HW2 Computer Org

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1 3.15.5

- a) Performance = $(\frac{Clock\ Rate}{CPI})$ instructions per sec
  Processor P1 performance = $(\frac{3GHz}{1.5}) = (2 \times 10^9)$ instructions per sec
  Processor P2 performance = $(\frac{2.5GHz}{1.0}) = (2.5 \times 10^9)$ instructions per sec
  Processor P3 performance = $(\frac{4.0GHz}{2.2}) = (1.82 \times 10^9)$ instructions per sec
  From these calculations we can see that P2 has the highest performance in terms of instructions per sec

- b) Number of cycles = $(clock\ rate \times 10)$ cycles
  Number of instructions = $\frac{(clock\ rate \times 10)}{CPI}$
  Processor P1 cycles = $(3GHz \times 10) = (3 \times 10^{10})$ cycles
  Processor P1 instructions = $\frac{(3GHz \times 10)}{1.5} = (2 \times 10^{10})$ instructions
  Processor P2 cycles = $(2.5GHz \times 10) = (2.5 \times 10^{10})$ cycles
  Processor P2 instructions = $\frac{(2.5GHz \times 10)}{1.0} = (2.5 \times 10^{10})$ instructions
  Processor P3 cycles = $(4GHz \times 10) = (4 \times 10^{10})$ cycles
  Processor P2 instructions = $\frac{(4.0GHz \times 10)}{2.2} = (1.82 \times 10^{10})$ instructions

- c) Execution time = $\frac{Number\ of\ instructions \times CPI}{Clock\ Rate}$
  Reduce exec time by 30 percent, increase of 20 percent in CPI value
  $(Execution\ time \times 0.7) = \frac{Number\ of\ instructions\ \times\ CPI\ \times\ 1.2}{1.71 \times Clock\ Rate}$
  New Clock Rate = $\frac{Clock\ Rate\ \times\ 1.2}{0.7}$
  Processor p1 new clock rate = $(3GHz \times 1.71) = 5.13$ GHz
  Processor p2 new clock rate = $(2.5GHz \times 1.71) = 4.27$ GHz
  Processor p3 new clock rate = $(4GHz \times 1.71) = 6.84$ GHz

2 3.15.7

- a) Formula for Global CPI = $\Sigma(CPI \times Fi)$, Fi = frequency count of each class
  Global CPI for p1 = $(1 \times 0.1) + (2 \times 0.2) + (3 \times 0.5) + (3 \times 0.2) = (0.1 + 0.4 + 1.5 + 0.6) = 2.6CPI$

Global CPI for p2 $= (2 \times 0.1) + (2 \times 0.2) + (2 \times 0.5) + (2 \times 0.2) = (0.2 + 0.4 + 1 + 0.4) = 2CPI$

- b) CPU clock cycles $= \Sigma(CPI \times Ci)$, Ci = instruction count
CPU clock cycles for P1 $= (1 \times 10^5) + (2 \times 2 \times 10^5) + (3 \times 5 \times 10^5) + (3 \times 2 \times 10^5) = 2.6 \times 10^6$
CPU clock cycles for P2 $= (2 \times 10^5) + (2 \times 2 \times 10^5) + (2 \times 5 \times 10^5) + (2 \times 2 \times 10^5) = 2 \times 10^6$
CPU execution time for P1 $= \frac{2.6 \times 10^5}{2.5 \times GHz} = 1.04ms$
CPU execution time for p2 $= \frac{2 \times 10^5}{3 \times GHz} = 666.67ms$
Therefore, processor p2 is faster

3 3.15.8

- a) CPU time $= (instruction\ count \times CPI \times Clock\ cycle\ time)$
CPI $= \frac{cpu\ time}{(instruction\ count \times clock\ cycle\ time)}$
Compiler A CPI $= (\frac{1.1}{1.0E9 \times 1.0E-9)} = 1.1$
Compiler B CPI $= (\frac{1.5}{1.2E9 \times 1.0E-9)} = 1.25$

- b) Execution time $= Instruction \times CPI\ clock\ rate$
instructions1 x CP11 clock rate1 = instructions2 x CP12 clock rate1
$(\frac{10^9 \times 1.1}{1 \times 10^9 \times 1.25}) \times (clockrate2) = 0.73clockrate2$
clockrate1 = 0.73clockrate2

- c) $CPU \times time_c = 0.66s$
$\frac{CPUtime_A}{CPUtime_C} = 1.67$
$\frac{CPUtime_B}{CPUtime_C} = 2.27$
Compiler C is 1.67 times faster then compiler A

4 3.15.10

- a) 1 processor execution time $= (\frac{(2.56E9 \times 1) + (1.28E9 \times 12) + (256 \times 1000000 \times 5)}{2 \times 1000000000} =$ 9.6 seconds

  2 processor execution time $= (\frac{(2.56E9 \times 1) + (1.28E9 \times 12)}{0.7 \times 2}) + (256 \times 1000000 \times 5) -> (\frac{14080000000}{2 \times 1000000000}) = 7.04$ seconds
  Relative speedup from 1 to 2 $= \frac{9.6}{7.04} = 1.36$

  4 processor execution time $= (\frac{(2.56E9 \times 1) + (1.28E9 \times 12)}{0.7 \times 4}) + (256 \times 1000000 \times 5) -> (\frac{7680000000}{2 \times 1000000000}) = 3.84$ seconds

