Homework 1

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Problems

4.15.5

(a)

$Performance = ClockRate/CPI$

P1 $= 3.0 * 10^9/1.5 = 2.0 * 10^9$ IPS
P2 $= 2.5 * 10^9/1.0 = 2.5 * 10^9$ IPS
P3 $= 4.0 * 10^9/2.2 = 1.8 * 10^9$ IPS

Processor P2 has the highest performance expressed in giga instructions per second

(b)

$Numberofcycles = (Clock\ Rate) * (Execution\ Time\ in\ seconds)$
$Numberofinstructions = (IPS) * (Execution\ Time\ in\ seconds)$

For P1
-Number of cycles $= (3.0 * 10^9) * (10) = 3.0 * 10^{10}$ cycles
-Number of instructions $= (2.0 * 10^9) * (10) = 2.0 * 10^{10}$ instructions

For P2
-Number of cycles $= (2.5 * 10^9) * (10) = 2.5 * 10^{10}$ cycles
-Number of instructions $= (2.5 * 10^9) * (10) = 2.5 * 10^{10}$ instructions

For P3
-Number of cycles $= 4.0 * 10^9 * (10) = 4.0 * 10^{10}$
-Number of instructions $= (1.8 * 10^9) * (10) = 1.8 * 10^{10}$

(c)

Clock Rate $= ((Total\ number\ of\ instructions) * (CPI))/(Execution\ Time)$
For P1
-Total number of instructions $= 2.0 * 10^{10}$
-CPI $= 1.2 * 1.5 = 1.8$
-Execution Time $= 0.7 * 10 = 7$ seconds
Clock Rate $= ((2.0 * 10^{10}) * 1.8)/7 = 5.14$ GHZ
For P2
-Total number of instructions $= 2.5 * 10^{10}$
-CPI $= 1.2 * 1 = 1.2$

-Execution Time $= 0.7 * 10 = 7$ seconds

Clock Rate $= ((2.5 * 10^{10}) * 1.2)/7 = 4.28$ GHZ

For P3

-Total number of instructions $= 1.8 * 10^{10}$

-CPI $= 1.2 * 2.2 = 2.64$

-Execution Time $= 0.7 * 10 = 7$ seconds

Clock Rate $= ((1.8 * 10^{10}) * 2.64)/7 = 6.79$ GHZ

4.15.8

(a)

Execution Time = Instruction Count * CPI * Clock Cycle Time

Average CPI = (Execution Time) / (Instruction Count * Clock Cycle Time)

Compiler A - $1.1/1.0e^9 * 1 = 1.1$

Compiler B - $1.5/1.2e^9 * 1 = 1.25$

(b)

Execution Time = Instruction Count * CPI * Clock Cycle Time

Execution Time/Clock Cycle Time = Instruction Count * CPI

1 / Clock Cycle Time = (Instruction Count * CPI) / Execution Time

1 / Clock Cycle Time = Clock Rate

Clock Rate = (Instruction Count * CPI) / Execution Time

Same CPU time so allow Execution Time to be 1

Clock Rate = CR

$CR_B/CR_A = (Instruction\ Count_B * CPI_B)/(Instruction\ Count_A * CPI_A)$

$CR_B/CR_A = (1.2e^9 * 1.25)/(1.0e^9 * 1.1) \approx 1.37$

1.37 times faster

(c)

Speedup $= \frac{Execution\ Time_A}{Execution\ Time_{new}}$

$\frac{Execution\ Time_A}{Execution\ Time_{new}} = \frac{(Instruction\ Count_A * CPI_A)}{(Instruction\ Count_{new} * CPI_{new})} = (1.0e^9 * 1.1)/(6.0e^8) \approx 1.67$ times faster

$\frac{Execution\ Time_B}{Execution\ Time_{new}} = \frac{(Instruction\ Count_B * CPI_B)}{(Instruction\ Count_{new} * CPI_{new})} = (1.2e^9 * 1.25)/(6.0e^8) \approx 2.27$ times faster

4.5.10

(a)

