CO 2021-Fall HW1 Solution

1.2

- **a.** Performance via Pipelining
- **b.** Dependability via Redundancy
- **c.** Performance via Prediction
- **d.** Make the Common Case Fast
- **e.** Hierarchy of Memories
- **f.** Performance via Parallelism
- **g.** Use Abstraction to Simplify Design

1.5

a.

$$\text{Performance}_{P1} = \frac{Clock\ \ rate_{P1}}{CPI_{P1}} = \frac{3\ \ GHz}{1.5} = 2\ \ \text{G}\ \ \text{insts/sec}$$

$$\text{Performance}_{P2} = \frac{Clock\ \ rate_{P2}}{CPI_{P2}} = \frac{2.5\ \ GHz}{1} = 2.5\ \ \text{G}\ \ \text{insts/sec}$$

$$\text{Performance}_{P3} = \frac{Clock\ \ rate_{P3}}{CPI_{P3}} = \frac{4\ \ GHz}{2.2} = 1.82\ \ \text{G}\ \ \text{insts/sec}$$

P2 has the highest performance.

b.

$$\#\text{cycle}_{P1} = 10 * clock\ \ rate_{P1} = 30\ \ G\ \ cycles$$
$$\#\text{inst}_{P1} = 10 * \text{Performance}_{P1} = 20\ \ G\ \ insts$$

$$\#\text{cycle}_{P2} = 10 * clock\ \ rate_{P2} = 25\ \ G\ \ cycles$$
$$\#\text{inst}_{P2} = 10 * \text{Performance}_{P2} = 25\ \ G\ \ insts$$

$$\#\text{Cycle}_{P3} = 10 * clock\ \ rate_{P3} = 40\ \ G\ \ cycles$$
$$\#\text{inst}_{P3} = 10 * \text{Performance}_{P3} = 18.2\ \ G\ \ insts$$

c.

$$\frac{execution\ \ time_{new}}{execution\ \ time_{old}} = \frac{\frac{CPI_{new} * \cancel{\#inst}}{Clock\ \ rate_{new}}}{\frac{CPI_{old} * \cancel{\#inst}}{Clock\ \ rate_{old}}} = 0.7$$

$$\Rightarrow \frac{Clock\ \ rate_{new}}{Clock\ \ rate_{old}} = \frac{1.2}{0.7} = 1.714$$

$$\text{Clock}\ \ \text{rate}_{P1new} = 3\ \ GHz * 1.714 = 5.142\ \ GHz$$
$$\text{Clock}\ \ \text{rate}_{P2new} = 2.5GHz * 1.714 = 4.285\ \ GHz$$
$$\text{Clock}\ \ \text{rate}_{P3new} = 4\ \ GHz * 1.714 = 6.856\ \ GHz$$

1.7

	A	B	C	D
CPI for P1@2.5GHz	1	2	3	3
CPI for P2@3GHz	2	2	2	2
% of #inst	10%	20%	50%	20%

a.

$$\mathrm{CPI}_{P1} = 1*0.1+2*0.2+3*0.5+3*0.2 = 2.6$$

$$\mathrm{CPI}_{P2} = 2*0.1+2*0.2+2*0.5+2*0.2 = 2$$

b.

$$\#\mathrm{cycle}_{P1} = 1*10^6*CPI_{P1} = 2.6*10^6$$

$$\#\mathrm{cycle}_{P2} = 1*10^6*CPI_{P2} = 2*10^6$$

$$\mathrm{execution\ \ time}_{P1} = \frac{\#cycle_{P1}}{clock\ \ rate_{P1}} = \frac{2.6*10^6}{2.5*10^9} = 1.04*10^{-3}$$

$$\mathrm{execution\ \ time}_{P2} = \frac{\#cycle_{P2}}{clock\ \ rate_{P2}} = \frac{2*10^6}{3*10^9} = 6.66*10^{-4}$$

P2 is faster.

