

Problem 1.

Consider two different machines, with two different instruction sets, both of which have a clock rate of 200 MHz. The following measurements are recorded on the two machines running a given set of benchmark programs:

Instruction Type	Instruction Count (millions)	Cycles per Instruction
Machine A		
Arithmetic and logic	8	1
Load and store	4	3
Branch	2	4
Others	4	3
Machine B		
Arithmetic and logic	10	1
Load and store	8	2
Branch	2	4
Others	4	3

a. Determine the effective CPI, MIPS rate, and execution time for each machine.

b. Comment on the results.

Answer:

a.

$$CPI_A = \frac{\sum CPI_i \times I_i}{I_c} = \frac{(8 \times 1 + 4 \times 3 + 2 \times 4 + 4 \times 3) \times 10^6}{(8 + 4 + 2 + 4) \times 10^6} \approx 2.22$$

$$MIPS_A = \frac{f}{CPI_A \times 10^6} = \frac{200 \times 10^6}{2.22 \times 10^6} = 90$$

$$CPU_A = \frac{I_c \times CPI_A}{f} = \frac{18 \times 10^6 \times 2.2}{200 \times 10^6} = 0.2 \text{ s}$$

$$CPI_B = \frac{\sum CPI_i \times I_i}{I_c} = \frac{(10 \times 1 + 8 \times 2 + 2 \times 4 + 4 \times 3) \times 10^6}{(10 + 8 + 2 + 4) \times 10^6} \approx 1.92$$

$$MIPS_B = \frac{f}{CPI_B \times 10^6} = \frac{200 \times 10^6}{1.92 \times 10^6} = 104$$

$$CPU_B = \frac{I_c \times CPI_B}{f} = \frac{24 \times 10^6 \times 1.92}{200 \times 10^6} = 0.23 \text{ s}$$

b. Even though, machine B has a higher MIPS than machine A, it needs a longer CPU time to execute the similar set of benchmark programs (instructions).

Problem 2.

A program is run on a 40 MHz processor. The object code consists of 100000 instructions, with the following instruction mix and clock cycle count.

Instruction type	Instruction count	Clock cycle count
Integer arithmetic	45000	1
Data transfer	32000	2
Floating point	15000	2
Control transfer	8000	2

Determine the effective CPI, MIPS and execution time of the program.

$$\text{CPI} = \frac{\sum(\text{Instruction count} \times \text{Cycle per instruction})}{\text{The number of instructions the program contains}}$$

$$= (45000 \times 1 + 32000 \times 2 + 15000 \times 2 + 8000 \times 2) / 100000$$

$$\text{CPI} = 1.55$$

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$$\text{MIPS} = f / \text{CPI} \times 10^6$$

$$= (40 \times 10^6) / (1.55 \times 10^6)$$

$$= 25.8$$

Program execution time, $T = I_c \times \text{CPI} \times t$

$$= 100000 \times 1.55 \times 1/f$$

$$= (100000 \times 1.55) / 40 \times 10^6$$

$$= 3.875 \text{ ms}$$

Problem 3.

When a CPU operates at a clock frequency of 500MHz, requires an average of 5 CPI for executing one instruction, what is the performance (in MIPS) of the CPU?

**Average executing time of one instruction:

$$= \text{CPI} * \text{Clock time}$$

$$= 5 \text{ clocks/instruction} * (1\text{sec}/500\,000\,000 \text{ clocks})$$

$$= 5/500000000$$

$$= 0.00000001 \text{ seconds/instruction.}$$

**Number of instructions that can be executed in 1 sec =

$$= 1 \text{ second} / \text{Average execution time of one instruction}$$

$$= 1/0.00000001 \text{ second}$$

$$= 100\,000\,000 \text{ instruction}$$

$$= 100 \text{ MIPS}$$

500 000 000 clocks in 1 sec

So, 1 clock = 1/500 000 000 sec.

[1 clock cycle means the time it takes to turn a transistor OFF and back ON again]

Problem 4.

When the instruction mix of a CPU in the values that are shown in the table below:

1. What is the average executing time of one instruction?
2. What is the performance of CPU?

Instruction type	Instruction execution time	Occurrence rate
Register to register operation	0.3 microsecond	30%
Register to /from	0.5 microsecond	50%

memory operation		
Unconditional branch	0.2 microsecond	20%

Average execution time of one instruction

$$= \sum (\text{instruction execution time} * \text{Occurrence rate})$$

$$= 0.3 * 0.30 + 0.5 * 0.5 + 0.2 * 0.2$$

$$= 0.38 \text{ microsecond}$$

CPU performance = $1 / \text{Average instruction execution time}$

$$= 1 / 0.38$$

$$= 100 / 38$$

$$= 2.6315 \text{ MIPS}$$