University of California, Santa Barbara
Dept. of Electrical and Computer Engineering
ECE154 – Computer Architecture
Homework #3 – due Thursday, October 25, 2007

Arithmetic

1. (20 points) Design a multiplier for two three bit numbers, A[2:0] and B[2:0], that stores the result in P[5:0]. You many use Full Adders (FA), Half Adders (HA) and basic gates (AND, OR, NOT, …). Derive the delay and area in terms of number of FA and HA.

2. (20 points) Devise the minimum sequence of shift, add or subtract instructions for the multiplication by each of the following constants. Assume 32-bit unsigned operands and the number you wish to multiply is in register $1. You should store your result in register $2 and should use the minimum number of additional registers for intermediate results.
    a. 13
    b. 43
    c. 63
    d. 135

3. (30 points) Multiplication – P+H 3.23

Performance

4. (15 points) You want to run a program P with 7.5×10^9 instructions that has a CPI of 0.8 on a 5 GHz machine.
    a. (5 points) What is the total number of CPU cycles that P needs?
    b. (5 points) What is the expected CPU time for P?
    c. (5 points) When you run P, the actual CPU running time is 3 seconds. What percentage of the CPU time did P receive?

5. (10 points) Program P runs on a 1 GHz machine M in 10 seconds. An optimization is made to P, replacing all instances of multiplying a value by 4 (mul X, X, 4) with two add instructions: add X, X, X; add X, X, X. Call this new optimized program P1. A mul instruction takes 4 cycles whereas an add instruction takes 1 cycle. After recompiling, the P1 runs in 9 seconds on machine M. How many multiplies were replaced by the compiler?

6. (15 points) Your company could speed up a Java program on their new computer by adding hardware support for garbage collection. Garbage collection currently comprises 20% of the cycles of the program. You have two possible changes to the machine:
    A) Automatically handle garbage collection in hardware. This causes an increase in cycle time by a factor of 1.2
    B) Provide new hardware instructions to be added to the ISA that could be used during garbage collection. This would halve the number of instructions needed for garbage collection without changing the overall CPI, but would increase the cycle time by a factor of 1.1
    Which of these two options, if either, should you choose?

7. (10 points) Assume that a program executes in 130 seconds, where 80 seconds is CPU time and the rest of the time is for I/O. If the CPU performance improves by 40% per year and I/O performance improves by 5% per year how much faster will the program run in 10 years?

8. (10 points) If a program has 400,000,000,000 instructions and takes 2 hours to run on a 50 MHz processor, what are the CPI and native MIPS rating for this processor on this program? If the clock frequency is increased to 100 MHz, what are the new CPI, native MIPS rating, and execution time for this processor on the same program?

9. (10 points) If a program currently takes 30 seconds to run and 10 seconds of that time is spent performing multiplications, by what factor will multiplication have to be speeded up, in order to achieve an overall speedup of 1.2? What is the maximum overall speedup that can be obtained by improving the performance of multiplication?