COMPSCI 2GA3 Tutorial 1 Note

Note:

This note does NOT cover all the materials in Chapter 1 -- Only the formulas rated to sample questions of this tutorial are included. Therefore, you may want to make yourself more familiar with things that are presented in lectures, such as logic gates, color display, "Integrated Circuit Cost", "CPI in More Detail", "Power Equation for CMOS" etc.

For any questions about the tutorials and courses, feel free to contact me. (Email: wangm235@mcmaster.ca)

GLHF :)
Mingzhe Wang

Definitions

(Note: terms like CPU Time / executing time / latency are used interchangeably for this chapter.)

CPU execution time Also called **CPU time**. The actual time the CPU spends computing for a specific task.

Components of performance	Units of measure
CPU execution time for a program	Seconds for the program
Instruction count	Instructions executed for the program
Clock cycles per instruction (CPI)	Average number of clock cycles per instruction
Clock cycle time	Seconds per clock cycle

What is a CPU clock cycle?

In computers, the clock cycle is the amount of time between two pulses of an oscillator.
https://www.youtube.com/watch?v=3PcO10iAXTk
(For now, only understand the basic idea is enough. Later, we will dive into this concept and show you the hardware implementation of a CPU :))

Performance

$$Performance = \frac{1}{Execution\ Time}$$

"Computer *X* is *n* time faster than Computer *Y* if"

$$\frac{Performance_X}{Performance_Y} = \frac{Execution\ time_Y}{Execution\ time_X} = n$$

*** CPU Time ***

$$CPU\ Time = Instruction\ Count \times CPI \times Clock\ Cycle\ Time$$

$$CPU\ Time = Instruction\ Count \times CPI\ /\ Clock\ Rate$$

(PS: abbreviations I will use in equations: IC for Instruction Count, CPI for CPI, CCT for Clock Cycle Time.)

