CO200 – COA. Tutorial 2. Duration: 60 minutes. Max: 4 – Aug – 2016

1. Our favorite program runs in 10 seconds on computer A, which has a 2 Ghz clock. We are trying to help a computer designer build a computer, B, which will run this program in 6 seconds. The designer has determined that a substantial increase in the clock rate is possible, but this increase will affect the rest of the CPU design, causing computer B to require 1.2 times as many clock cycles as computer A for this program. What clock rate should we tell the designer to target?

Let's first find the number of clock cycles required for the program on A:

$$=$$

$$=$$

$$= 10 \text{ seconds} \quad 2 \qquad = 20 \qquad \text{cycles}$$

CPU time for B can be found using this equation:

$$=$$

$$6 \text{ seconds} =$$

$$= \qquad = \qquad = \qquad = 4\text{GHz}$$

To run the program in 6 seconds, B must have twice the clock rate of A.

2. Suppose we have two implementations of the same instruction set architecture. Computer A has a clock cycle time of 250 ps and a CPI of 2.0 for some program, and computer B has a clock cycle time of 500 ps and a CPI of 1.2 for the same program. Which computer is faster for this program and by how much?

We know that each computer executes the same number of instructions for the program; let's call this number *I*. First, find the number of processor clock cycles for each computer:

$$= I$$
$$= I$$

Now we can compute the CPU time for each computer:

$$=$$
$$= I \qquad \text{ps} = 500$$

Likewise, for B:

$$= I \qquad\qquad = 600$$

Clearly, computer A is faster. The amount faster is given by the ratio of the execution times:

We can conclude that computer A is 1.2 times as fast as computer B for this program.

3. A compiler designer is trying to decide between two code sequences for a particular computer. The hardware designers have supplied the following facts.

	CPI for each instruction class		
	A	B	C
CPI	1	2	3

For a particular high level language statement, the compiler writer is considering two code sequences that require the following instruction counts:

Code Sequence	Instruction counts for each instruction class		
	A	B	C
1	2	1	2
2	4	1	1

Which code sequence executes the most instructions? Which will be faster? What is the CPI of each sequence?

Sequence 1 executes 2 + 1 + 2 = 5 instructions. Sequence 2 executes 4 + 1 + 1 = 6 instructions. Therefore, sequence 1 executes fewer instructions.

We can use the equation for CPU clock cycles based on instruction count and CPI to find the total number of clock cycles for each sequence:

$$\Sigma$$

This yields

$$= (2 \times 1) + (1 \times 2) + (2 \times 3) = 2 + 2 + 6 = 10 \text{ cycles}$$

$$= (4 \times 1) + (1 \times 2) + (1 \times 3) = 4 + 2 + 3 = 9 \text{ cycles}$$

So code sequence 2 is faster, even though it executes one extra instruction. Since code sequence 2 takes fewer overall clock cycles but has more instructions, it must have a lower CPI. The CPI values can be computed by

$$= \frac{\qquad}{\qquad}$$

$$= \frac{\qquad}{\qquad} = \frac{\quad}{\quad} = 2.0$$

$$= \frac{\qquad}{\qquad} = \frac{\quad}{\quad} = 1.5$$

4. Represent -8.125 in the IEEE 754 Single Precision Floating Point Format.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

5. Consider three different processorsP1,P2andP3executing the same instruction set.P1has a 3GHz clock rate and a CPI of 1.5.P2has a 2.5 GHz clock rate and CPI of 1.0.P3has a 4.0 GHzclock rate and has a CPI of 2.2(a)Whichprocessor has the highest performance expressed in instructions per second?(b) If the processors each execute a program in 10 seconds,findthe number of cycles and thenumber of instructions.(c) we are trying to reduce the execution time by 30% but this leads to an increase of 20% inthe CPI.Whatclock rate should we have to get this time reduction?

