Problem -1
Performance Metrics

Q1. For the purpose of solving a given problem, you benchmark a program on two computer systems. On system A ,the object code executed 80 million Arithmetic Logic Unit operations(ALU ops), 40 million Load instructions, 25 million branch instructions. On system B, the object code executed 50 million ALU ops, 50 million loads and 40 million branch instructions. In both the systems, each ALU op takes 1 clock cycle, each load takes 3 clock cycles, and each branch takes 5 clock cycles.

a) Compute the relative frequency of occurrence of each type of instruction executed in both the systems.

b) Find the CPI for each system.

c) Assuming that the clock on system B is 10% faster than the clock on system A, which system is faster for the given application problem and by how much percent ?

Sys.A. 80 + 40 + 25 = 145 million

Sys B 50 +

Relative frequency = $\frac{Freq of one event}{Sum of freq}$

Solution -1

Instruction Type	System A	System B
ALU	80 Million	50 Million
Load	40 Million	50 Million
Branches	25 Million	40 Million

- Relative freq of occurrence is given by count of instruction type /Total instr count.
- **System A:**

Total instruction count=80+40+25 =145 million .

Freq. (ALU) = 80/145= 0.55.

Freq. (Load) =40/145= 0.28.

Freq. (Br.)=25/145=0.17.

- **System B:**

Total instruction count =50+50+40 =140.

Freq. (ALU) = 50/140 =0.36.

Freq. (Load) =50/140 =0.36.

Freq. (Br.) =40/140 = 0.29.

Solution -1

b) CPI (Cycles per Instruction)

Freq. (ALU) x Clk cycle + Freq. (Load) x Clk cycle + Freq. (Br) x Clk cycle

CPI (A):

$= 0.55 \times 1 + 0.28 \times 3 + 0.17 \times 5 = 2.24$

CPI (B) :

$= 0.36 \times 1 + 0.36 \times 3 + 0.29 \times 5 = 2.89$

Solution -1

- C) Given

clock cycle time (A)/clock cycle time(B) = 1.1
=> clock cycle time (A)=1.1 clock cycle time(B).

Exec time (A) = $145 \times 10^6 \times 2.24 \times 1.1$ cct (b) = 357.28×10^6 xcct(b) .
Exec time (B) = $140 \times 10^6 \times 2.89 \times$ cct(b) = $404.6 \times 10^6 \times$ cct(b).

Hence system (A) is faster by (Exec time(B)/Exec time (A))
$(404.6 \times 10^6 / 357.28 \times 10^6) = 1.134$ times
=> 13.4 %

Tutorial -1
Performance Metrics

Q2) Consider three different processors,p1,p2 and p3,executing the same instruction set.P1 has a 3 GHz clock rate and a CPI of 1.5 .P2 has a 2.5 GHz clock rate and a CPI of 1.0 .P3 has a 4.0 GHz clock rate and a CPI of 2.2.

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

b) If the processors each execute a program in 10 seconds , find the number of cycles and the number of instructions.

c) 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 -2

- a) Given P1 : clock rate =3GHz , CPI 1.5
  P2 : clock rate =2.5GHz , CPI 1.0.
  P3 : clock rate =4GHz , CPI 2.2.
  Executing the same instruction set

Performance in terms of **instructions per second** (clock Rate/cpi)

P1 :3GHz /1.5 = 2×10^9

P2 : 2.5 GHz/1.0 = 2.5×10^9 .

P3 : 4GHz /2.2 = 1.82×10^9.

from p1,p2,p3 we can see that P2 is having the highest performance.

Solution -2

- b) Given : execution time of program = 10 s.
  number of cycles = ?
  Number of instructions = ?

Number of cycles = cpu time x clock rate

P1 : 10 x 3 GHz = $10 \times 3 \times 10^9 = 3 \times 10^{10}$.

P2 : 10 x 2.5GHz = 2.5×10^{10}.

P3 : 10 x 4GHz = 4×10^{10}.

Number of instructions = cpu time x clock rate /(CPI)

P1 : $10 \times 3 \times 10^9$ /(1.5) = 2×10^{10} instructions.

P2 : $10 \times 2.5 \times 10^9$ /(1.0) = 2.5×10^{10} instructions.

P3 : $10 \times 4 \times 10^9$ /(2.2) = 1.82×10^{10} instructions.

Solution – 2

c) Given reduction in execution time =30%

increase in cpi = 20%.

new clock rate = ?

Execution time = (Instr count x cpi)/(clock rate)

0.7 Exec time = (Ic(instr count) x 1.2 x Cpi) /(New clock rate)

=> new clock rate = 1.2 x clock rate / 0.7 = 1.71 x clock rate .

