

2. I1: ld a1, 0(s1)

I2: mul a2, a0, a2

I3: add a1, a2, a2

I4: ld a2, 0(s2)

I5: add a3, a1, a2

I6: sd a3, 0(s3)

I1            I2            I3            I4            I5            I6

I1

I2

I3 WAW      RAW

I4            WAW      WAR

I5                      RAW      RAW

I6                                      RAW

4. (1)  $\frac{1}{S} = \frac{T_B \times CPI_B \times N}{T_A \times CPI_A \times N} = \frac{T_B}{T_A} \times \frac{CPI_B}{CPI_A}$  N为指令数, 且  $N \rightarrow \infty$

∵ B有0.6ns时钟周期且为12级流水线  
A有1ns时钟周期且为5级流水线

∴  $T_B = \frac{0.6ns}{12}$

$T_A = \frac{1ns}{5}$

$CPI_B = \frac{N + 12 - 1 + \frac{3N}{8}}{N}$

$CPI_A = \frac{N + 5 - 1 + \frac{N}{5}}{N}$

$$\begin{aligned}
 1) \frac{1}{S} &= \frac{T_B}{T_A} \times \frac{CPI_B}{CPI_A} \\
 &= \frac{0.6 \text{ ns}}{0.5 \text{ ns}} \times \frac{N+11+\frac{3N}{8}}{N+4+\frac{N}{5}} = \frac{3}{5} \times \frac{11+\frac{11}{8}N}{4+\frac{1}{5}N} \quad (N \rightarrow \infty) \\
 &= \lim_{N \rightarrow \infty} \frac{3}{5} \times \frac{\frac{11}{8} + \frac{11}{8} \frac{N}{N}}{\frac{1}{5} + \frac{4}{N}} = \frac{3}{5} \times \frac{\frac{11}{8}}{\frac{1}{5}} = \frac{11}{16}
 \end{aligned}$$

$$1) \text{ 加速比 } S = \frac{16}{11}$$

(2) 设指令数为  $N$  则分支预测指令数为  $0.2N$

对于 A: 执行  $N$  条指令所需周期数为:

$$\begin{aligned}
 &N + 5 - 1 + \frac{N}{5} + 0.2N \times 5\% \times 2 \\
 &= 4 + \frac{61}{50}N
 \end{aligned}$$

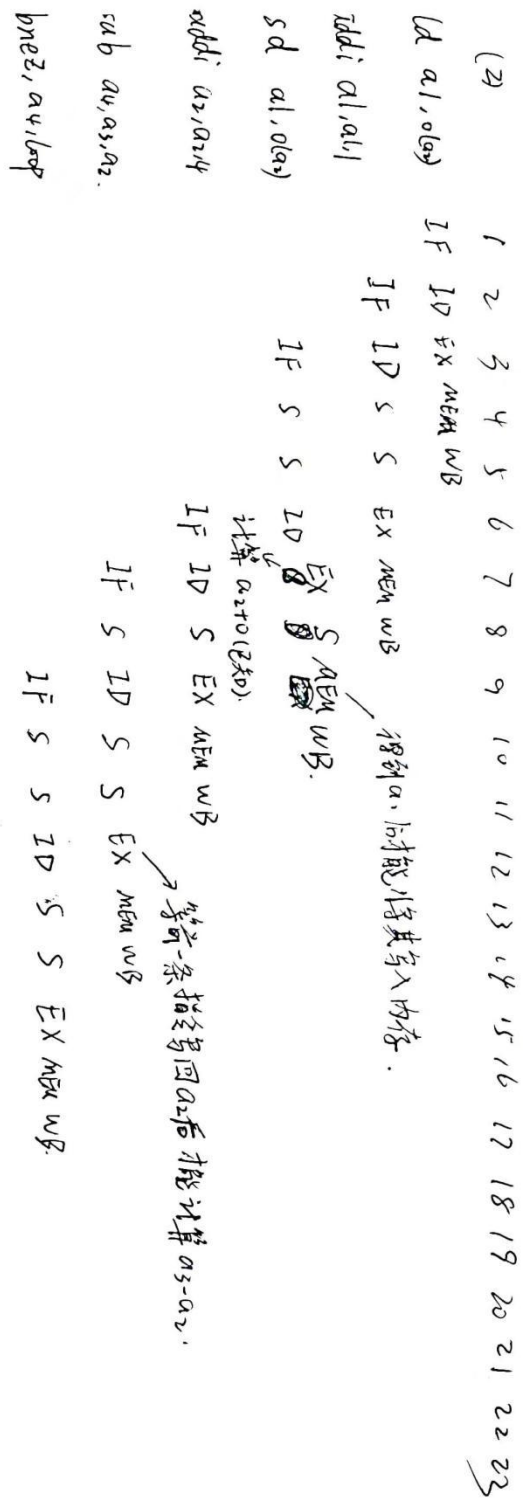
$$1) CPI_A = \lim_{N \rightarrow \infty} \frac{4 + \frac{61}{50}N}{N} = \frac{61}{50}$$

对于 B: 执行  $N$  条指令所需周期数为:

$$\begin{aligned}
 &N + 12 - 1 + \frac{3N}{8} + 0.2N \times 5\% \times 5 \\
 &= 11 + \frac{57}{40}N
 \end{aligned}$$

$$1) CPI_B = \lim_{N \rightarrow \infty} \frac{11 + \frac{57}{40}N}{N} = \frac{57}{40}$$