1.8

	#insts	execution time
Compiler A	$1*10^9$	1.1 s
Compiler B	$1.2*10^9$	1.5 s

a.

$$\mathrm{CPI_A} = \frac{\#cycle_A}{\#inst_A} = \frac{\frac{execution\ \ time_A}{clock\ \ period}}{\#inst_A} = \frac{\frac{1.1}{1*10^{-9}}}{1*10^9} = 1.1$$

$$\mathrm{CPI_B} = \frac{\#cycle_B}{\#inst_B} = \frac{\frac{execution\ \ time_B}{clock\ \ period}}{\#inst_B} = \frac{\frac{1.5}{1*10^{-9}}}{1.2*10^9} = 1.25$$

b.

$$\frac{execution\ \ time_{A_{new}}}{execution\ \ time_{B_{new}}} = \frac{execution\ \ time_{A_{old}}}{execution\ \ time_{B_{old}}} * \frac{clock\ \ rate_B}{clock\ \ rate_A} = 1$$

$$\Rightarrow \frac{clock\ \ rate_A}{clock\ \ rate_B} = \frac{execution\ \ time_{A_{old}}}{execution\ \ time_{B_{old}}} = \frac{1.1}{1.5} = 0.733$$

c.

$$\frac{execution\ \ time_A}{execution\ \ time_{new}} = \frac{\#inst_A * CPI_A}{\#inst_{new} * CPI_{new}} = \frac{1*10^9*1.1}{6*10^8*1.1} = 1.67$$

$$\frac{execution\ \ time_B}{execution\ \ time_{new}} = \frac{\#inst_B * CPI_B}{\#inst_{new} * CPI_{new}} = \frac{1.2*10^9*1.25}{6*10^8*1.1} = 2.27$$

1.10

inst for 1 P	arithmetic	load/store	branch
CPI	1	12	5
#inst	$2.56 * 10^9$	$1.28 * 10^9$	$256 * 10^6$

1.10.1

$$\#\text{cycle} = \text{CPI}_{arith} * \#\text{inst}_{arith} + \text{CPI}_{ls} * \#\text{inst}_{ls} + \text{CPI}_{branch} * \#\text{inst}_{branch}$$

$$\text{execution time} = \#\text{cycle} * \text{clock period}$$

P	#arith	#load/store	#branch	#cycle	exe. time	speed up
1	$2.56 * 10^9$	$1.28 * 10^9$	$256 * 10^6$	$1.92 * 10^{10}$	9.6 s	1
2	$1.83 * 10^9$	$9.14 * 10^8$		$1.41 * 10^{10}$	7.04 s	1.36
4	$9.14 * 10^8$	$4.57 * 10^8$		$7.68 * 10^9$	3.84 s	2.5
8	$4.57 * 10^8$	$2.29 * 10^8$		$4.48 * 10^9$	2.24 s	4.29

1.10.2

P	#arith	#load/store	#branch	#cycle	exe. time
1	$2.56 * 10^9$	$1.28 * 10^9$	$256 * 10^6$	$2.18 * 10^{10}$	10.9 s
2	$1.83 * 10^9$	$9.14 * 10^8$		$1.59 * 10^{10}$	7.95 s
4	$9.14 * 10^8$	$4.57 * 10^8$		$8.59 * 10^9$	4.3 s
8	$4.57 * 10^8$	$2.29 * 10^8$		$4.94 * 10^9$	2.47 s

1.10.3

$$\#\text{cycle}_{1P} = \#cycle_{4P}$$

$$\Rightarrow \#arith_{1P} * CPI_{arith} + \#ls_{1P} * CPI_{ls_{1P}} = \#arith_{4P} * CPI_{arith} + \#ls_{4P} * CPI_{ls_{4P}}$$

$$\Rightarrow 2.56 * 1 + 1.28 * CPI_{ls_{1P}} = \frac{2.56}{0.7*4} * 1 + \frac{1.28}{0.7*4} * 12$$

$$\Rightarrow \quad CPI_{ls_{1P}} = 3$$

1.12.1

$$\text{CPI} = \frac{\frac{execution\ time}{cycle\ time}}{\#inst} = \frac{750}{2.389*10^{12}*0.333*10^{-9}} = 0.943$$

