

1) Suppose you have a load/store computer with the following instruction mix:

| Operation | Frequency | No. of Clock cycles |
|------------------|------------------|----------------------------|
| ALU ops | 35% | 1 |
| Loads | 25% | 2 |
| Stores | 15% | 2 |
| Branches | 25% | 3 |

a) Compute the CPI.

$$CPI_{old} = (0.35 * 1) + (0.25 * 2) + (0.15 * 2) + (0.25 * 3) = 1.9$$

b) We observe that 35% of the ALU ops are paired with a load, and we propose to replace these ALU ops and their loads with a new instruction. The new instruction takes 1 clock cycle. With the new instruction added, branches take 5 clock cycles, Compute the CPI for the new version.

$$0.35 * 0.35 = 0.1225$$

$$CPI_{new} = \frac{(0.35 - 0.1225) * 1 + (0.25 - 0.1225) * 2 + 0.15 * 2 + 0.25 * 5 + 0.1225 * 1}{(1 - 0.1225)}$$

$$= \frac{2.155}{0.8775} = 2.455$$

c) If the clock of the old version is 20% faster than the new version, which version has faster CPU Execution time and by how much percent?

$$\frac{CCT_{new}}{CCT_{old}} = 1.2 \qquad CCT_{new} = 1.2 * CCT_{old}$$

$$CPU \text{ Exec. Time}_{old} = 1.9 * IC_{old} * CCT_{old}$$

$$CPU \text{ Exec. Time}_{new} = 0.8775 * IC_{old} * 2.46 * 1.2 * CCT_{old}$$

$$= 2.59 * IC_{old} * CCT_{old}$$

So, old version is faster $\frac{2.59}{1.9} = 1.36$

By 36%

2) For the purpose of solving a given application 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, and 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 systems, each ALU op takes 1 clock cycles, 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 systems.

| | <u>A</u> | <u>B</u> |
|----------|-------------------------|-------------------------|
| ALU ops | $\frac{80}{145} = 0.55$ | $\frac{50}{140} = 0.36$ |
| Loads | $\frac{40}{145} = 0.28$ | $\frac{50}{140} = 0.36$ |
| Branches | $\frac{25}{145} = 0.17$ | $\frac{40}{140} = 0.28$ |

b) Find the CPI for each system.

$$CPI_A = (0.55 * 1) + (0.28 * 3) + (0.17 * 5) = 2.24$$

$$CPI_B = (0.36 * 1) + (0.36 * 3) + (0.28 * 5) = 2.84$$

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?

$$\frac{CCT_A}{CCT_B} = 1.1 \quad CCT_A = 1.1 * CCT_B$$

$$\begin{aligned} CPU \text{ Exec. Time }_A &= 145 * 10^6 * 2.24 * 1.1 * CCT_B \\ &= 357.28 * 10^6 * CCT_B \end{aligned}$$

$$\begin{aligned} CPU \text{ Exec. Time }_B &= 140 * 10^6 * 2.84 * CCT_B \\ &= 397.6 * 10^6 * CCT_B \end{aligned}$$

$$\text{So, System A is faster} \quad \frac{397.6}{357.28} = 1.11$$

By 11%