National Chung Cheng University
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Quiz #1 Solution

1. 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 have a 2.5 GHz clock rate and CPI of 1.0. P3 has a 4.0 GHz clock rate and has a CPI of 4.0.

   a. Which processor has the highest performance expressed in instructions per second? (10 points)

   Solution:
   Execute time = $\frac{Instruction\ \ count \times CPI}{Clock\ \ rate}$

   The same number of instructions for the porgram, let's call this numbe I

   CPU clock cycles$_{P1}$ = I ×1.5
   CPU clock cycles$_{P2}$ = I ×1.0
   CPU clock cycles$_{P3}$ = I ×4.0

   CPU time$_{P1}$ $= I \times 1.5 \times \frac{1}{3GHz} = I \times 0.5 \times 10^{-9}$

   CPU time$_{P2}$ $= I \times 1.0 \times \frac{1}{2.5GHz} = I \times 0.4 \times 10^{-9}$

   CPU time$_{P3}$ $= I \times 4.0 \times \frac{1}{4.0GHz} = I \times 1 \times 10^{-9}$

   So,P2 has the highest performance expressed in instructions per second.

   b. If the processors each execute a program in 20 seconds, find the number of cycles and the number of instructions. (10 points)

   Solution:

   CPU clock cycles$_{P1}$ = 20 seconds × 3 × 10^9 = 60 × 10^9 cycles
   CPU clock cycles$_{P2}$ = 20 seconds × 2.5 × 10^9 = 50 × 10^9 cycles
   CPU clock cycles$_{P3}$ = 20 seconds × 4.0 × 10^9 = 80 × 10^9 cycles

   Instructions for a program$_{P1}$ = 60 × 10^9 cycles ÷ 1.5 = 40 × 10^9
   Instructions for a program$_{P2}$ = 50 × 10^9 cycles ÷ 1.0 = 50 × 10^9
   Instructions for a program$_{P3}$ = 80 × 10^9 cycles ÷ 4.0 = 20 × 10^9

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? (15 points)

Solution:

Execution time = 20×0.7=14, CPI' = 1.2×CPI

clock rate$_{P1}$=$\frac{40G\times1.2\times1.5}{14}$ = 5.14G

clock rate$_{P2}$=$\frac{50G\times1.2\times1.0}{14}$ = 4.29G

clock rate$_{P3}$=$\frac{20G\times1.2\times4.0}{14}$ = 6.86G

2. Assume a program requires the execution of 50×10^6 FP instructions, 100×10^6 INT instructions, 80×10^6 L/S instructions, and 20×10^6 Branch instructions. The CPI for each type of instructions is 1, 1, 4, and 3, respectively. Assume that the processor has a 2 GHz clock rate.

a. By how much must we improve the CPI of FP instructions if we want the program to run two times faster? (15 points)

Solution:

	FP	INT	L/S	Branch
instructions	50×10^6	100×10^6	80×10^6	20×10^6
CPI	1	1	4	3

Clock cycle = $\mathrm{IC}_{FP}\times\mathrm{CPI}_{FP} + \mathrm{IC}_{INT}\times\mathrm{CPI}_{INT} + \mathrm{IC}_{L/S}\times\mathrm{CPI}_{L/S} + \mathrm{IC}_{Branch}\times\mathrm{CPI}_{Branch}$

$= 50 \times 10^6 + 100 \times 10^6 + 80 \times 10^6 \times 4 + 20 \times 10^6 \times 3 = 5.3 \times 10^8$

Execution time = $\frac{clock\ cycle}{clock\ rate}$ = $\frac{5.3\times10^8}{2\times10^9}$ = 0.265 s

Clock cycle' = $\frac{clock\ cycle}{2}$

$= \mathrm{IC}_{FP}\times\text{new }\mathrm{CPI}_{FP} + \mathrm{IC}_{INT}\times\mathrm{CPI}_{INT} + \mathrm{IC}_{L/S}\times\mathrm{CPI}_{L/S} + \mathrm{IC}_{Branch}\times\mathrm{CPI}_{Branch}$

new CPI_{FP}= ($\frac{5.3\times10^8}{2}$ - 100×10^6 +$80 \times 10^6 \times 4$ + $20 \times 10^6 \times 3$) / 50×10^6

= -4.3

Can't achieve

b. 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 20% ? (15 points)

Solution:

$$\text{Clock Cycle} = \text{IC}_{FP}\times 0.6\times \text{CPI}_{FP} + \text{IC}_{INT}\times 0.6\times \text{CPI}_{INT} + \text{IC}_{L/S}\times 0.8\times \text{CPI}_{L/S} + \text{IC}_{Branch}\times 0.8\times \text{CPI}_{Branch}$$

$$= 50 \times 0.6 \times 10^6 + 100 \times 0.6 \times 10^6 + 80 \times 0.8 \times 10^6 \times 4 + 20 \times 0.8 \times 10^6 \times 3 = 3.94 \times 10^8$$

$$\text{Execution time} = \frac{\textit{clock cycle}}{\textit{clock rate}} = \frac{3.94\times 10^8}{2\times 10^9} = 0.197 \text{ s}$$

$$\frac{0.265-0.197}{0.265} \times 100\% = 25.66\%$$

3. Consider the following MIPS loop:

```
LOOP: slt   $t2,  $0,  $t1
      beq   $t2,  $0,  DONE
      subi  $t1,  $t1, 1
      addi  $s2,  $s2, 2
      j      LOOP
DONE:
```

a. Assume that the register `$t1` is initialized to the value 10. What is the value in register `$s2` assuming `$s2` is initially zero? (10 points)

Solution:

Value in register \$s2 is 20

b. For each of the loops above, write the equivalent C code routine. Assume that the registers `$s1, $s2, $t1`, and `$t2` are integers `A, B, i`, and temp, respectively. (15 points)
Solution:

```
i = 10;
do{
    B+=2;
    i-=1;
}while(i>0)
```

c. For the loops written in MIPS assembly above, assume that the register `$t1` is initialized to the value N. How many MIPS instructions are executed? (10 points)
Solution:

$5 \times \mathrm{N} + 2$