Performance Measurement

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Performance

- Performance is the ability of the computer to quickly execute a program.
- Three factors affects the performance:

  Design of the hardware.

  Design Instruction set.

  Design Compiler.

Hence it is necessary to design the above three in a coordinated way.

Measuring Performance

to maximize performance, need to minimize execution time

$$performance_X = 1 \;/\; execution\_time_X$$

If X is n times faster than Y, then

$$\frac{performance_X}{performance_Y} = \frac{execution\_time_Y}{execution\_time_X} = n$$

cpu time or Cpu Execution Time

cpu execution time or execution time):time spend in executing the line of code in a program

Iron law of processor performance

$$\frac{\text{Instructions}}{\text{Program}} \times \frac{\text{Clock cycles}}{\text{Instruction}} \times \frac{\text{Seconds}}{\text{Clock cycle}} = \frac{\text{Seconds}}{\text{Program}} = \text{CPU time}$$

- As this formula demonstrates, processor performance is dependent upon three characteristics: clock cycle (or rate), clock cycles per instruction, and instruction count. Furthermore, CPU time is equally dependent on these three characteristics;
- for example, a 10% improvement in any one of them leads to a 10% improvement in CPU time. Unfortunately, it is difficult to change one parameter in complete isolation from others because the basic technologies involved in changing each characteristic are interdependent:

Instructions/Program (Instruction count)

- Instructions executed, not static code size
- Determined by algorithm, compiler, ISA

Cycles/Instruction (CPI)

- Determined by ISA and CPU organization
- Overlap among instructions reduces this term

Time/cycle (Cycle time)

- Determined by technology, organization, clever circuit design

processor Performance Equation

CPU time for a program can then be expressed two ways:

$$\text{CPU time} = \text{\# CPU clock cycles for a program} \times \text{clock cycle time}$$

or

$$\text{CPU time} = \frac{\text{\# CPU clock cycles for a program}}{\text{clock rate}}$$

The Processor Performance Equation

- In addition to the number of clock cycles needed to execute a program, we can also count the number of instructions executed—the instruction path length or instruction count (IC).
- If we know the number of clock cycles and the instruction count, we can calculate the average number of clock cycles per instruction (CPI).
- Because it is easier to work with, and because we will deal with simple processors , we use CPI. Designers sometimes also use instructions per clock (IPC), which is the inverse of CPI

Clock Cycles per Instruction(CPI)

Not all instructions take the same amount of time to execute

One way to think about execution time is that it equals the number of instructions executed multiplied by the average time per instruction

- Clock cycles per instruction (CPI) – the average number of clock cycles each instruction takes to execute.
- CPI is computed as

$$\text{CPI} = \frac{\text{CPU clock cycles for a program}}{\text{Instruction count}}$$

$$\begin{array}{c} \text{\# CPU clock cycles} \\ \text{for a program} \end{array} = \begin{array}{c} \text{\# Instructions} \\ \text{for a program} \end{array} \times \begin{array}{c} \text{Average clock cycles} \\ \text{per instruction} \end{array}$$

Our basic processor performance equation is then

$$\text{CPU time} = \text{Instruction\_count} \times \text{CPI} \times \text{clock\_cycle time}$$

or

$$\text{CPU time} = \frac{\text{Instruction\_count} \times \text{CPI}}{\text{clock\_rate}}$$

Q. **If a 8GHz computer takes 7 clock cycles for ALU instructions, 11 clock cycles for branch instructions and 6 clock cycles for data transfer instructions. Then Find the total time taken by the computer to execute the program that consists of 10 ALU instructions, 5 branch instructions and 5 data transfer instructions.**

#IC(instruction count)=20
CPI=total cycles/total instruction count
=(10*7+11*5+6*5) /20
=155/20
CPI=7.75

Cpu time=
=(20*7.75)/8*10^9
=19.375ns

Example on Performance equation

Consider two processors P1 and P2 executing the samesame program. Assume that under identical conditions, for the same input, a program running on P2 takes 25% less time but incurs 20% more CPI (clock cycles per instruction) as compared to the program running on P1. If the clock frequency of P1 is 1GHz, then the clock frequency of P2 (in GHz) is __________.

(A) 1.2
(B) 3.2
(C) 1.6
(D) 0.8

Q.ADD takes 1 clock cycle and MULT takes 3 clock cycles. If a program consists of 20 ADD and 10 MULT instructions, and clock rate is 1GHz,
what is the average CPI and the execution time?

Solution:avergage CPI=50/30=1.66
Execution time=(30*1.66)/10^{-9}=50*10^{-9}=50ns

cpu time Example

Consider an implementation of MIPS ISA with 500 MHz clock and

-each ALU instruction takes 3 clock cycles,

-each branch/jump instruction takes 2 clock cycles,

-each sw(store) instruction takes 4 clock cycles,

-each lw(load) instruction takes 5 clock cycles.

