

指令	数据依赖
2. I1	无
I2	$a_0/a_2$
I3	$a_1, a_2$ 与 I2 存在 RAW 依赖
I4	无
I5	$a_1/a_2$
I6	$a_3$

4. 加速比  $\approx \frac{1ns}{0.6ns} = 1.67$

(1)  $CP1A = 5 + \frac{1}{5} + 2 \times 5\% \times 20 = 5.22$

$CP2B = 12 + \frac{3}{8} + 5 \times 5\% \times 20 = 12.425$

6. (1) 1. RAW:  $addi\ a1, a1, 1$  在  $ld\ a1, 0(a2)$  前执行

2. WBR:  $l3\ a3, a2$  与  $a_1$  发生 WBR

3. WAW:  $l3\ a3, a2$  与  $a_2$  发生 WAW

4. 数据冲突:  $bnez\ a4, loop$  与  $sub\ a4, a3, a2$  冲突

(2) Loop:  $ld\ a1, 0(a2)$  IF ID EX MBM WB

$addi\ a1, a1, 1$  IF ID S S EX MBM WB

$sd\ a1, 0(a2)$  IF ID S S S S EX MBM WB

$addi\ a2, a2, 4$  IF ID S S S S S S EX MBM WB

$sub\ a4, a3, a2$  IF ID S S S S S S S S

$bnez\ a4, loop$  IF ID

$\therefore$  共  $14+3+3=20$  个周期完成

7. (1) 共 11 个周期

(2) 共存在分支预测器  $bnez$  阶段少执行 7 个周期，共 8 个周期

loop:                    1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17  
 8. ld a1, 0(a2) 17, 17, 20, 20, EX, EX, MEM, M<sub>2</sub>, WB, WB<sub>2</sub>  
 addi a1, a1, 1 17, 17, 20, 20, S S S EX, EX, M, M<sub>2</sub>, WB, WB<sub>2</sub>  
 sd a1, 0(a2) 17, 17, 20, 20, S S S S EX, EX, M, M<sub>2</sub>, WB, WB<sub>2</sub>  
 addi a2, a2, 4 17, 17, 20, 20, S S S S S EX, EX, M, M<sub>2</sub>, WB, WB<sub>2</sub>  
 sub a4, a3, a2  
 bne a4, 0, loop

∴ 共 22 个周期

$$(2) CP_{L6} = \frac{20}{6} = \frac{10}{3} \quad CP_{L7} = \frac{11}{6} = \frac{11}{6} \quad CP_{L8} = \frac{22}{6} = \frac{11}{3}$$

19. (1) add addi ld sd bne jal jalr  
           ✓     x     x     x     x     x     x

(2) 17 20 EX MEM WB

17 20, 20, S EX MEM WB

17 S 20 S S S EX MEM WB

17 S 20 S S S S S EX MEM WB

17 S 20 S S S S S S S ...

∴ 共 17 个周期

(3) 17 20 EX MEM WB

17 20 ...

∴ 共 84 个周期