submitting by Rotem Kashani 209073352

Computer Architecture Exercise 4

The compilation of a C language program produces the following distributions of instructions:

Type i	Instructions	Clock Cycles per Instruction
ALU	475	6
Branch	128	10
Load	154	8
Store	141	8
Other	102	7

Find (up to 3 places after the decimal point):

1. **IC**

IC = 475 + 128 + 154 + 141 + 102 = **1000**

2. $\mathbf{IC_i/IC}$ for each instruction type **i** in percent

type i – ALU: 475/1000 = 47.5%
type i – Branch: 128/1000 = 12.8%
type i – Load: 154/1000 = 15.4%
type i – Store: 141/1000 = 14.1%
type i – Other: 102/1000 = 10.2%

3. **CPI**

CPI i is the average of the number of clock cycles to run one type i command, therefore

$$CPI = 6 * \frac{IC_i}{IC}(ALU) + 10 * \frac{IC_i}{IC}(Branch) + 8 * \frac{IC_i}{IC}(Load) + 8 * \frac{IC_i}{IC}(Store) + 7 * \frac{IC_i}{IC}(Other) = 6 * 0.475 + 10 * 0.128 + 8 * 0.154 + 8 * 0.141 + 7 * 0.102 = \mathbf{7.204}$$

4. The relative improvement in run time after lowering the **CPI** for branch instructions from **10** to **7**.

$$CPI' = 6 * \frac{IC_i}{IC}(ALU) + 7 * \frac{IC_i}{IC}(Branch) + 8 * \frac{IC_i}{IC}(Load) + 8 * \frac{IC_i}{IC}(Store) + 7 * \frac{IC_i}{IC}(Other) = 6 * 0.475 + 7 * 0.128 + 8 * 0.154 + 8 * 0.141 + 7 * 0.102 = \mathbf{6.82}$$

So, the relative improvement is $\frac{CPI}{CPI'} = \frac{7.204}{6.82} = \mathbf{1.056}$

5. Of the 128 branch instructions, 52 are **JMP** with **CPU = 15** and the rest are conditional branch **JCC**.

   Find the **CPI** of the **JCC** instructions.

According to the definition: $\mathrm{CPI}_{\mathrm{Branch}} = \sum_{k\in \mathrm{Branch}} \mathrm{CPI}_k \times \frac{\mathrm{IC}_k}{\mathrm{IC}_{\mathrm{Branch}}}$

We will separate the Branch commands into commands that are a JCC conditional branch and commands that are a JMP conditional branch.

$$\mathrm{CPI}_{\mathrm{Branch}} = \sum_{k\in \mathrm{JCC}} \mathrm{CPI}_k \times \frac{\mathrm{IC}_k}{\mathrm{IC}_{\mathrm{Branch}}} + \mathrm{CPI}_{\mathrm{JMP}} \times \frac{\mathrm{IC}_{\mathrm{JMP}}}{\mathrm{IC}_{\mathrm{Branch}}}$$

Now multiply the equation on the right by $\frac{\mathrm{IC}_{\mathrm{JCC}}/\mathrm{IC}}{\mathrm{IC}_{\mathrm{JCC}}/\mathrm{IC}}$ and by $\frac{1/\mathrm{IC}}{1/\mathrm{IC}}$

$$\mathrm{CPI}_{\mathrm{Branch}} = \left[\sum_{k\in \mathrm{JCC}} \mathrm{CPI}_k \times \frac{\mathrm{IC}_k}{\mathrm{IC}_{\mathrm{Branch}}}\right] \times \frac{\mathrm{IC}_{\mathrm{JCC}}/\mathrm{IC}}{\mathrm{IC}_{\mathrm{JCC}}/\mathrm{IC}} + \left[\mathrm{CPI}_{\mathrm{JMP}} \times \frac{\mathrm{IC}_{\mathrm{JMP}}}{\mathrm{IC}_{\mathrm{Branch}}}\right] \times \frac{1/\mathrm{IC}}{1/\mathrm{IC}}$$