Name: Id#

COE 301/ICS 233, Term 171

Computer Architecture & Assembly Language

Quiz# 6 Solution

Date: Tuesday, Dec. 5, 2017

**Q1.** Suppose that you have a processor that executes a certain program with the following characteristics: 50% of the execution time is taken by multiply, 20% of the execution time is taken by divide, and the remaining 30% of the execution time is taken by other instructions.

We want the program to run faster. Suppose that we can improve the multiply to run 2 times faster and the divide to run 4 times faster. However, due to hardware cost, only one improvement can be made.

1. Which improvement should be done (multiply or divide?), assuming that the hardware cost is identical. Justify your answer.
2. Given that the program executes on the processor without improvement in 10s, what will be the execution time of the program with the chosen improvement?
3. Suppose we can now improve both the multiply and divide instructions. What is the speedup of the improved machine relative to the original machine?

We will use Amdahl’s Law as follows:

ExT after improvement = ExT affected by improvement + unaffected ExT

(1)Suppose the original execution time = 100

Improving the multiply by a factor of 2:

Execution time with improved multiply = 50/2 + 20 + 30 = 75

OR Speedup due to multiply = 1/(0.5/2 + 0.5) = 1/0.75 = 1.33

Improving the divide by a factor of 4:

Execution time with improved divide = 50 + 20/4 + 30 = 85

OR Speedup due to divide = 1/(0.2/4 + 0.8) = 1/0.85 = 1.176

If only one improvement should be made then it is better to improve the multiply.

(2) Speedup of improving the multiply = 100 / 75 = 1.33

Execution time for a 10s program execution = 10 / 1.33 = 7.5 s

- another solution using Amdahl’s Law -

Execution time for a 10s program execution = 5/2 + 2 + 3 = 7.5 s

(3) Execution time with improved multiply and divide = 50/2 + 20/4 + 30 = 60

Speedup of improving both multiply and divide = 100 / 60 = 1.67

OR Speedup of improving both multiply and divide = 1/(0.5/2 + 0.2/4 + 0.3) = 1/0.6=1.67

**Q2.** Given a certain processor that has the following operation times for processor components: instruction and data memories: 150 ps, ALU and adders: 140 ps, decode and register file access (read or write): 100 ps, which of the following would be faster and by how much, a single-cycle implementation for all instructions, or a multi-cycle implementation optimized for every class of instructions.

Assume the following instruction mix: 50% ALU, 10% Loads, 10% stores, 15% branches and 15% jumps. Ignore the delays in PC, mux, extender, and wires.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Class | IM | RR | ALU | DM | RW | Total (ps) |
| ALU | 150 | 100 | 140 |  | 100 | 490 |
| Load | 150 | 100 | 140 | 150 | 100 | 640 |
| Store | 150 | 100 | 140 | 150 |  | 540 |
| Branch | 150 | 100 | 140 |  |  | 390 |
| Jump | 150 | 100 |  |  |  | 250 |

# Fora single-cycle implementation, the clock cycle is determined by longest delay, which is load instruction, and that is 640 ps.

For a multi-cycle implementation, the clock cycle is determined by longest delay at any step, which is the IM or DM steps, and that is 150 pm.

Next, we show the CPI for each instruction class:

|  |  |  |  |
| --- | --- | --- | --- |
| Instruction | # cycles | Instruction | # cycles |
| ALU & Store | 4 | Branch | 3 |
| Load | 5 | Jump | 2 |

# Average CPI = 0.5x4 + 0.1x5 + 0.1x4 + 0.15x3 + 0.15x2 = 3.65

Multiple cycle is faster by a factor = 640/(3.65x150) = 1.17

**Q3.** We wish to compare the performance of two different computers: M1 and M2. The following measurements have been made on these computers:

|  |  |  |
| --- | --- | --- |
| Program | Time on M1 | Time on M2 |
| 1 | 2.0 seconds | 1.5 seconds |
| 2 | 5.0 seconds | 10.0 seconds |

|  |  |  |
| --- | --- | --- |
| Program | Instructions executed on M1 | Instructions executed on M2 |
| 1 | 5 × 109 | 6 × 109 |

## Which computer is faster for each program, and how many times as fast is it?

Computer M2 is faster for program 1 and it is faster by a factor=2/1.5=1.33

Computer M1 is faster for program 2 and it is faster by a factor=10/5=2

## Find the instruction execution rate (instructions per second) for each computer when running program 1.

Instruction execution rate for M1= 5 × 109/2=2.5 × 109 (instructions per second)

Instruction execution rate for M2= 6 × 109/1.5=4 × 109 (instructions per second)

## The clock rates for M1 and M2 are 3 GHz and 5 GHz respectively. Find the CPI for program 1 on both machines.

CPI for program 1 on M1= (3 × 109 x 2)/ 5 × 109=1.2

CPI for program 1 on M2= (5 × 109 x 1.5)/ 6 × 109=1.25

## Suppose that program 1 must be executed 1600 times each hour. Any remaining time should be used to run program 2. Which computer is faster for this workload? Performance is measured here by the throughput of program 2.

Executing program 1 on M1 1600 times each hour will consume 1600x2=3200 seconds. Remaining time for running program 2 on M1= 3600-3200=400 seconds.

Thus, program2 can be run in M1 400/5=80 times.

Executing program 1 on M2 1600 times each hour will consume 1600x1.5=2400 seconds. Remaining time for running program 2 on M1= 3600-2400=1200 seconds.

Thus, program2 can be run in M2 1200/10=120 times.

Thus, for this workload computer M2 is faster.