Processors - 1

Execution Time = Clock Cycle / Clock Rate
Clock Rate = 2GHz = $2e9$

Clock Cycles = $(CPI_{arithmetic} * Instructions_{arithmetic}) + (CPI_{load/store} * Instructions_{load/store}) + (CPI_{branch} * Instructions_{branch})$

Clock Cycles = $(2.56e9 * 1) + (1.28e9 * 12) + (2.56e8 * 5)$
Clock Cycles = $(2.56e9) + (1.536e10) + (1.28e9) = 19.2e9$ cycles
Execution Time = $\frac{19.2e9\ cycles}{2e9\ cycles/sec}$ = 9.6 seconds

Relative Speedup = $\frac{Processors-1}{Processors-p} = \frac{9.6}{9.6} = 1$

(Processors - 2)

Clock cycles = $\frac{(2.56e9*1)}{0.7*2} + \frac{(1.28e9*12)}{0.7*2} + (2.56e8 * 5)$

Clock cycles = $\frac{2.56e9}{1.4} + \frac{1.536e10}{1.4} + (1.28e9)$

Clock cycles = $1.404e10$ cycles

Execution Time = $\frac{1.404e10\ cycles}{2e9\ cycles/sec}$ = 7.02 seconds

Relative Speedup = $\frac{Processors-1}{Processors-p} = \frac{9.6}{7.02} = 1.37$

Processors - 4

Clock cycles = $\frac{(2.56e9*1)}{0.7*4} + \frac{(1.28e9*12)}{0.7*4} + (2.56e8 * 5)$

Clock cycles = $\frac{2.56e9}{2.8} + \frac{1.536e10}{2.8} + (1.28e9)$

Clock cycles = $7.22e9$ cycles

Execution Time = $\frac{7.22e9\ cycles}{2e9\ cycles/sec}$ = 3.86 seconds

Relative Speedup = $\frac{Processors-1}{Processors-p} = \frac{9.6}{3.86} = 2.49$

Processors - 8

Clock cycles = $\frac{(2.56e9*1)}{0.7*8} + \frac{(1.28e9*12)}{0.7*8} + (2.56e8 * 5)$

Clock cycles = $\frac{2.56e9}{5.6} + \frac{1.536e10}{5.6} + (1.28e9)$

Clock cycles = $4.5e9$ cycles

Execution Time = $\frac{4.5e9\ cycles}{2e9\ cycles/sec}$ = 2.25 seconds

Relative Speedup = $\frac{Processors-1}{Processors-p} = \frac{9.6}{2.25} = 4.27$

(b)

Processors - 1

Execution Time = Clock Cycle / Clock Rate
Clock Rate = 2 Ghz = $2e9$
Clock Cycle = $(2.56e9 * 2) + (1.28e9 * 12) + (2.56e8 * 5)$

Clock Cycle $= (5.12e9) + (1.536e10) + (1.28e9) = 21.76e9$

Execution Time $= \frac{21.76e9\ cycles}{2e9\ cycles/secs} = 10.88$ seconds

Processors - 2

Execution Time = Clock Cycle / Clock Rate
Clock Rate = 2 Ghz = $2e9$

Clock Cycle $= \frac{(2.56e9*2)}{0.7*2} + \frac{(1.28e9*12)}{0.7*2} + (2.56e8*5)$

Clock Cycle $= (3.657e9) + (1.097e10) + (1.280e9) = 15.94e9$

Execution Time $= \frac{15.907e9\ cycles}{2e9\ cycles/secs} = 7.954$ seconds

Processors - 4

Execution Time = Clock Cycle / Clock Rate
Clock Rate = 2 Ghz = $2e9$

Clock Cycle $= \frac{(2.56e9*2)}{0.7*4} + \frac{(1.28e9*12)}{0.7*4} + (2.56e8*5)$

Clock Cycle $= (1.829e9) + (5.486e9) + (1.280e9) = 8.595e9$

Execution Time $= \frac{8.595e9\ cycles}{2e9\ cycles/secs} = 4.298$ seconds

Processors - 8

Execution Time = Clock Cycle / Clock Rate
Clock Rate = 2 Ghz = $2e9$

Clock Cycle $= \frac{(2.56e9*2)}{0.7*8} + \frac{(1.28e9*12)}{0.7*8} + (2.56e8*5)$