6. (1)  $\left. \begin{array}{l} ld \ a1, 0(a2) \\ addi \ a1, a1, 1 \end{array} \right\} \text{ RAW}$   
 $\left. \begin{array}{l} sd \ a1, 0(a2) \\ addi \ a2, a2, 4 \end{array} \right\} \text{ RAW}$   
 $\left. \begin{array}{l} sub \ a4, a3, a2 \\ bnez \ a4, Loop \end{array} \right\} \text{ RAW}$



程序总共执行了 25 个 ~~周期~~ 循环  
 1 个循环 有 17 个周期  
 ∴ 有 25 × 17 = 425 个时钟周期。

7. (1) 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

ld a1, 0(a2) IF ID EX MEM WB  $\rightarrow$  在 MEM 处就得到了 a1 的值.

addi a1, a1 IF ID S EX MEM WB

sd a1, 0(a2) IF S ID EX MEM WB

addi a2, a2, 4 IF ID EX MEM WB (a2 的值已知)

sub a4, a3, a2 IF ID EX MEM WB

bne a4, loop IF ID EX MEM WB

IF (用于跳转预测) 跳转. 则去取指待跳转指令不跳转则继续 EX. MEM. WB

∴ 共有:  $11 \times 25 = 275$  个时钟周期.

(2) 在 sub 经过 EX 后, 可以得到 a4 的值, 从而 ~~bne~~ 可以跳转, 即第 8 个周期跳转. 最后一次循环不跳转, 共执行 11 个周期.  
∴ 共有  $11 + 8 \times 24 = 203$  个时钟周期.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
ld a1, 0(a1)	IF <sub>1</sub>	IF <sub>2</sub>	ID <sub>1</sub>	ID <sub>2</sub>	EX <sub>1</sub>	EX <sub>2</sub>	M <sub>1</sub>	M <sub>2</sub>	WB <sub>1</sub>	WB <sub>2</sub>																
addi a1, a1, 1		IF <sub>1</sub>	IF <sub>2</sub>	ID <sub>1</sub>	ID <sub>2</sub>	S	S	S	EX <sub>1</sub>	EX <sub>2</sub>	M <sub>1</sub>	M <sub>2</sub>	WB <sub>1</sub>	WB <sub>2</sub>												
sd a1, 0(a1)			IF <sub>1</sub>	IF <sub>2</sub>	ID <sub>1</sub>	S	S	S	ID <sub>2</sub>	EX <sub>1</sub>	EX <sub>2</sub>	M <sub>1</sub>	M <sub>2</sub>	WB <sub>1</sub>	WB <sub>2</sub>											
addi a2, a2, 4				IF <sub>1</sub>	IF <sub>2</sub>	S	S	S	ID <sub>1</sub>	ID <sub>2</sub>	EX <sub>1</sub>	EX <sub>2</sub>	M <sub>1</sub>	M <sub>2</sub>	WB <sub>1</sub>	WB <sub>2</sub>										
sub a4, 03, a2					IF <sub>1</sub>	S	S	S	ID <sub>1</sub>	ID <sub>2</sub>	S															
bne a4, loop									IF <sub>1</sub>	IF <sub>2</sub>	ID <sub>1</sub>	ID <sub>2</sub>	S	S	ID <sub>2</sub>	S	EX <sub>1</sub>	EX <sub>2</sub>	M <sub>1</sub>	M <sub>2</sub>	WB <sub>1</sub>	WB <sub>2</sub>				

(11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25)  
 (M<sub>1</sub>, M<sub>2</sub> 在 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25)  
 (EX<sub>1</sub> 在 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25)  
 (EX<sub>2</sub> 在 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25)  
 (WB<sub>1</sub> 在 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25)  
 (WB<sub>2</sub> 在 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25)

共需要 21 x 25 = 525 个时钟周期

(2) CPI 为 单位指令所需时钟周期数

7. (1)  $CPI = \frac{11}{6}$

(2)  $CPI = \frac{203}{6 \times 25} = \frac{203}{150}$

8.  $CPI = \frac{21}{6} = \frac{7}{2}$

无条件跳转  
 jal 否  
 jalr 否  
 计算 PC+4  
 计算 PC+4 及 YSI+偏移量

19. (1)  
 add 是  
 addi 否  
 ld 否  
 sd 否  
 bne 是

(2)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
lw a4, a3	IF	ID	EX	MEM	WB									
addw a1, a4, a1		IF	ID	ID	S	EX	MEM	WB						
addiw a2, a2, -1			IF	ID	S	EX	MEM	WB						
addiw a3, a3, 4				IF	S	ID	EX	MEM	WB					
bnez a2, loop							IF	ID	EX	MEM	WB			

10个周期。

(3)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
lw a4, 0(a3)	IF	ID	EX	MEM	WB									
addw a1, a4, a1		IF	ID	<del>EX</del>	S	EX	MEM	WB						
addiw a2, a1, 1			IF	S	ID	EX	MEM	WB						
addiw a3, a3, 4						IF	ID	EX	MEM	WB				
bnez a2, loop							IF	ID	EX	MEM	WB			

通过前馈获得a4的值

还是10个周期。