answers. Please upload your solution document (PDF or TXT) to Canvas.

100/100 points possible – Due Wednesday, October 28th by 11:59 PM through Canvas.

Notes between the square brackets are simply to help you find the equivalent of the problem or question in the textbook.

Part 1: Floating-point Representation

Exercise 1: [3.27 [20] <§3.5>]
IEEE 754-2008 contains a half precision that is only 16 bits wide. The left most bit is still the sign bit, the exponent is 5 bits wide and has a bias of 15, and the mantissa is 10 bits long. A hidden 1 is assumed. Write down the bit pattern to represent -1.5625 * 10^1 assuming a version of this format, which uses an excess-16 format to store the exponent.

Exercise 2: [3.32 [20] <§3.9>]
Calculate (3.984375 * 10^-1 + 3.4375 * 10^-1) + 1.771 * 10^3 by hand, assuming each of the values are stored in the 16-bit half precision format described in Exercise 1 (and also described in the text book). Show all the steps, and write your answer in both the 16-bit floating-point format and in decimal.

Part 2: Assembly-level Programming

Exercise 1: [2.26]
Consider the following MIPS loop:

```
LOOP: slt $t2, $0, $t1
       beq $t2, $0, DONE
       subi $t1, $t1, 1
       addi $s2, $s2, 2
       j LOOP
DONE:
```

a. [2.26.1 [5] <§2.7>] Assume that the register $t1 is initialized to the value 10. What is the value in register $s2 assuming $s2 is initially zero?

b. [2.26.2 [5] <§2.7>] For each of the loops above, write the equivalent C code routine. Assume that the registers $s1, $s2, $t1, and $t2 are integers A, B, i, and tmp, respectively.

c. [2.26.3 [5] <§2.7>] For the loops written in MIPS assembly above, assume that the register $t1 is initialized to the value N. How many MIPS instructions are executed?
Translate the following C code to MIPS assembly code. Use a minimum number of instructions. Assume that the values of a, b, i, and j are in registers $s0, $s1, $t0, and $t1, respectively. Also, assume that register $s2 holds the base address of the array D.

\[
\text{for}(i=0; \ i<a; \ i++)
\text{for}(j=0; \ j<b; \ j++)
D[4*j] = i + j;
\]

How many MIPS instructions does it take to implement the C code from Exercise 2? If the variables a and b are initialized to 10 and 1 and all elements of D are initially 0, what is the total number of MIPS instructions that is executed to complete the loop?

Translate the following loop into C. Assume that the C-level integer i is held in register $t1, $s2 holds the C-level integer called result, and $s0 holds the base address of the integer array MemArray.

\[
\text{addi} \quad \text{$t1, \ 0, \ 0}
\text{LOOP:} \quad \text{lw} \quad \text{$s1, \ 0($s0)}
\text{add} \quad \text{$s2, \ $s2, \ $s1}
\text{addi} \quad \text{$s0, \ $s0, \ 4}
\text{addi} \quad \text{$t1, \ $t1, \ 1}
\text{slti} \quad \text{$t2, \ $t1, \ 100}
\text{bne} \quad \text{$t2, \ 0, \ \text{LOOP}}
\]

Part 3: Computer Systems Performance Analysis
Execution Time is the main measure of computer performance: the computer that performs the same amount of work in the least time is the fastest. Program execution time is measured in seconds per program.

\[
\frac{\text{Performance}_{\text{System A}}}{\text{Performance}_{\text{System B}}} = \frac{\text{Time}_{\text{System B}}}{\text{Time}_{\text{System A}}}
\]

\[
\frac{\text{Time}}{\text{Program}} = \frac{\text{Instructions}}{\text{Program}} \times \frac{\text{Cycles}}{\text{Instructions}} \times \frac{\text{Time}}{\text{Cycle}}
\]

\[
\text{CPI} = \frac{\text{Cycles}}{\text{Instructions}}
\]

\[
\text{Clock rate} = \frac{\text{Cycle}}{\text{Time}}
\]
Exercise 1: [1.5 [4] <§1.6>]
Consider three different processors P1, P2, and P3 executing the same instruction set. P1 has a 3 GHz clock rate and a CPI of 1.5. P2 has a 2.5 GHz clock rate and a CPI of 1.0. P3 has a 4.0 GHz clock rate and has a CPI of 2.2.
   a. Which processor has the highest performance expressed in instructions per second?
   b. If the processors each execute a program in 10 seconds, find the number of cycles and the number of instructions.
   c. We are trying to reduce the execution time by 30% but this leads to an increase of 20% in the CPI. What clock rate should we have to get this time reduction?

Exercise 2: [1.6 [20] <§1.6>]
Consider two different implementations of the same instruction set architecture. The instructions can be divided into four classes according to their CPI (class A, B, C, and D). P1 with a clock rate of 2.5 GHz and CPIs of 1, 2, 3, and 3, and P2 with a clock rate of 3 GHz and CPIs of 2, 2, 2, and 2.
Given a program with a dynamic instruction count of 1.0E6 instructions divided into classes as follows: 10% class A, 20% class B, 50% class C, and 20% class D:
   a. What is the global CPI for each implementation?
   b. Which implementation is faster?
   c. Find the clock cycles required in both cases.

Exercise 3: [1.7 [15] <§1.6>] Compilers can have a profound impact on the performance of an application. Assume that for a program, compiler A results in a dynamic instruction count of 1.0E9 and has an execution time of 1.1 s, while compiler B results in a dynamic instruction count of 1.2E9 and an execution time of 1.5 s.
   a. Find the average CPI for each program given that the processor has a clock cycle time of 1ns.
   b. Assume the compiled programs run on two different processors. If the execution times on the two processors are the same, how much faster is the clock of the processor running compiler A’s code versus the clock of the processor running compiler B’s code?
   c. A new compiler is developed that uses only 6.0E8 instructions and has an average CPI of 1.1. What is the speedup of using this new compiler versus using compiler A or B on the original processor?