Solution

(a) ProcessorP2has the highest performance (instructions/second):•Performance ofP1(instructions/sec) =3×1091.5= 2×109

•Performance ofP2(instructions/sec) =2.5×1091.0= 2.5×109•Performance ofP3(instructions/sec) =4×1092.2= 1.8×109

(b) The number of cycles:

•Cycles (P1) = 10×3×109= 30×109•Cycles (P2) = 10×2.5×109= 25×109•Cycles (P3) = 10×4×109= 40×109

(c) The number of instructions:

•No. Instructions (P1) =10×3×1091.5= 20×109•No. Instructions (P2) =10×2.5×1091.0= 25×109•No. Instructions (P3) =10×4×1092.2= 18.18×109

(d) The required clock rate for each processor:

Reducing execution time by 30% means that new execution timeis 7 seconds.•CP Inew=CP Iold×1.2 .. So,CP IP1= 1.8, CP IP2= 1.2, CP IP3= 2.6•f=No.Instr×CP Itime, then–f(P1) =20×109×1.87= 5.14 GHz–f(P2) =25×109×1.27= 4.28 GHz–f(P3) =18.18×109×2.67= 6.75 GHz

6.Consider two different implementations of the same instruction set architecture. The instructionscan be divided into four classes according to their CPI (class A, B, C and D).P1with a clockrate of 2.5 GHz and CPIs of 1,2,3, and 3.P2with 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 asfollows: 10% class A, 20% class B, 50% class C, and 20% class D.Whichis faster ProcessorP1orP2?(a)Whatis the global CPI for each implementation?(b)Findthe clock cycles required in both cases.

Solution

(a) The global CPI for each implementation:•Since the given program with a dynamic instruction count of 1.0E6 instructions is dividedinto classes of 10% A, 20% B, 50% C and 20% D, then

Class A = 10%×1.0E6 = 105instr.

–Class B = 20%×1.0E6 = 2×105instr.

–Class C = 50%×1.0E6 = 5×105instr.

–Class D = 20%×1.0E6 = 2×105instr.

•T ime=No.Instr×CP IClockRate–Total TimeP1=(105×1)+(2×105×2)+(5×105×3)+(2×105×3)(2.5×109)= 10.4×10−4s–Total TimeP2=(105×2)+(2×105×2)+(5×105×2)+(2×105×2)(3×109)= 6.66×10−4s

Global;CPI =T otalT ime×ClockRateInstructionCount–CP I(P1) =(10.4×10−4)×(2.5×109)106= 2.6–CP I(P2) =(6.66×10−4)×(3.0×109)106= 2.0

(b) The clock cycles required in both bases:

•Clock Cycles = Instruction Count x CPI–Clock Cycles(P1) = (105×1)+(2×105×2)+(5×105×3)+(2×105×3) = 26×10^ 5–Clock Cycles(P2) = (105×2)+(2×105×2)+(5×105×2)+(2×105×2) = 20×10 ^ 5

7.Compilers can have a profound impact on the performance ofan application. Assume that for aprogram, compilerAresults in a dynamic instruction count of 1.0E9 and has an execution timeof 1.1 seconds, while compilerBresults in a dynamic instruction count of 1.2E9 and an executiontime of 1.5 seconds.(a)Findthe average CPI for each program given that the processor hasa clock cycle time of 1ns.(b) Assume the compiled programs run on two different processors. If the execution times onthe two processors are the same,how much fasteris the clock of the processor runningcompilerA'scode versus the clock of the processor running compilerB'scode?(c) A new compiler is developed that uses only 6.0E8 instructions and has an average CPI of1.1.Whatis the speedup of using this new compiler versus using compilerAorBon theoriginal processor?

Solution

(a) The average CPI for each program:

•CP I=Texec×fNo.Instr

•Compiler A CPI =1.1×109109= 1.1

•Compiler B CPI =1.5×1091.2×109= 1.25(

b) Clock speed of processor running compiler A relative to processor running compiler B:

•fBfA= (No.Instr(B)×CP I(B)No.Instr(A)×CP I(A)) = 1.37

(c) Speedup of using new compiler:

•TATnew= 1.67

•TBTnew= 2.2