COMP1047 Lab Week 02 - Solution

Part 1: Computer Performance

Q1. Consider three different processors P1, P2, and P3, executing the same set of instructions. P1 has 3GHz clock rate and a CPI of 1.5; P2 has a 2.5GHz clock rate and a CPI of 1.0; P3 has a 4.0GHz clock rate and has a CPI of 2.2.

(i) Which processor has the highest performance expressed in instructions per second?

Solution

$IPS_1 = CR_1/CPI_1 = 3GHz/1.5 = 2 * 10^9$

$IPS_2 = CR_2/CPI_2 = 2.5GHz/1.0 = 2.5 * 10^9$

$IPS_3 = CR_3/CPI_3 = 4GHz/2.2 \approx 1.8 * 10^9$

Hence the processor P2 has the highest performance in terms of instructions per second.

(ii) If the processor each execute a program in 10 seconds, find the number of cycles and the number of instructions.

Solution

$numOfCycles_1 = 10sec \times ClockRate_1 = 10 * 3 * 10^9 = 3 * 10^{10}$

$numOfInstr_1 = numOfCycles_1/CPI_1 = 2 * 10^{10}$

$numOfCycles_2 = 10sec \times ClockRate_1 = 10 * 2.5 * 10^9 = 2.5 * 10^{10}$

$numOfInstr_2 = numOfCycles_1/CPI_1 = 2.5 * 10^{10}$

$numOfCycles_3 = 10sec \times ClockRate_1 = 10 * 4 * 10^7 = 4 * 10^{10}$

$numOfInstr_3 = numOfCycles_1/CPI_1 = 1.8 * 10^{10}$

(iii) 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?

Solution

$time = \frac{numOfInstr*CPI}{CR} \quad \rightarrow \quad new\_CR\_ratio = 120\%/70\% \approx 1.7$

$CR_1^{new} = CR_1 * 1.7 = 5.1GHz$

$CR_2^{new} = CR_2 * 1.7 = 4.3GHz$

$CR_3^{new} = CR_3 * 1.7 = 6.8GHz$

Q2. Compliers can have profound impact on the performance of an application. Assume that for a program, complier A results in a dynamic instruction count of 1.0E9 and has an execution time of 1.1s, while complier B results in a dynamic instruction count of 1.2E9 and an execution time of 1.5s.

(i) Find the average CPI for each program given that the processor has a clock cycle time of 1ns.

Solution

$CPI_A = 1.1s * 10^9/(1.0E9) = 1.1$

$CPI_B = 1.5s * 10^9/(1.2E9) = 1.25$

(ii) 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 complier A's code versus the clock of the processor running complier B's code?

Solution

$CPUTime = \frac{ClockCycles}{ClockRate} = \frac{InstrCount*CPI}{ClockRate}$

Same CPU time, hence $\frac{InstrCount_A*CPI_A}{ClockRate_A} = \frac{InstrCount_B*CPI_B}{ClockRate_B}$

We have $\frac{ClockRate_A}{ClockRate_B} = \frac{InstrCount_A*CPI_A}{InstrCount_B*CPI_B} = \frac{1.0E9*1.1}{1.2E9*1.25} = 0.73$

So running on compiler A is 27% faster than B.

(iii) A new complier is developed that uses only 6.0E8 instructions and has an average CPI of 1.1. What is the speedup of using this new complier versus using complier A or B on the original processor?

Solution

$CPUTime_{new} = \frac{InstrCount*CPI_{new}}{ClockRate}$

$\frac{CPUTime_{new}}{CPUTime_A} = \frac{InstrCount_{new}*CPI_{new}}{InstrCount_A*CPI_A} = \frac{6.0E8*1.1}{1.0E9*1.1} = 0.6$

$\frac{CPUTime_{new}}{CPUTime_B} = \frac{InstrCount_{new}*CPI_{new}}{InstrCount_B*CPI_B} = \frac{6.0E8*1.1}{1.2E9*1.25} = 0.44$

So the speedup compared to A or B is 40% or 56%.

Q3. Read the Textbook's section 1.7 "The Power Wall" on Page 40.
The Pentium 4 Prescott processor, released in 2004, had a clock rate of 3.6GHz and voltage of 1.25V. Assume that, on average, it consumed 10W of static power and 90W of dynamic power. The Core i5 Ivy Bridge, released in 2012, had a clock rate of 3.4GHz and voltage of 0.9V. Assume that, on average, it consumed 30W of static power and 40W of dynamic power.

(i) For each processor find the average capacitive loads.

