Computer Organization (0306-550) - Winter 2012

Homework Assignment #2 - Due Thursday, December 20

Show all intermediate steps clearly and legibly to obtain full credit.

1. Assume that the code given in question #10 of homework assignment #1 is run on a CPU with a clock frequency of 1.6 GHz, that requires the following number of cycles for each instruction.

Instruction	Cycles
add, addi, sll	3
bne	4
lw	7

Ignoring the four instructions before the loops, how many seconds will it take to execute this code in the worst case?

2. Consider two different CPU implementations of the same instruction set: CPU_1 and CPU_2. This instruction set has five classes (A, B, C, D, and E) of instructions whose CPIs for each CPU are given in the table below. CPU_1 has a clock rate of 2 GHz, and CPU_2 has a clock rate of 2.4 GHz

Class	CPI_1	CPI_2
A	1	3
B	3	3
C	4	3
D	5	4
E	6	4

   a. What are the peak MIPS ratings of CPU_1 and CPU_2 ?

   b. If the number of instructions executed in a certain program is divided equally among these instruction classes except for class A, which occurs five times as often as each of the other classes, which CPU implementation is faster for this program (i.e., CPU_1 or CPU_2), and by how much?

3. Consider two different implementations, CPU1 and CPU2, of the same instruction set, which has three classes of instructions (A, B, and C). CPU1 has a clock rate of 3 GHz, and CPU2 has a clock rate of 1.5 GHz. The CPIs for each instruction class on CPU1 and CPU2 are given in the table below.

   There are three compilers available for these CPUs: compiler C1 produced by the makers of CPU1, compiler C2 produced by the makers of CPU2, and compiler C3 produced by a third party. For a given program, each compiler produces the same number of instructions executed, but the instruction mix among the instruction classes differs as shown in the table.

Instruction Class	CPI on CPU1	CPI on CPU2	C1 Freq. (%)	C2 Freq. (%)	C3 Freq. (%)
A	2	1	40.0	40.0	50.0
B	3	2	40.0	20.0	25.0
C	5	2	20.0	40.0	25.0

   Based on this information, answer the following questions.

   a. Using C1 on both CPU1 and CPU2, which CPU is faster and by how much?
   b. Using C2 on both CPU1 and CPU2, which CPU is faster and by how much?
   c. Using C3 on both CPU1 and CPU2, which CPU is faster and by how much?
   d. For CPU1, which compiler is the best?
   e. For CPU2, which compiler is the best?
   f. Which CPU and compiler combination would you use if all other criteria are the same.

4. Consider program P running on a 1-GHz machine M in 10 seconds. Someone optimizes P by replacing each of 5×10^8 instances of multiplying a value *x* by 2 (`mult` *x*,*x*,2) each with a single add instruction (`add` *x*,*x*,*x*) and by replacing all instances of multiplying by 4 (`mult` *x*,*x*,4) each with a single shift instruction (`sll` *x*,*x*,2). The optimized program P′ runs in 7 seconds on the same machine. If the CPI of `mult` is 6, the CPI of `add` is 2, and the CPI of `sll` is 1, how many multiplies by 4 were replaced with `sll` instructions by the optimization?

5. Suppose you have a program that runs in 100 seconds on a particular computer, and profiling of the execution time indicates that 20% is for multiplication, 50% is for memory access, and 30% for other instructions.

   a. Determine the speedup for these enhancements to the computer.
      i. Make multiply instructions run ten times faster.
      ii. Make memory access instructions run three times faster.
      iii. Make both enhancements i and ii.

   b. Suppose you change the program so that the execution time distribution is no longer 20%, 50%, and 30%. If none of the percentages can be zero, what sort of program would result in a tie (with regard to speedup) between the two individual enhancements above? Provide both a formula and some examples.

6. Three enhancements are used to improve three execution aspects of a CPU, where each enhancement affects a different portion of the execution time, with the following enhancement factors:

   Enhancement #1 factor = 6
   Enhancement #2 factor = 4
   Enhancement #3 factor = 3

   For a specific application, enhancements 1, 2, 3 are useable 15%, 10%, and 5% of the resulting execution time after the enhancements were applied, respectively.

   a. What is the overall speedup obtained?

   b. What where the fractions of original execution time where each enhancement was applied?

7. a. If multiply instructions require 13 cycles and account for 28% of the instructions executed in a typical program, what percentage of time does the CPU spend on multiplication if the average CPI of all other instructions is 6?

   b. Suppose that you could reduce the number of cycles for multiplication to 8 but that the CPU cycle time would need to be increased by 15%. Should you make this modification?