New clock rates :

P1 : 1.71 x 3GHz = 5.13 GHz

P2 : 1.71 x 2.5GHz = 4.28 GHz

P3 : 1.71 x 4GHz = 6.84 GHz

Tutorial-1
Performance Metrics

Q3) utilization of a subset of the performance equation as a performance metric is a fallacy . To illustrate this, consider the following two processors. P1 has a clock rate of 4 GHz, average CPI of 0.9, and requires the execution of 5.0E9 instructions. P2 has a clock rate of 3 GHz, an average CPI of

0.75, and requires the execution of 1.0E9 instructions.

a) One usual fallacy is to consider the computer with the largest clock rate as having the largest performance. Check if this is true for P1 and P2.

b)Another fallacy is to consider that the processor executing the largest number of instructions will need a larger CPU time. Considering that processor P1 is executing a sequence of 1.0E9 instructions and that the CPI of processors P1 and P2 do not change, determine the number of instructions that P2 can execute in the same time that P1 needs to execute 1.0E9 instructions.

Solution -3

a) Given P1 : clock rate = 4 GHz, CPI =0.9,ins count = 5×10^9 .
P2 : clock rate = 3 GHz, CPI =0.75,ins count = 1.0×10^9 .
given Fallacy : CPU with largest clk rate has largest performance .

Cputime/exec time = (Ins count x cpi) /clk rate .

P1 : cputime/exectime = $5 \times 10^9 \times 0.9 \times 0.25 \times 10^{-9} = 1.125$ s.
P2 : cputime/exectime = $1.0 \times 10^9 \times 0.75 \times 0.333 \times 10^{-9} = 0.24975$ s

Performance =1/exec time . P1= 0.889 ins/s , p2 = 4.004 ins/s

Hence from the cputimes and performance values computed we can come to the conclusion that though the P1 has higher clk rate (4GHz) when compared to P2 which is 3GHz ,performance of P2 is much larger than P1. which Disproves the fallacy. Performance depends on other factors apart from mere clk rate , such as Ins count and cpi .

Solution-3

b) fallacy 2 : processor executing the largest number of instructions will need a larger CPU time.

Given

P1 : ins count = 1.0×10^9 , cpi =0.9 , clk rate =4 GHz => cct = 0.25 ns

P2 : cpi = 0.75 ,clk rate = 3GHz => 0.333 ns.

In the cputime of P1 ins count executed by P2 =?

Cputime (P1) = $1.0 \times 10^9 \times 0.9 \times 0.25 \times 10^{-9} = 0.225$ s

P2 :

$0.225 = \text{Ins count} \times 0.75 \times 0.333 \times 10^{-9}$

ins count = $0.225 / (0.75 \times 0.333 \times 10^{-9}) = 9.009 \times 10^8$.

From Ins count of P1 and P2 it is clear in the same CPU time P1 executes more instructions than P2. Hence the Fallacy Disproved .

Tutorial -1
Performance Metrics

Q 4)Consider two different implementations of the same instruction set architecture. The instructions can be divided into four classes according to their CPI (class A, B, C, and D). P1 with a clock rate of 2.5 GHz and CPIs of 1, 2, 3,and 3, and P2 with a clock rate of 3 GHz and CPIs of 2, 2, 2, and 2.

Given a program with a dynamic instruction count of 1.0E6 instructions divided into classes as follows: 10% class A, 20% class B, 50% class C, and 20% class D, which implementation is faster?

a. What is the global CPI for each implementation?

b. Find the clock cycles required in both cases.

Solution -4

- Given instruction count $=1.0 \times 10^6$, INS classes A = 10% ,class B =20%,Class C =50% ,class D =20%.

processor 1 :CPIs class A = 1,class B = 2,class c =3 ,class D =3,
clock rate 2.5 GHz.

Processor2 : CPIs class A = 2,class B = 2,class c =2 ,class D =2,
clock rate 3 GHz.

a) Which implementation is faster?

cpu time = total no of clk cycles /clk rate .

Total no Clk cycles = $\sum^{n}_{i=0} f_i \, CPI_i$

Processor 1

Total clk cycles $= (0.1 \times 10^6 \times 1 + 0.2 \times 10^6 \times 2 + 0.5 \times 10^6 \times 3 + 0.2 \times 10^6 \times 3) = 2.6 \times 10^6$

clk rate =2.5 GHz

Cpu time $= 2.6 \times 10^6 / 2.5 \times 10^9 = 1.04$ ms