1.12.2

$$\text{SPECratio}_{bzip2} = \frac{9650\ s}{750\ s} = 12.87$$

1.12.3

$$\text{CPU time} = \frac{\#\text{inst}*\text{CPI}}{clock\ rate}$$

increase #inst by 10% => increase CPU time by 10%

1.12.4

$$\text{CPU time} = \frac{\#\text{inst}*\text{CPI}}{clock\ rate}$$

$$1.1 * \#\text{inst} * 1.05 * \text{CPI} = 1.155$$

increase CPU time by 15.5%

1.12.5

$$\frac{SPECratio_{before}}{SPECratio_{after}} = \frac{1}{1.155} = 0.866$$

1.12.6

$$\text{CPI} = \frac{CPU\ time*clock\ rate}{\#inst} = \frac{700*4*10^{9}}{0.85*2.389*10^{12}} = 1.379$$

1.12.7

此題提到的 1.11.1 應為 1.12.1。

$$\text{Clock rate ratio} = \frac{4\ GHz}{3\ GHz} = 1.33$$

$$\text{CPI ratio} = \frac{1.37}{0.94} = 1.45$$

They are different because, although the number of instructions has been reduced by 15%, the CPU time has been reduced by a lower percentage.

1.12.8

$\frac{700}{750} = 0.933$, reduced by 6.7%

1.12.9

此題 execution time 應為 960 s 較符合題旨，以 960 s 或 960 ns 作答均不會扣分。

$$\#\text{inst} = \frac{\text{execution time}*\text{clock rate}}{CPI} = \frac{960*0.9*4*10^{9}}{1.61} = 2.147 * 10^{12}$$

1.12.10

$$\frac{clock\ rate_{new}}{clock\ rate_{old}} = \frac{CPU\ time_{old}}{CPU\ time_{new}} \Rightarrow clock\ rate_{new} = 3\ GHz * \frac{1}{0.9} = 3.33\ GHz$$

1.12.11

$$\frac{clock\ rate_{new}}{clock\ rate_{old}} = \frac{CPU\ time_{old}}{CPU\ time_{new}} * \frac{CPI_{new}}{CPI_{old}} \Rightarrow clock\ rate_{new} = 3\ GHz * \frac{1}{0.8} * 0.85 = 3.1875\ GHz$$

1.13.1

$$\text{execution time}_{P1} = \frac{\#inst_{P1} * CPI_{P1}}{clock\ rate_{P1}} = \frac{5*10^9*0.9}{4*10^9} = 1.125\ \text{s}$$

$$\text{execution time}_{P2} = \frac{\#inst_{P2} * CPI_{P2}}{clock\ rate_{P2}} = \frac{1*10^9*0.75}{3*10^9} = 0.25\ \text{s}$$

$$\text{clock rate}_{P1} > clock\ rate_{P2}\ \ but\ \ performance_{P1} < performance_{P2}$$

1.13.2

$$\text{execution time}_{P1} = execution\ time_{P2} \Rightarrow \frac{\#inst_{P1} * CPI_{P1}}{clock\ rate_{P1}} = \frac{\#inst_{P2} * CPI_{P2}}{clock\ rate_{P2}}$$

$$\#inst_{P2} = \#inst_{P1} * \frac{CPI_{P1}}{CPI_{P2}} * \frac{clock\ rate_{P2}}{clock\ rate_{P1}} = 1 * 10^9 * \frac{0.9}{0.75} * \frac{3\ GHz}{4\ GHz} = 9 * 10^8$$

1.13.3

$$\text{MIPS} = \frac{clock\ rate}{CPI} * 10^{-6}$$

$$\text{MIPS}_{P1} = \frac{4*10^9}{0.9} * 10^{-6} = 4.44 * 10^3$$

$$\text{MIPS}_{P2} = \frac{3*10^9}{0.75} * 10^{-6} = 4 * 10^3$$

$$\text{MIPS}_{\text{P1}} > \text{MIPS}_{\text{P2}}\ \ but\ \ performance_{P1} < performance_{P2}$$

1.13.4

$$\text{MFLOPS} = \frac{\#FPop}{T*10^6}$$

$$\text{MFLOPS}_{P1} = \frac{0.4*5*10^9}{1.125*10^6} = 1777.78$$

$$\text{MFLOPS}_{P2} = \frac{0.4*1*10^9}{0.25*10^6} = 1600$$

$$\text{MFLOPS}_{\text{P1}} > \text{MFLOPS}_{\text{P2}}\ \ but\ \ performance_{P1} < performance_{P2}$$