Computer Organization

Reference Solution

Home work 1

(10%)

1.5

a. performance of P1 (instructions/sec) = $3 \times 10^9/1.5 = 2 \times 10^9$

performance of P2 (instructions/sec) = $2.5 \times 10^9/1.0 = 2.5 \times 10^9$

performance of P3 (instructions/sec) = $4 \times 10^9/2.2 = 1.8 \times 10^9$

b. cycles(P1) = $10 \times 3 \times 10^9 = 30 \times 10^9$ s

cycles(P2) = $10 \times 2.5 \times 10^9 = 25 \times 10^9$ s

cycles(P3) = $10 \times 4 \times 10^9 = 40 \times 10^9$ s

c. No. instructions(P1) = $30 \times 10^9/1.5 = 20 \times 10^9$

No. instructions(P2) = $25 \times 10^9/1 = 25 \times 10^9$

No. instructions(P3) = $40 \times 10^9/2.2 = 18.18 \times 10^9$

$CPI_{new} = CPI_{old} \times 1.2$, then CPI(P1) = 1.8, CPI(P2) = 1.2, CPI(P3) = 2.6

f = No. instr. × CPI/time, then

f(P1) = $20 \times 10^9 \times 1.8/7 = 5.14$ GHz

f(P2) = $25 \times 10^9 \times 1.2/7 = 4.28$ GHz

f(P1) = $18.18 \times 10^9 \times 2.6/7 = 6.75$ GHz

ps : (c) 小題作答時應算出個別 clock rate 為佳

(10%)

1.6

a. Class A: 10^5 instr. Class B: 2×10^5 instr. Class C: 5×10^5 instr. Class D: 2×10^5 instr.

Time = No. instr. × CPI/clock rate

Total time P1 = $(10^5 + 2 \times 10^5 \times 2 + 5 \times 10^5 \times 3 + 2 \times 10^5 \times 3)/(2.5 \times 10^9) = 10.4 \times 10^{-4}$ s

Total time P2 = $(10^5 \times 2 + 2 \times 10^5 \times 2 + 5 \times 10^5 \times 2 + 2 \times 10^5 \times 2)/(3 \times 10^9) = 6.66 \times 10^{-4}$ s

CPI(P1) = $10.4 \times 10^{-4} \times 2.5 \times 10^9/10^6 = 2.6$

CPI(P2) = $6.66 \times 10^{-4} \times 3 \times 10^9/10^6 = 2.0$

b. clock cycles(P1) = $10^5 \times 1 + 2 \times 10^5 \times 2 + 5 \times 10^5 \times 3 + 2 \times 10^5 \times 3 = 26 \times 10^5$

clock cycles(P2) = $10^5 \times 2 + 2 \times 10^5 \times 2 + 5 \times 10^5 \times 2 + 2 \times 10^5 \times 2 = 20 \times 10^5$

(10%)

1.7

a. CPI = $T_{exec} \times$ f/No. instr.

Compiler A CPI = 1.1

Compiler B CPI = 1.25

b. f_B/f_A = (No. instr.(B) × CPI(B))/(No. instr.(A) × CPI(A)) = 1.37

c. $T_A/T_{new} = 1.67$

$T_B/T_{new} = 2.27$

本題共 5 個答案，每個答案 2 分

1.8

1.8.1

$$P_{dynamic} = 0.5 \cdot C \cdot V^2 \cdot f$$

P4: $90 = C_{P4} \cdot 1.25^2 \cdot 3.6 \cdot 10^9 / 2$

$C_{P4} = 32\,\text{nF}$

I5: $40 = C_{i5} \cdot 0.9^2 \cdot 3.4 \cdot 10^9 / 2$

$C_{i5} = 29\,\text{nF}$

1.8.2

P4:

$$percentage = \frac{10}{10+90} = 10\%$$

$$ratio = \frac{10}{90} = 0.11$$

I5

$$percentage = \frac{30}{30+40} = 42.8\%$$

$$ratio = \frac{30}{40} = 0.75$$

1.8.3

P4:

$$I_{leak} = \frac{10}{1.25} = 8$$

$$0.9 \cdot 100 = \frac{1}{2} \cdot 32 \cdot 10^{-9} \cdot V^2 \cdot 3.6 \cdot 10^9 + V \cdot 8$$

V=1.18

I5:

$$I_{leak} = \frac{30}{0.9} = 33.3$$

$$0.9 \cdot 70 = \frac{1}{2} \cdot 29 \cdot 10^{-9} \cdot V^2 \cdot 3.4 \cdot 10^9 + V \cdot 33.3$$

