EECS40300 Computer Architecture
Spring, 2022 Homework 1

(1)、

(a)

	ADD_recursive	ADD_iterative
InsC	276	66
CycC	375	105

Recursive way needs to store additional registers value into stack (more instructions), thus introducing additional time to access memory. The execute time will raise in this example.

(b)

Q1: The RISC architecture will need **more register than CISC to hold values as it loads each instruction**, acts upon it, then loads the next one. The CISC architecture can execute one, albeit more complex instruction, that does the same operations, all at once, directly upon memory.
Q2: a0

(c)

For ADD_recursive:

$CPI = \frac{375}{276} = 1.36$ (四捨五入至小數點後第二位)

For ADD_iterative:

$CPI = \frac{105}{66} = 1.5$ (四捨五入至小數點後第二位)

(d)

For add_recur:

CPU execution time $= \frac{375}{1 \times 10^9} = 375\ ns$

For add_iter:

CPU execution time $= \frac{105}{1 \times 10^9} = 105\ ns$

(e)

Total Cycle: 105/4+900-105+50 = 871.25

Program execution time $= \frac{871.25}{1 \times 10^9} = 871.25\ ns$

(f)

optimization levels, -O0		optimization levels, -O1	
For add_iter	For add_recur	For add_iter	For add_recur
InsC: 259	InsC: 492	InsC: 65	InsC: 295
CycC: 576	CycC: 763	CycC: 98	CycC: 394
CPI: 2.22	CPI: 1.55	CPI: 1.51	CPI: 1.34

-O0: Do not optimize; -O1: Optimize for speed. -Og: Optimize for speed with better debuggability than -O1

-O1 比起 -O0 InsC、CycC、CPI 都有減少。

- 補充: optimization levels 執行截圖

1. ADD_iteration

A. Opt: -Og

Simulator Performance Meter

Mode	InsC	CycC	I$Miss	D$Miss	Branch Misprediction
D	60	86	0	0	7
D	417	814	0	0	92

Simulator Profiling

Total Self Cycle Count: 900

Name	Calls	Self InsC	Self CycC	Total InsC	Total CycC	Time Percentage
do_printf	1	209	464	285	599	51.56%
add_iter	1	66	105	66	105	11.67%
strlen	1	27	50	27	50	5.56%
vprintf_help	3	27	45	27	45	5.00%
__riscv_save_12	1	22	40	22	40	4.44%
memset	1	26	38	35	51	4.22%
_start	1	24	36	477	900	4.00%
vprintf	1	25	35	317	652	3.89%
printf	1	15	21	332	673	2.33%
main	1	12	20	410	798	2.22%
_write	1	7	18	7	18	2.00%
_exit	1	8	15	8	15	1.67%
memset + 84	1	9	13	9	13	1.44%

B. Opt: -O0

Simulator Performance Meter

Mode	InsC	CycC	I$Miss	D$Miss	Branch Misprediction
D	64	90	0	0	7
D	613	1,293	0	0	93

Simulator Profiling

Total Self Cycle Count: 1383

Name	Calls	Self InsC	Self CycC	Total InsC	Total CycC	Time Percentage
add_iter	1	259	576	259	576	41.65%
do_printf	1	209	468	285	597	33.84%
strlen	1	27	47	27	47	3.40%
vprintf_help	3	27	42	27	42	3.04%
__riscv_save_12	1	22	40	22	40	2.89%
memset	1	26	39	35	51	2.82%
_start	1	24	36	677	1,383	2.60%
vprintf	1	25	35	317	650	2.53%
main	1	19	34	610	1,281	2.46%
printf	1	15	21	332	671	1.52%
_write	1	7	18	7	18	1.30%
_exit	1	8	15	8	15	1.08%
memset + 84	1	9	12	9	12	0.87%