Clock Cycle $= (9.142e8) + (2.743e9) + (1.280e9) = 4.937e9$

Execution Time $= \frac{4.937e9\ cycles}{2e9\ cycles/secs} = 2.469$ seconds

(c)

Execution Time for 4 Processors

Clock cycles $= \frac{(2.56e9*1)}{0.7*4} + \frac{(1.28e9*12)}{0.7*4} + (2.56e8*5)$

Clock cycles $= \frac{2.56e9}{2.8} + \frac{1.536e10}{2.8} + (1.28e9)$

Clock cycles $= 7.22e9$ cycles

Execution Time $= \frac{7.22e9\ cycles}{2e9\ cycles/sec} = 3.86$ seconds

Find new CPI for single processor

x will represent the new CPI for load/store instructions that we will find
Clock Cycles $= (2.56e9*1) + (1.28e9*x) + (2.56e8*5)$
Clock Cycles $= (2.56e9) + (1.28e9*x) + (1.28e9)$

Clock Cycles = $(3.84e9) + (1.28e9 * x)$

Execution Time = $\frac{3.84e9+(1.28e9*x)}{2e9}$

$3.86 = \frac{3.84e9}{2e9} + \frac{1.28e9*x}{2e9}$

$3.86 = 1.92 + .64 * x$

$x = 3.03$
$\frac{3.03}{12} = .25 = 25\%$

The CPI of load/store instructions should be reduced by 25% in order for a single processors to match the performance of four processors using its original CPI value

4.15.13

(a)

Execution Time = Clock Cycles / Clock Rate
Clock Cycles = (CPI * Instructions)
P1 Clock Rate = 4GHz = 4.0e9
P1 CPI = 0.9
P1 Instructions = 5.0e9

P2 Clock Rate = 3GHz = 3.0e9
P2 CPI = 0.75
P2 Instructions = 1.0e9

$Execution\ Time_{P1} = \frac{0.9*5.0e9}{4.0e9} = \frac{4.5e9}{4.0e9} = 1.125$ seconds
$Execution\ Time_{P2} = \frac{0.75*1.0e9}{3.0e9} = \frac{0.75e9}{3.0e9} = 0.25$ seconds
We can see that this fallacy is not true for P1 and P2, although P1 has a higher clock rate, it is slower than P2 as shown above

(b)

Find P1 execution time

Execution Time = Clock Cycles / Clock Rate
Clock Cycles = (CPI * Instructions)
P1 Clock Rate = 4GHz = 4.0e9
P1 CPI = 0.9
P1 Instructions = 1.0e9

$Execution\ Time_{P1} = \frac{0.9*1.0e9}{4.0e9} = .225\ seconds$

Find the numbers of instructions P2 can execute

Let x represent the numbers of instructions P2 can execute
P2 Clock Rate = 3GHz = 3.0e9
P2 CPI = 0.75
P2 Instructions = 1.0e9

$Execution\ Time_{P1} = \frac{(0.75*x)}{3.0e9}$
$.225 = \frac{.75*x}{3.0e9}$
$0.675e9 = .75 * x$
$0.9e9 = x$

$x = 9.0e8$

P2 can execute 9.0e8 instructions in the same time that P1 executes 1.0e9 instructions

(c)

MIPS = Number of Instructions / Execution Time * 10^6

$MIPS_{P1} = \frac{5.0e9}{1.125e6} = 4.44e3$

$MIPS_{P2} = \frac{1.0e9}{0.25e6} = 4.0e3$

This fallacy is not true for P1 and P2, although P1 has a bigger MIPS, it is slower than P2 regarding performance

(d)

MFLOPS = # FP Operations / Execution Time * 1.0e6

$\#\ FP\ Operations_{P1} = 5.0e9 * .40 = 2.0e9$

$\#\ FP\ Operations_{P2} = 1.0e9 * .40 = 4.0e8$

$MLOPS_{P1} = \frac{2.0e9}{1.125 * 1.0e6} = 1.77e3$

$MLOPS_{P2} = \frac{4.0e8}{.25 * 1.0e6} = 1.6e3$