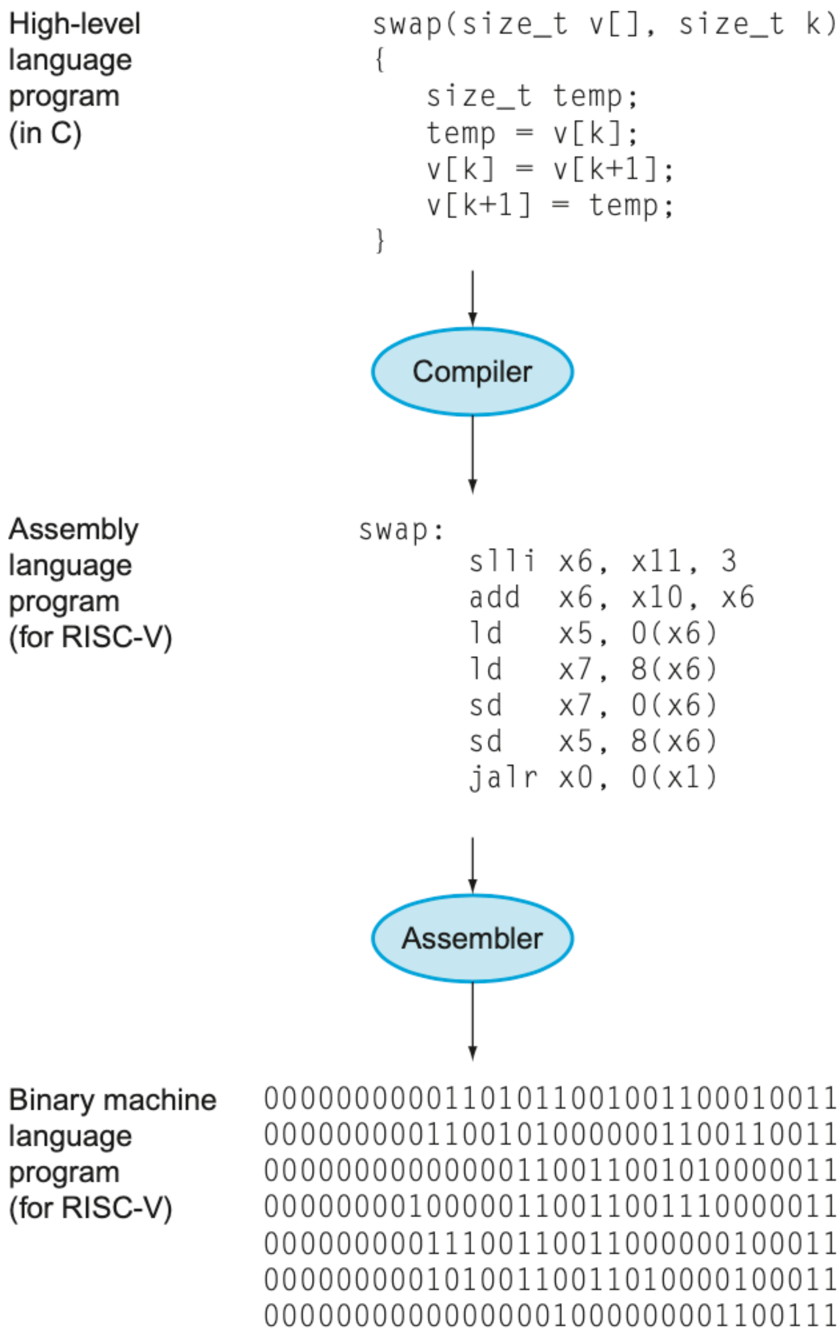
Weighted average CPI

(Used if different instruction classes take different numbers of cycles.)

$$CPI = \frac{Clocl\ Cycles}{Instruction\ Count} = \sum_{i=1}^{n} (CPI_i \times \frac{Instruction\ Count_i}{Instruction\ Count})$$

An important example

Consider the following process for a C program to be executed in a machine.



$$\text{CPU time} = \text{IC} * \text{CPI} * \text{CCT}$$

$$\text{CPU time} = 7 * \frac{1 * C_{slli} + 1 * C_{add} + 2 * C_{ld} + 2 * C_{sd} + 1 * C_{jalr}}{7} * \text{CCT}$$

where C_i — clock cycles of executing the instruction i and CCT — a given constant.

What does this tell us?

The performance of a program depends on the algorithm, the language, the compiler, the architecture, and the actual hardware. The following table summarizes how these components affect the factors in the CPU performance equation.

Hardware or software component	Affects what?	How?
Algorithm	Instruction count, CPI	The algorithm determines the number of source program instructions executed and hence the number of processor instructions executed. The algorithm may also affect the CPI, by favoring slower or faster instructions. For example, if the algorithm uses more divides, it will tend to have a higher CPI.
Programming language	Instruction count, CPI	The programming language certainly affects the instruction count, since statements in the language are translated to processor instructions, which determine instruction count. The language may also affect the CPI because of its features; for example, a language with heavy support for data abstraction (e.g., Java) will require indirect calls, which will use higher CPI instructions.
Compiler	Instruction count, CPI	The efficiency of the compiler affects both the instruction count and average cycles per instruction, since the compiler determines the translation of the source language instructions into computer instructions. The compiler's role can be very complex and affect the CPI in varied ways.
Instruction set architecture	Instruction count, clock rate, CPI	The instruction set architecture affects all three aspects of CPU performance, since it affects the instructions needed for a function, the cost in cycles of each instruction, and the overall clock rate of the processor.

Elaboration: Although you might expect that the minimum CPI is 1.0, as we'll see in Chapter 4, some processors fetch and execute multiple instructions per clock cycle. To reflect that approach, some designers invert CPI to talk about *IPC*, or *instructions per clock cycle*. If a processor executes on average two instructions per clock cycle, then it has an IPC of 2 and hence a CPI of 0.5.

Common F&Q

How does compiler affect IC and CPI?

- Compilers affect CPI…
  - Wise instruction selection
    - "Strength reduction": x * 2n → x << n
    - Use registers to eliminate loads and stores
  - More compact code -> less waiting for instructions
- …and instruction count
  - Common sub-expression elimination
  - Use registers to eliminate loads and stores

Operation	Intger or Floating Point	Typical Latency in Cycles
+,-,<<, |, &	Int	1
/	Int	32
*	Int	2
+ - *	FP	4
/ Sqrt	FP	12
Loads, Stores	Int or FP	3,8,30, or 200

(Ref: https://cseweb.ucsd.edu/classes/sp10/cse141/pdf/02/02_performance.key.pdf)