C. Opt: -O1

Simulator Performance Meter

Mode	InsC	CycC	I$Miss	D$Miss	Branch Misprediction
D	60	86	0	0	7
D	416	810	0	0	91

Simulator Profiling

Total Self Cycle Count: 896

Name	Calls	Self InsC	Self CycC	Total InsC	Total CycC	Time Percentage
do_printf	1	209	467	285	602	52.12%
add_iter	1	65	98	65	98	10.94%
strlen	1	27	50	27	50	5.58%
vprintf_help	3	27	45	27	45	5.02%
__riscv_save_12	1	22	40	22	40	4.46%
memset	1	26	38	35	51	4.24%
_start	1	24	36	476	896	4.02%
vprintf	1	25	35	317	655	3.91%
printf	1	15	21	332	676	2.34%
main	1	12	20	409	794	2.23%
_write	1	7	18	7	18	2.01%
_exit	1	8	15	8	15	1.67%
memset + 84	1	9	13	9	13	1.45%

2. Add_recursive

A. Opt: -Og

Simulator Performance Meter

Mode	InsC	CycC	I$Miss	D$Miss	Branch Misprediction
D	60	86	0	0	7
D	627	1,085	0	0	115

Simulator Profiling

Total Self Cycle Count: 1171

Name	Calls	Self InsC	Self CycC	Total InsC	Total CycC	Time Percentage
do_printf	1	209	468	285	600	39.97%
add_recur	1	276	375	276	375	32.02%
strlen	1	27	50	27	50	4.27%
vprintf_help	3	27	42	27	42	3.59%
__riscv_save_12	1	22	40	22	40	3.42%
memset	1	26	39	35	51	3.33%
_start	1	24	36	687	1,171	3.07%
vprintf	1	25	35	317	653	2.99%
printf	1	15	21	332	674	1.79%
main	1	12	20	620	1,069	1.71%
_write	1	7	18	7	18	1.54%
_exit	1	8	15	8	15	1.28%
memset + 84	1	9	12	9	12	1.02%

B. Opt: -O0

Simulator Performance Meter

Mode	InsC	CycC	I$Miss	D$Miss	Branch Misprediction
D	64	90	0	0	7
D	846	1,483	0	0	113

Simulator Profiling

Total Self Cycle Count: 1573

Name	Calls	Self InsC	Self CycC	Total InsC	Total CycC	Time Percentage
add_recur	1	492	763	492	763	48.51%
do_printf	1	209	468	285	600	29.75%
strlen	1	27	50	27	50	3.18%
vprintf_help	3	27	42	27	42	2.67%
__riscv_save_12	1	22	40	22	40	2.54%
memset	1	26	39	35	51	2.48%
_start	1	24	36	910	1,573	2.29%
vprintf	1	25	35	317	653	2.23%
main	1	19	34	843	1,471	2.16%
printf	1	15	21	332	674	1.34%
_write	1	7	18	7	18	1.14%
_exit	1	8	15	8	15	0.95%
memset + 84	1	9	12	9	12	0.76%

C. Opt: -O1

Simulator Performance Meter

Mode	InsC	CycC	I$Miss	D$Miss	Branch Misprediction
D	60	86	0	0	7
D	646	1,103	0	0	112

Simulator Profiling

Total Self Cycle Count: 1189

Name	Calls	Self InsC	Self CycC	Total InsC	Total CycC	Time Percentage
do_printf	1	209	464	285	599	39.02%
add_recur	1	295	394	295	394	33.14%
strlen	1	27	50	27	50	4.21%
vprintf_help	3	27	45	27	45	3.78%
__riscv_save_12	1	22	40	22	40	3.36%
memset	1	26	38	35	51	3.20%
_start	1	24	36	706	1,189	3.03%
vprintf	1	25	35	317	652	2.94%
printf	1	15	21	332	673	1.77%
main	1	12	20	639	1,087	1.68%
_write	1	7	18	7	18	1.51%
_exit	1	8	15	8	15	1.26%
memset + 82	1	9	13	9	13	1.09%

(2) 、

(a) (5 points)

Hardware	
CPU Name:	Intel Core i3-4340
CPU Characteristics:	
CPU MHz:	3600
FPU:	Integrated
CPU(s) enabled:	2 cores, 1 chip, 2 cores/chip, 2 threads/core
CPU(s) orderable:	1 chip
Primary Cache:	32 KB I + 32 KB D on chip per core
Secondary Cache:	256 KB I+D on chip per core
L3 Cache:	4 MB I+D on chip per chip
Other Cache:	None
Memory:	8 GB (2 x 4 GB 2Rx4 PC3-12800U-11)
Disk Subsystem:	1 TB Seagate SATA HDD, 7200 RPM
Other Hardware:	None

