HW #1

1.5 [4] <§1.6> 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 has 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?

a. P1: $\frac{3\,GHz}{1.5\,/\text{instructions}} = 2\times10^9$ instructions/s

P2: $\frac{2.5\,GHz}{1.0\,/\text{instructions}} = 2.5\times10^9$ instructions/s

P3: $\frac{4.0\,GHz}{2.2\,/\text{instructions}} = 1.8\times10^9$ instructions/s

$\therefore$ P2 has the highest performance

b. P1: $2\times10^9\times10 = 2\times10^{10}$ instructions

$2\times10^{10}\times1.5 = 3\times10^{10}$ cycles

P2: $2.5\times10^9\times10 = 2.5\times10^{10}$ instructions

$2.5\times10^{10}\times1.0 = 2.5\times10^{10}$ cycles

P3: $1.8\times10^9\times10 = 1.8\times10^{10}$ instructions

$1.8\times10^{10}\times2.2 = 4\times10^{10}$ cycles

c. execution time $= 10s \times 70\% = 7s$

P1: CPI $= 1.5\times1.2 = 1.8$

the number of instructions $= 2\times10^{10}$

clock rate $= \frac{2\times10^{10}\times1.8}{7s} = 5.1\,GHz$

P2: CPI $= 1.0\times1.2 = 1.2$

the number of instructions $= 2.5\times10^{10}$

clock rate $= \frac{2.5\times10^{10}\times1.2}{7s} = 4.3\,GHz$

P3: CPI $= 2.2\times1.2 = 2.64$

the number of instructions $= 1.8\times10^{10}$

clock rate $= \frac{1.8\times10^{10}\times2.64}{7s} = 6.8\,GHz$

1.6 [20] <§1.6> Consider two different implementations of the same instruction set architecture. The instructions can be divided into four classes according to their CPI (classes 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 is faster: P1 or P2?

a. What is the global CPI for each implementation?

b. Find the clock cycles required in both cases.

a. P1: global CPI $= 1\times 10\% + 2\times 20\% + 3\times 50\% + 3\times 20\%$

$= 2.6$

P2: global CPI $= 2$

b. P1: clock cycles $= 1\times 10^6 \times 2.6 = 2.6\times 10^6$

P2: clock cycles $= 1\times 10^6 \times 2 = 2\times 10^6$

1.7 [15] <§1.6> Compilers can have a profound impact on the performance of an application. Assume that for a program, compiler A results in a dynamic instruction count of 1.0E9 and has an execution time of 1.1 s, while compiler B results in a dynamic instruction count of 1.2E9 and an execution time of 1.5 s.

a. Find the average CPI for each program given that the processor has a clock cycle time of 1 ns. 1×10^{-9}ns

b. Assume the compiled programs run on two different processors. If the execution times on the two processors are the same, how much faster is the clock of the processor running compiler A's code versus the clock of the processor running compiler B's code?

为什么用a.中的CPI计算?

c. A new compiler is developed that uses only 6.0E8 instructions and has an average CPI of 1.1. What is the speedup of using this new compiler versus using compiler A or B on the original processor?

a. A: $CPI = \dfrac{1.1s}{1.0\times 10^9 \times 1\times 10^{-9}s} = 1.1$

B: $CPI = \dfrac{1.5s}{1.2\times 10^9 \times 1\times 10^{-9}s} = 1.25$

b. $\dfrac{f_B}{f_A} = \dfrac{1.2\times 10^9 \times 1.25}{1.0\times 10^9 \times 1.1} = 1.36$

c. $\dfrac{T_A}{T_C} = \dfrac{1.0\times 10^9 \times 1.1}{6\times 10^8 \times 1.1} = 1.67$ $\quad \dfrac{T_B}{T_C} = \dfrac{1.2\times 10^9 \times 1.25}{6\times 10^8 \times 1.1} = 2.27$

1.9 Assume for arithmetic, load/store, and branch instructions, a processor has CPIs of 1, 12, and 5, respectively. Also assume that on a single processor a program requires the execution of 2.56E9 arithmetic instructions, 1.28E9 load/store instructions, and 256 million branch instructions. Assume that each processor has a 2 GHz clock frequency.

Assume that, as the program is parallelized to run over multiple cores, the number of arithmetic and load/store instructions per processor is divided by $0.7 \times p$ (where p is the number of processors) but the number of branch instructions per processor remains the same.

1.9.1 [5] < §1.7> Find the total execution time for this program on 1, 2, 4, and 8 processors, and show the relative speedup of the 2, 4, and 8 processors result relative to the single processor result.