Also, consider a program that during its execution executes:

-x=200 million ALU instructions

-y=55 million branch/jump instructions

-z=25 million sw(store) instructions

-w=20 million lw(load) instructions

Find CPU time. Assume sequentially executing CPU.

a. Approach 1:

Clock_cycles_for_a_program = $(x \times 3 + y \times 2 + z \times 4 + w \times 5)$

$= 910 \times 10^6$ clock cycles

CPU_time = Clock cycles for a program / Clock rate

$= 910 \times 10^6 / 500 \times 10^6 = 1.82$ sec

b. Approach 2:

CPI = Clock cycles for a program / Instructions count

CPI = $(x \times 3 + y \times 2 + z \times 4 + w \times 5) / (x + y + z + w)$

= 3.03 clock cycles/ instruction

CPU time = Instruction count × CPI / Clock rate

$= (x+y+z+w) \times 3.03 / 500 \times 10^6$

$= 300 \times 10^6 \times 3.03 / 500 \times 10^6$

= 1.82 sec

Example

program 1 consist of 5000 floating point instructions and 25000 integer instructions.Processor A has a clock rate of 2.0GHZ.Floating point instruction takes 7 clock cycle and integer instruction take 1 clock cycle.

a.How long does it take to for this processor to run the program1.

b.What is the average CPI for the processor A for the given program 1?

C.processor A runs program 2 consist of 10,00,00 floating point instructions and 50000 integer instructions.What is the average CPI for the program2

d.Processor B has an average CPI for program2 of 3.5.its clock rate is 1.8GHZ.How much time it will take to execute the program2?

e. processor -------- is ----------- time faster than processor ----- for running program 2.

A.How long does it take to for this processor to run the program1.

$$\text{CPU time} = \frac{\text{Instruction\_count} \times \text{CPI}}{\text{clock\_rate}}$$

instruction count=5000+25000=30,000

CPI=(total number of clock cycles)/(total number of Instruction)

CPI=(5000*7+25000*1)/30000=2 cycles per Instruction

Execution time=(30000*2)/(2*10^9)

=30microsecond

b.What is the average CPI for the processor A for the given program 1?

Ans: 2 clock cycle per instruction

C.processor A runs program 2 consist of 10,00,00 floating point instructions and 50000 integer instructions.What is the average CPI for the program2

Ans:average CPI=(100000*7+50000*1)/150000

=750000/150000=5 cycles per instruction

d.Processor B has an average CPI for program2 of 3.5.its clock rate is 1.8GHZ.How much time it will take to execute the program2?

Ans: Execution time for processor B=(150000*3.5)/(1.8*10^9)=292microsecond

e.Execution time of processor A=(150000*5)/(2.0*10^9)=375 microsecond

Ans: processor B is 1.29 time faster than A.

In designing the processor, sometimes it is useful to calculate the number of total processor clock cycles as

$$\text{CPU clock cycles} = \sum_{i=1}^{n} \text{IC}_i \times \text{CPI}_i$$

where ICi represents the number of times instruction i is executed in a program and **CPI_i** represents the average number of clocks per instruction for instruction i. This form can be used to express CPU time as

$$\text{CPU time} = \left(\sum_{i=1}^{n} \text{IC}_i \times \text{CPI}_i\right) \times \text{Clock cycle time}$$

and overall CPI as

$$\text{CPI} = \frac{\sum_{i=1}^{n} \text{IC}_i \times \text{CPI}_i}{\text{Instruction count}} = \sum_{i=1}^{n} \frac{\text{IC}_i}{\text{Instruction count}} \times \text{CPI}_i$$

form of the CPI calculation uses each individual CPIi and the fraction of occurrences of that instruction in a program (i.e., ICi Instruction count)

Calculating CPI

The table below indicates frequency of all instruction types executed in a "typical" program and, we are provided with a number of cycles per instruction for each type.

Instruction Type	Frequency	No of cycles Cycles per Instruction
ALU instruction	50%	4
Load instruction	30%	5
Store instruction	5%	4
Branch instruction	15%	2

Overall CPI = $0.5*4 + 0.3*5 + 0.05*4 + 0.15*2 = 4$ cycles/instruction

Example-

Suppose a program (or a program task) takes 1 billion instructions to execute on a processor running at 2 GHz. Suppose also that 50% of the instructions execute in 3 clock cycles, 30% execute in 4 clock cycles, and 20% execute in 5 clock cycles. What is the execution time for the program or task?

solution:

We have the instruction count: 10^9 instructions. The clock time can be computed quickly from the clock rate to be 0.5×10-9 seconds. So we only need to to compute clocks per instruction as an effective value:

Value	Frequency	Product
3	0.5	1.5
4	0.3	1.2
5	0.2	1.0
CPI =		3.7

Then we have

Execution time = $10^9 \times 3.7 \times 0.5\times10^{-9}$ *sec* = 1.85 *sec*