Hardware	
CPU Name:	Intel Core i5-4430
CPU Characteristics:	Intel Turbo Boost Technology up to 3.20 GHz
CPU MHz:	3000
FPU:	Integrated
CPU(s) enabled:	4 cores, 1 chip, 4 cores/chip
CPU(s) orderable:	1 chip
Primary Cache:	32 KB I + 32 KB D on chip per core
Secondary Cache:	256 KB I+D on chip per core
L3 Cache:	6 MB I+D on chip per chip
Other Cache:	None
Memory:	8 GB (2 x 4 GB 2Rx4 PC3-12800U-11)
Disk Subsystem:	1 TB Seagate SATA HDD, 7200 RPM
Other Hardware:	None

Hardware	
CPU Name:	Intel Core i7-4770
CPU Characteristics:	Intel Turbo Boost Technology up to 3.90 GHz
CPU MHz:	3400
FPU:	Integrated
CPU(s) enabled:	4 cores, 1 chip, 4 cores/chip, 2 threads/core
CPU(s) orderable:	1 chip
Primary Cache:	32 KB I + 32 KB D on chip per core
Secondary Cache:	256 KB I+D on chip per core
L3 Cache:	8 MB I+D on chip per chip
Other Cache:	None
Memory:	8 GB (2 x 4 GB 2Rx4 PC3-12800U-11)
Disk Subsystem:	1 TB Seagate SATA HDD, 7200 RPM
Other Hardware:	None

i3-4340 是 2 cores 的 CPU，L3 Cache 是 4MB，CPU MHz 為 3600
i5-4430 是 4 cores 的 CPU, L3 Cache 是 6MB，CPU MHz 為 3000
i7-4770 是 4 cores 的 CPU，L3 Cache 是 8MB，CPU MHz 為 3400

三者的 software specifications 都一樣

(b) (Performance ratio 3 points, Arithmetic mean 2 points)

執行秒數表

	i3-4340	i5-4430	i7-4770
h264ref	323	373	323
omnetpp	257	251	223
astar	233	247	200

1. h264ref:

Reference	Performance ratio		
	Intel Core i3-4340	Intel Core i5-4430	Intel Core i7-4770
Intel Core i3-4340	1	0.86595	1
Intel Core i5-4430	1.15480	1	1.15480
Intel Core i7-4770	1	0.86595	1

2. omnetpp

Reference	Performance ratio		
	Intel Core i3-4340	Intel Core i5-4430	Intel Core i7-4770
Intel Core i3-4340	1	1.02390	1.15247
Intel Core i5-4430	0.97665	1	1.12556
Intel Core i7-4770	0.86770	0.88845	1

3. astar

Reference	Performance ratio		
	Intel Core i3-4340	Intel Core i5-4430	Intel Core i7-4770
Intel Core i3-4340	1	0.94332	1.165
Intel Core i5-4430	1.06009	1	1.235
Intel Core i7-4770	0.85837	0.80972	1

4. Arithmetic mean

Reference	Performance ratio		
	Intel Core i3-4340	Intel Core i5-4430	Intel Core i7-4770
Intel Core i3-4340	1	0.94439	1.10582
Intel Core i5-4430	1.06385	1	1.17179
Intel Core i7-4770	0.90869	0.85471	1

(c) (5 points)

Geometric mean

Reference	Performance ratio		
	Intel Core i3-4340	Intel Core i5-4430	Intel Core i7-4770
Intel Core i3-4340	1	0.94219	1.10319
Intel Core i5-4430	1.06136	1	1.17088
Intel Core i7-4770	0.90646	0.85406	1

(d) (5 points)