Solution

For Pentium 4 Prescott,

$CapacitiveLoad = \frac{Power}{0.5*Voltage^2*Frequency} = \frac{90}{0.5*1.25^2*3.6E9} = 3.2 * 10^{-8}$

For Core i5 Ivy Bridge,

$CapacitiveLoad = \frac{Power}{0.5*Voltage^2*Frequency} = \frac{40}{0.5*0.9^2*3.4E9} = 2.9 * 10^{-8}$

(ii) Read about CPU power dissipation from Internet. e.g,
https://en.wikipedia.org/wiki/Processor_power_dissipation

(iii) Find the percentage of the static power out of the total dissipated power and the ratio of static power to dynamic power for each technology.

Solution

For Pentium 4 Prescott,

$Percentage = \frac{10W}{10W+90W} = 10\%$

$Ratio = \frac{10W}{90W} = 0.11$

For Core i5 Ivy Bridge:

$Percentage = \frac{30W}{30W+40W} \approx 42.9\%$

$Ratio = \frac{30W}{40W} = 0.75$

Part 2: Getting Familiar with QtSpim

We will program the MIPS assembly code using an IDE named QtSpim. Please download and install it at (https://sourceforge.net/projects/spimsimulator/files/). Some useful information can be found at (http://spimsimulator.sourceforge.net/). You may also see that QtSpim has already been installed on the computers in our lab room.

Try your first MIPS program

Once you are familiar with the software, you can now try to execute some simple MIPS programs. The first one you could try is the famous \Hello World", which almost every programmer will use as their first program. To do this, firstly, create a new text file and named it “HelloWorld.asm" or “HelloWorld.s". Open the file using any text editor (e.g. notepad) and copy/paste the following text into the file:

```
        .data 0x10010010
msg:  .asciiz "Hello world!\n"
        .text
        .globl main
main:
        la $a0, msg     #load label msg
        li $v0, 4       #load immediate
        syscall         # print it
        li $v0, 10
        syscall         # exit
```

Save the file before you close the text editor. Now load the program that you just created into QtSpim by clicking the Load File in File menu. Click the Run/Continue button (i.e. the triangle icon) on the menu bar and observe what you get in the console window.

Now change the \Hello world!" string in the program to \Hello COMP1047". Load the program again. Did you observe any difference in QtSpim compared with that of the previous program?

Some Common Q&A for Part 2 – Sorted from current and previous semesters
Q1: Where can I write code, and how to run it?

A: You can write code with any text editor, e. g. notepad, sublime, vim, and use QtSpim->file->open to load the file, then click '>' to run. The output will show in console.
If you close your console, find it by 'window->console'.

Q2: Can I use MARS (or other software) but not QtSpim to run MIPS code?

A: You can use it but we still suggest for QtSpim, because in very few cases, MARS could get different result with same code. So if you prefer MARS, remember to double-check with QtSpim before submitting your coursework.

Q3: Why I get error message - 'double define 'main'' when I want to load and run my program again?

A: That's caused by double define of .asm/.s file. Try 'file->reinitialize and open' to load your code file and run it again.

Q4: Why I get compile error?

A: It depends, firstly I suggest you to check if you use full version of comma in Chinese. Please use ',' (English comma) but not '，' (Chinese comma).

Q5: I change the msg from 'helloworld' to 'hellocomp1047', as Lab request, but output didn't change in QtSpim console.

A: Please save the code file, then reload & rerun.

Q6: I finish today's lab, but still confused about those code, like 'li' and 'syscall'.

A: That's OK for the first lab, as we are just begin to learning how to write SPIM code. Details for each command are introduced in 'MIPS Reference Card', which I will uploaded to moodle. And more information will be included in future lectures & labs, like how 'syscall' works and what does 'li $v0, 1' means.

Q7: Just 'helloworld'? That's too easy to me, can I get more practice?

A: You can try to finish if/else logic in MIPS as additional practice. An example is provided in Page 31 in Lecture 4. But note that this is not necessary for you, and not included in this lab. More practice is also provided in the textbook.

Q8: I have tried the example program on Page 26 of Lecture 4, while always get 0.

A: That might caused by number encoding standard of input method. Please switch your keyboard input method to English, not English style on other method (e. g.

English mode of Microsoft Chinese Keyboard).

Q9: The textbook is too easy to me.

A: If you finished Computer Organization and Design (5th) and require more, I will suggest the dragon book and SICP, which is available at:
https://suif.stanford.edu/dragonbook/
https://mitpress.mit.edu/sites/default/files/sicp/full-text/book/book-Z-H-4.html

Q10: In QtSpim, backspace doesn't work. A strange char is inserted instead.

A: Some of you asked this question during the lab, while I tell you to not use it.

This issue has get proposed online, and the maintainer of QtSpim - James Larus have replied in 2011 by "This is by design. The console runs in raw mode, not allowing editing." on https://sourceforge.net/p/spimsimulator/bugs/16/

For more details about so-called 'raw mode', see:
https://unix.stackexchange.com/questions/21752/