V=0.84

1.9

	Arithmetic	Load / store	branch
CPI	1	12	5
1 processor	2.56E9	1.28E9	256E6
2 processors	1.83E9	914E6	256E6
4 processors	914E6	457E6	256E6
8 processors	457E6	229E6	256E6

1.9.1

1 processor:

Execution time

$(2.56 \cdot 10^9 \cdot 1 + 1.28 \cdot 10^9 \cdot 12 + 256 \cdot 10^6 \cdot 5) / 2 \cdot 10^9 = 9.6(\text{sec})$

2 processor

Execution time: $(1.83 \cdot 10^9 \cdot 1 + 0.914 \cdot 10^9 \cdot 12 + 256 \cdot 10^6 \cdot 5) / 2 \cdot 10^9 = 7.04(\text{sec})$

Speedup= $\frac{9.6}{7.04} = 1.36$

4 processor

Execution time: $(0.914 \cdot 10^9 \cdot 1 + 0.457 \cdot 10^9 \cdot 12 + 256 \cdot 10^6 \cdot 5) / 2 \cdot 10^9 = 3.84(\text{sec})$

Speedup= $\frac{9.6}{3.84} = 2.5$

8 processor

Execution time: $(0.457 \cdot 10^9 \cdot 1 + 0.229 \cdot 10^9 \cdot 12 + 256 \cdot 10^6 \cdot 5) / 2 \cdot 10^9 = 2.23(\text{sec})$

Speedup= $\frac{9.6}{2.23} = 4.3$

1.9.2

1 processor:

Execution time

$(2.56 \cdot 10^9 \cdot 2 + 1.28 \cdot 10^9 \cdot 12 + 256 \cdot 10^6 \cdot 5) / 2 \cdot 10^9 = 10.88(\text{sec})$

2 processor

Execution time: $(1.83 \cdot 10^9 \cdot 2 + 0.914 \cdot 10^9 \cdot 12 + 256 \cdot 10^6 \cdot 5) / 2 \cdot 10^9 = 7.954(\text{sec})$

4 processor

Execution time: $(0.914 \cdot 10^9 \cdot 2 + 0.457 \cdot 10^9 \cdot 12 + 256 \cdot 10^6 \cdot 5) / 2 \cdot 10^9 = 4.296(\text{sec})$

8 processor

Execution time: $(0.457 \cdot 10^9 \cdot 2 + 0.229 \cdot 10^9 \cdot 12 + 256 \cdot 10^6 \cdot 5) / 2 \cdot 10^9 = 2.471(\text{sec})$

1.9.3

$(2.56 \cdot 10^9 \cdot 1 + 1.28 \cdot 10^9 \cdot CPI + 256 \cdot 10^6 \cdot 5) / 2 \cdot 10^9 = 3.84(\text{sec})$

CPI=3

1.11

Cycle count = $750 / 0.333 \cdot 10^{-9} = 2.252 \cdot 10^{12}$

1.11.1

$CPI = 2.252 \cdot 10^{12} / 2.389 \cdot 10^{12} = 0.94265$

1.11.2

$SPECratio = 9650 / 750 = 12.866$

1.11.3

$Increased\_CPU\_Time = 750 \cdot 1.1 = 825$

Increase = 825-750=75

1.11.4

$Increased\_CPU\_Time = 750 \cdot 1.1 \cdot 1.05 = 866.25$

Increase=866.25-750=116.25

1.11.5

$SPECratio = 9650 / 866.25 = 11.14$

1.11.6

$Instruction\_count = 2.389 \cdot 10^{12} \cdot 0.85 = 2.03065 \cdot 10^{12}$

$Cycle\_count = 700 \cdot 4 \cdot 10^{9} = 2.8 \cdot 10^{12}$

$CPI = 2.8 \cdot 10^{12} / 2.03065 \cdot 10^{12} = 1.379$

1.11.7

$Increase\_ratio\_of\_CPI = 1.379 / 0.94265 = 1.463$

$Increase\_ratio\_of\_clock = 4 / 3 = 1.333$

1.11.8

750 – 700 = 50 (sec)

(or 6.67%)

1.11.9

$New\_execution\_time = 960 \cdot 0.9 = 864$

$New\_cycle\_count = 864 \cdot 10^{-9} \cdot 4 \cdot 10^{9} = 3456$

$CPI = 1.61 = 3456 / Inst\_count$

$$Inst\_count = 2146.58$$

1.11.10

題意不清楚，不算分

(Actually, we don't know what the "further reduction" means.)

