

3.2. I1: ld a1, 0 CS1

I2: mul a2, a0, a2

I3: add a1, a2, a2

I4: ld a2, 0 CS2

I5: add a3, a1, a2

I6: sd a3, 0 CS3

I1 I2 I3 I4 I5 I6

I2 无

I3 RAW

I4 WAR

I5 WAR

I6 RAW

I7 无 无 无 无 无 WAW

3.4. A有1ns时钟周期的5级流水线，平均每5条指令经历一周期停顿，B有0.6ns时钟周期的12级流水线，平均每8条指令经历三周期停顿。

(1) B相对A加速比。

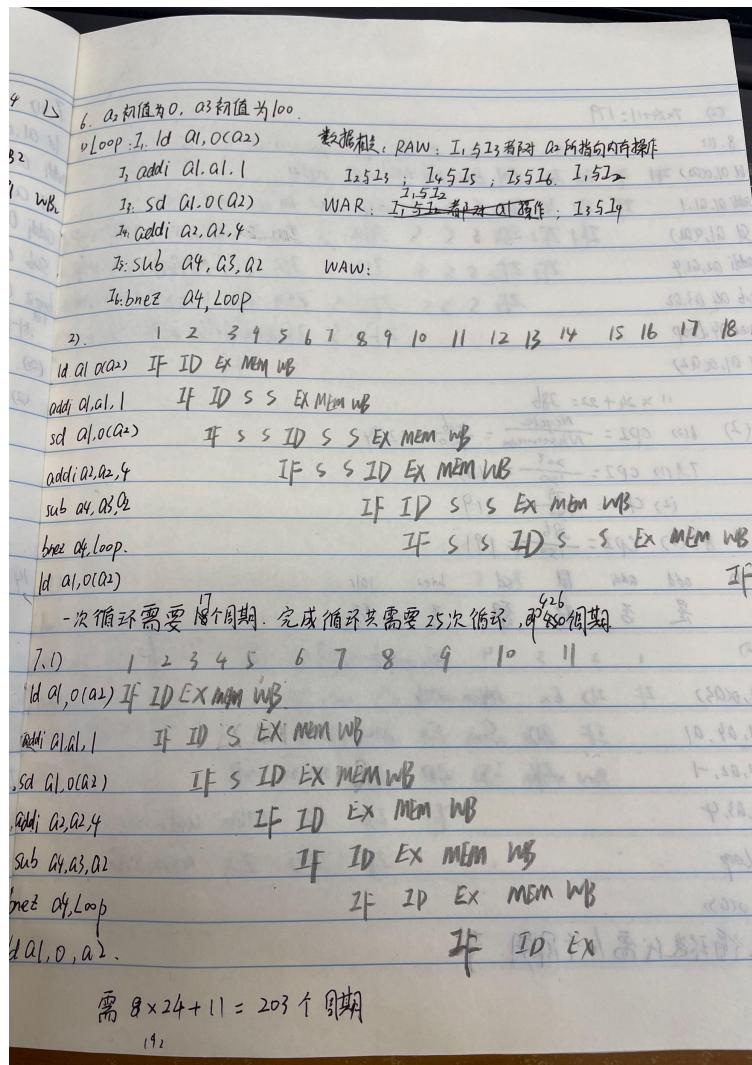
(2) 待指令占指令类型20%，A错误预测代价2周期，B...5周期，错误预测率为5%。计算两处理器CPI。

$$(1) \text{ 加速比} = \frac{\frac{1}{0.6}}{\frac{1}{1} + \frac{N+1+\frac{N}{5} \times 3}{N+4+\frac{N}{5} \times 5} \frac{t_A}{t_B}} = \frac{1 \times (1 + \frac{1}{5} \times 1)}{0.6 \times (1 + \frac{1}{5} \times 3)} = \frac{6}{5} \times \frac{10}{6} \times \frac{8}{11} = 1.45$$

$N \rightarrow \infty$ 时，加速比 = $\frac{10}{11}$

$$(2) CPI_A = 20\% \times 5\% \times 2 + 20\% \times 95\% \times 0 + 1 + 0 \frac{1}{5} = 1.22$$

$$CPI_B = 20\% \times 5\% \times 5 + 1 + \frac{3}{8} = 1.16 \quad 1.41$$



$$8(2) 7 \times 24 + 11 = 179$$

6.8. (1) 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 2R (d A1, 0(A2)) ZF1 ZD1 ZD2 EX1 EX2 M1 M2 WB1 WB2
 SPaddi A1, A1, 1 ZF1 ZF2 ZD1 ZD2 S S S EX1 EX2 M1 M2 WB1 WB2
 A, Sd A1, 0(A2) ZF1 ZF2 ZD1 S S S ZD2 S EX1 EX2 M1 M2 WB1 WB2
 S, addi A2, A2, 4 ZF1 ZF2 S S S ZD1 S ZD2 EX1 EX2 M1 M2 WB1 WB2
 b, sub A4, A3, A2 ZF1 S S S ZF2 S ZD1 ZD2 S EX1 EX2 M1 M2 WB1 WB2
 l, bneq A4, Loop ZF1 S ZF2 ZD1 S ZD2 S EX1 EX2 M1 M2 WB1 WB2
 (d A1, 0(A2)) ZF1

$$11 \times 24 + 22 = 286$$

$$(2) 6.1(2) CPI = \frac{N_{cycle}}{N_{instruction}} = \frac{426}{150} = 2.84$$

$$7.1(1) CPI = \frac{203}{150} = 1.35$$

$$(2) CPI = \frac{179}{150} = 1.19$$

$$8. (1) CPI = \frac{286}{150} = 1.91$$

19. (1) add addi ld sd bneq jalr

是否需要暂停

(2) 1 2 3 4 5 6 7 8 9 10

lw A4, 0(A3) ZF ZD EX MEM WB

addi A1, A4, A1 IF ZD SD EX MEM WB

addi A2, A2, -1 ZF ZS ZD EX MEM WB

addi A3, A3, 4 ZF ZD ZD EX MEM WB

bneq A2, Loop

lw A4, 0(A3)

单次循环迭代需 10 个周期。

(3) 1 2 3 4 5 6 7 8 9

lw A4, 0(A3) ZF ZD EX MEM WB

addi A1, A4, A1 ZF ZD EX MEM WB

addi A2, A2, -1 ZF ZB EX MEM WB

addi A3, A3, 4 ZF ZD EX MEM WB

bneq A2, Loop ZF ZB EX MEM WB

9 个周期。