Relative speedup from 1 to 4 = $\frac{9.6}{3.84} = 2.5$

8 processor execution time = $(\frac{(2.56E9\times 1)+(1.28E9\times 12)}{0.7\times 8}) + (256 \times 1000000 \times 5) -> (\frac{4480000000}{2\times 1000000000}) = 2.24$ seconds
Relative speedup from 1 to 8 = $\frac{9.6}{2.24} = 4.3$

- b) 1 processor execution time = $(\frac{(2.56E9\times 2)+(1.28E9\times 12)+(256\times 1000000\times 5)}{2\times 1000000000} =$ 10.88 seconds

  2 processor execution time = $(\frac{(2.56E9\times 2)+(1.28E9\times 12)}{0.7\times 2}) + (256 \times 1000000 \times 5) -> (\frac{15900000000}{2\times 1000000000}) = 7.95$ seconds

  4 processor execution time = $(\frac{(2.56E9\times 2)+(1.28E9\times 12)}{0.7\times 4}) + (256 \times 1000000 \times 5) -> (\frac{8600000000}{2\times 1000000000}) = 4.3$ seconds

  8 processor execution time = $(\frac{(2.56E9\times 2)+(1.28E9\times 12)}{0.7\times 8}) + (256 \times 1000000 \times 5) -> (\frac{4940000000}{2\times 1000000000}) = 2.47$ seconds

- c) The CPI of load/store instruction should be reduced by 25 percent
  Using values from part a with 4 processors
  $3.84 = \frac{(2.56E9+1.26E9\times i)+(2.56E8\times 5)}{2.0E9}$

  i = $\frac{((3.84)(2.0E9)-(2.56E8\times 5)-(2.56E9))}{1.26E9} = 3.047$

  3.047 / 12 = 0.25

5 3.15.12

- a) CPI = $\frac{(750sec)\times(3\times 10^9 s^-1)}{2.389\times(10)^{12}} = 0.9427$
- b) SPECratio = $\frac{reference\ time}{measured\ time} = \frac{9650sec}{750sec} = 12.867$
- c) New CPU time = (New instruction count) x (CPI) x (Clock cycle time) = (1.1)(old time) = (1.1) × (750) = 825 sec
- d) New CPU time = (1.1 x IC) x (1.05 x CPI) x (clock cycle time) = (1.55)(old time) = (1.155) × (750) = 866.25 sec, increase of 15.5 percent in CPU time
- e) change in SPECratio = (reference time) / (1.55 x measured time) = $\frac{12.867}{1.155} = 11.139$

- f) CPI = $\frac{(700sec)\times(4\times10^9 cycles*s^-1)}{(0.85)(2.389\times(10)^{12})} = 1.38$

- g) Change in CPI = $\frac{1.37-0.94}{0.94} = 0.43$
  Clock rate change = $\frac{(4.0\times10^9)-(3\times10^9)}{e\times10^9} = 0.333$
  Instruction count has been reduced so the increase in CPI is similar to that of the clock rate.

- h) Percentage of CPU reduction time = $\frac{750-700}{750} \times 100 = 6.66\%$

- i) New execution time = $960 - (960 \times \frac{10}{100}) = 864$
  Number of instructions = $\frac{864\times4\times10^9}{1.61} = 2.15 \times (10)^{11}$

- j) New number of instructions = $864 - (864 \times \frac{10}{100}) = 777.6$
  New Clock rate = $\frac{2.146\times10^9\times1.61}{864} = 3.33$ GHz

- k) Reduced Execution time = $960 - 0.2 \times 960 = 768$ sec
  Reduced CPI = $1.61 - 0.15 \times 1.62 = 1.37$
  Clock Rate = $\frac{2146\times10^9\times1.37}{768} = 3.82$ GHz

6 3.15.15

- a) Clock Cycle = $(50 \times 10^6 \times 1) + (110 \times 10^6 \times 1) + (80 \times 10^6 \times 4) + (16 \times 10^6 \times 2) + (50 \times 10^6) + (110 \times 10^6) + (320 \times 10^6) + (32 \times 10^6) = 512 \times 10^6 s$

  Execution time = clock cycle / clock rate = $\frac{512\times10^6}{2\times10^9} = 256 \times (10)^{-3}s$
  $CPI_F Pimproved = \frac{\frac{512\times10^6}{2}-((110\times10^6\times1)+(80\times10^6\times4)+(16\times10^6\times2))}{50\times10^6} = -4.12$
  Since the value is negative, the CPI of FP instructions cannot be improved since the value might be negative when the program runs two times faster.

- b) CPI (improved FP) = $\frac{\frac{512\times10^6}{2}-((50\times10^6\times1)+(110\times10^6\times1)+(16\times10^6\times2))}{80\times10^6} = \frac{512-944}{80} = 0.8$
  For the program to run two times faster, must improve the CPI of L/S instruction as $\frac{4}{0.8} = 5$
  Therefore, CPI of L/S instructions must improve by 5 times.

- c) Clock Cycles = $(50 \times 10^6 \times 0.6) + (110 \times 10^6 \times 0.6) + (80 \times 10^6 \times 2.8) + (16 \times 10^6 \times 1.4) = 342.4 \times 10^6$
  Execution time = $\frac{342.4\times10^6}{2\times10^9} = 171.2 \times (10)^{-3}$
  Improving execution time of program by $\frac{0.256}{0.171} = 1.497$ *times*