1.9.1 1 core : total execution time

$$= \frac{2.56\times10^9\times1 + 1.28\times10^9\times12 + 256\times10^6\times5}{2\times10^9}$$

$= 9.6s$

2 cores : total execution time

$$= \frac{2.56\times10^9\div(0.7\times2)\times1 + 1.28\times10^9\div(0.7\times2)\times12 + 256\times10^6\times5}{2\times10^9}$$

$= 7.04s$

relative speed up $= \frac{9.6s}{7.04s} = 1.36$

4 cores : total execution time

$$= \frac{2.56\times10^9\div(0.7\times4)\times1 + 1.28\times10^9\div(0.7\times4)\times12 + 256\times10^6\times5}{2\times10^9}$$

$= 3.84s$

relative speed up $= \frac{9.6s}{3.84s} = 2.5$

similarly, 8 cores execution time $= 2.24s$

relative speed up $= \frac{9.6s}{2.24s} = 4.29$

1.9.2 [10] <§§1.6, 1.8> If the CPI of the arithmetic instructions was doubled, what would the impact be on the execution time of the program on 1, 2, 4, or 8 processors?

1.9.3 [10] <§§1.6, 1.8> To what should the CPI of load/store instructions be reduced in order for a single processor to match the performance of four processors using the original CPI values?

1.9.2 1 core execution time $= \dfrac{2.56\times10^9\times2 + 1.28\times10^9\times12 + 256\times10^6\times5}{2\times10^9} = 10.88s$

similarly, 2 cores execution time $= 7.95s$

4 cores execution time $= 4.30s$

8 cores execution time $= 2.47s$

1.9.3 $\dfrac{2.56\times10^9\times2 + 1.28\times10^9\times CPI + 2.56\times10^6\times5}{2\times10^9}$

$= \dfrac{2.56\times10^9\div2.8\times2 + 1.28\times10^9\div2.8\times12 + 2.56\times10^6\times5}{2\times10^9}$

$\Rightarrow 2.56\times2 + 1.28\times CPI = 2.56\times2\div2.8 + 1.28\times12\div2.8.$

$CPI = 1.7$

1.13 Another pitfall cited in Section 1.10 is expecting to improve the overall performance of a computer by improving only one aspect of the computer. Consider a computer running a program that requires 250 s, with 70 s spent executing FP instructions, 85 s executed L/S instructions, and 40 s spent executing branch instructions.

1.13.1 [5] <§1.10> By how much is the total time reduced if the time for FP operations is reduced by 20%?

1.13.2 [5] <§1.10> By how much is the time for INT operations reduced if the total time is reduced by 20%?

? 除了fp, L/S, branch以外的指令

1.13.3 [5] <§1.10> Can the total time can be reduced by 20% by reducing only the time for branch instructions?

1.13.1 $1-\frac{250-70+70\times0.8}{250}=5.6\%$

1.13.2 $T_{new}=250\times0.8=200s$ $\quad T_{fp}+T_{L/S}+T_{branch}=165s$ $\quad T_{int}=35s$

Reduce T_{int} 58%

1.13.3 By Amdahl's Law:

$$250\times0.8=250-40+\frac{40}{n}$$

$$200=210+\frac{40}{n}$$

$\because n<0 \quad \therefore$ It's impossible

1.14 Assume a program requires the execution of 50×10^6 FP instructions, 110×10^6 INT instructions, 80×10^6 L/S instructions, and 16×10^6 branch instructions. The CPI for each type of instruction is 1, 1, 4, and 2, respectively. Assume that the processor has a 2 GHz clock rate.

1.14.1 [10] <§1.10> By how much must we improve the CPI of FP instructions if we want the program to run two times faster?

1.14.2 [10] <§1.10> By how much must we improve the CPI of L/S instructions if we want the program to run two times faster?

1.14.3 [5] <§1.10> By how much is the execution time of the program improved if the CPI of INT and FP instructions is reduced by 40% and the CPI of L/S and Branch is reduced by 30%?

1.14.1 total clock cycles $=50\times10^6\times1+110\times10^6\times1+80\times10^6\times4+16\times10^6\times2$

$$\text{total clock cycles}\times0.5=110\times10^6\times1+80\times10^6\times4+16\times10^6\times2+50\times10^6\times CPI$$

$\Rightarrow CPI<0$ no way

1.14.2 similarly we can list the equation.

thus $CPI=0.725$

1.14.3 improved clock cycles $= 50\times10^6\times0.6\times1 + 110\times10^6\times0.6\times1 +$
$80\times10^6\times0.7\times4 + 16\times10^6\times0.7\times2$

$$\frac{\text{improved clock cycles}}{\text{total clock cycles}} = 0.67$$

reduced by 33%

$$T_{cpu} = \frac{\text{total clock cycles}}{f} = 0.256s$$

$$T_{cpu,\ improved} = \frac{\text{improved clock cycles}}{f} = 0.171s$$