從 Geometric mean 來比較 Performance 是 i7-4770>i3-4340>i5-4430

從 Arithmetic mean 來比較 Performance 也是 i7-4770>i3-4340> i5-4430

從 SPECint_base2006 ratio 來比較 Performance 也是 i7-4770>i3-4340> i5-4430

(3)、

(a)

$$Clock\ cycles = CPI_{fp} \times \#\ of\ FP\ instr. + CPI_{int} \times \#\ of\ INT\ instr. + CPI_{l/s} \times \#\ of\ L/S\ instr. + CPI_{branch} \times \#\ of\ BRANCH\ instr.$$

$$T_{CPU} = clock\ cycles\ /\ clock\ rates$$

$$Clock\ cycles = (2 \times 90\ +\ 1 \times 110\ +\ 5\ \times 100\ +\ 2 \times 25) \times 10^6 = 840 \times 10^6$$

$$\frac{T_{CPU\ new}}{T_{CPU\ old}} = \frac{clock\ cycles_{new}}{clock\ cycles_{old}} = \frac{1}{2}$$

To have the number of clock cycles by improving the CPI of FP instructions:

$$CPI_{fp\ improved} \times \#\ of\ FP\ instr. + CPI_{int} \times \#\ of\ INT\ instr. + CPI_{l/s} \times \#\ of\ L/S\ instr. + CPI_{branch} \times \#\ of\ BRANCH\ instr.\ = \ clock\ cycles\ /\ 2$$

$$CPI_{fp\ improved} = (clock\ cycles\ /\ 2 - (CPI_{int} \times \#\ of\ INT\ instr. + \ CPI_{l/s}\ \times \#\ of\ L/S\ instr. + CPI_{branch} \times \#\ of\ BRANCH\ instr.))\ /\ \#\ of\ FP\ instr.$$

$$CPI_{fp\ improved} = \frac{420 - 660}{90} < 0$$

 impossible

(b)

$$\frac{T_{CPU\ new}}{T_{CPU\ old}} = \frac{clock\ cycles_{new}}{clock\ cycles_{old}} = \frac{2 \times 90 \times 0.69 + 1 \times 110 \times 0.69 + 5 \times 100 \times 0.23 + 2 \times 25 \times 0.23}{2 \times 90 + 1 \times 110 + 5 \times 100 + 2 \times 25} = 0.39$$

 reduced by 0.61%

(4)、

(a)

$$90 = \frac{1}{2} \times capacitive\ load\ \times (1.25)^2\ \times 5 \times 10^9$$

$$capacitive\ load = 2 \times 90 \times \frac{1}{1.25^2} \times \frac{1}{5} \times 10^{-9} = 23.04\ nF$$

(b)

$$total\ dissipated\ power\ comprised\ by\ dynamic\ power = \frac{90}{60 + 90} = 0.6$$

$$ratio\ of\ static\ power\ to\ dynamic\ power = \frac{60}{90} = 0.67$$

(c)

$$\frac{S_{new} + D_{new}}{S_{old} + D_{old}} = 0.65$$

$$V_{new} = (2 \times D_{new}/(C \times F))^{1/2}$$

$$D_{new} = 0.65 \times (S_{old} + D_{old}) - S_{new}$$

$$S_{new} = V_{new} \times (S_{old}\ /\ V_{old}) = V_{new} \times (60\ /1.25) = 48 \times V_{new}$$

$$D_{new} = 0.65 \times (60 + 90) - 48 \times V_{new} = 97.5 - 48 \times V_{new}$$

$$V_{new} = \left(\frac{2 \times (97.5 - 48 \times V_{new})}{2 \times 90 \div 1.25^2}\right)^{\frac{1}{2}} = \left(\frac{2 \times (97.5 - 48 \times V_{new})}{115.2}\right)^{\frac{1}{2}}$$

$$115.2\ {V_{new}}^2 + 96\ V_{new} - 195 = 0$$

$$V_{new} = 0.95\ V$$

(5)、

(a)

$$die\ area = \frac{wafer\ area}{dies\ per\ wafer} = \frac{12.5^2 \times \pi}{120} = 4.09$$

$$yield = \frac{1}{(1 + (0.02 \times 4.09/2))^2} = 0.92296$$

(b)

$$cost\ per\ die = \frac{cost}{die} = \frac{15}{120 \times 0.92296} = 0.1354$$

(c)

$$die\ area = \frac{wafer\ area}{dies\ per\ wafer} = \frac{12.5^2 \times \pi}{120 \times 1.2} = 3.41$$

$$yield = \frac{1}{(1 + (0.02 \times 1.35 \times 3.41/2))^2} = 0.9139$$