1.11.11

同上

(Similarly, I don't know what the CPI and CPU time is in this exercise.)

1.12

1.12.1 $T(P1) = 5 \times 10^9 \times 0.9 / (4 \times 10^9) = 1.125$ s

$T(P2) = 10^9 \times 0.75 / (3 \times 10^9) = 0.25$ s

clock rate (P1) > clock rate(P2), performance(P1) < performance(P2)

1.12.2 T(P1) = No. instr. × CPI/clock rate

T(P1) = 2.25 3 1021 s

T(P2) 5 N × 0.75/(3 × 10^9), then N = 9 × 10^8

1.12.3 MIPS = Clock rate × 10^{-6}/CPI

$MIPS(P1) = 4 \times 10^9 \times 10^{-6}/0.9 = 4.44 \times 10^3$

$MIPS(P2) = 3 \times 10^9 \times 10^{-6}/0.75 = 4.0 \times 10^3$

MIPS(P1) > MIPS(P2), performance(P1) < performance(P2) (from 11a)

1.12.4 MFLOPS = No. FP operations × 10^{-6}/T

MFLOPS(P1) = .4 × 5E9 × 1E-6/1.125 = 1.78E3

MFLOPS(P2) = .4 × 1E9 × 1E-6/.25 = 1.60E3

MFLOPS(P1) > MFLOPS(P2), performance(P1) < performance(P2) (from 11a)

1.13

1.13.1 $T_{fp} = 70 \times 0.8 = 56$ s. $T_{new} = 56+85+55+40 = 236$ s. Reduction: 5.6%

1.13.2 $T_{new} = 250 \times 0.8 = 200$ s, $T_{fp}+T_{l/s}+T_{branch} = 165$ s, $T_{int} = 35$ s. Reduction time INT: 58.8%

1.13.3 $T_{new} = 250 \times 0.8 = 200$ s, $T_{fp}+T_{int}+T_{l/s} = 210$ s. NO

(**10%**)

1.14

a.

	FP	INT	L/S	Branch
IC	50×106	110×106	80×106	16×106
CPI	1	1	4	2
Clock rate	2 GHz			

$$Ex\_time = \frac{IC \times CPI}{Clock\ rate} \propto IC \times CPI$$

$$\frac{Ex\_time_{(old)}}{Ex\_time_{(new)}} = \frac{2}{1} = \frac{(50\times1+110\times1+80\times4+16\times2)\times10^6}{(CPI_{FP}\times1+110\times1+80\times4+16\times2)\times10^6}$$

解得 $CPI_{FP} < 0$，故**不可能**加速 2 倍

b.

$$\frac{Ex\_time_{(old)}}{Ex\_time_{(new)}} = \frac{2}{1} = \frac{(50\times1+110\times1+80\times4+16\times2)\times10^6}{(50\times1+110\times1+CPI_{L/S}\times4+16\times2)\times10^6}$$

解得 $\boxed{CPI_{L/S} = 0.8}$

c.

	FP	INT	L/S	Branch
IC	50×106	110×106	80×106	16×106
CPI	1→0.6	1→0.6	4→2.8	2→1.4
Clock rate	2 GHz			

$$\frac{Ex\_time_{(old)}}{Ex\_time_{(new)}} = \frac{(50\times1+110\times1+80\times4+16\times2)\times10^6}{(50\times0.6+110\times0.6+80\times2.8+16\times1.4)\times10^6} \approx 1.5$$

所以加速了 1.5 倍（或答減少 33% Ex_time）（或答減少 8988.8ns）

ps：本題的各個 instructions 的個數是 × 106，不是 $\times10^6$
但在求比例上，並不會影響作答

(**10%**)

1.15

processor #	Ex_time(s)	Ex_time/processor	speed up	ratio(actual/ideal)
1	100			
p	t/p+4			
1	100	100		
2	54	27	1.85	0.925
4	29	7.25	3.45	0.8625
8	16.5	2.0625	6.06	0.7575
16	10.25	0.64	9.76	0.61
32	7.125	0.223	14	0.4375
64	5.5625	0.087	17.98	0.28
128	4.78	0.037	20.92	0.16

共三欄 Ex_time or Ex_time/processor (**3%**)、speed up (**3%**)、ratio(**3%**)

缺項 -**2**%