

## 4.17 (1)

Instruction 1: Invalid target address (EX)

Instruction 2: Invalid data address (MEM)

(2) 同流水线的 EX 和 MEM 阶段添加异常检测器。当异常发生时, 我们将流水线中导致异常的指令之后更改为 nops。之后, 我们将相应异常处理程序的地址发送到 PC, 可用一个多路复用器单元实现。

(3) I1 处于 ID 阶段, 故 I2 可被正常提取。然后 I1 进入 EX 阶段, I2 进入 ID 阶段。由于 I1 触发异常, 故 I2 被转换为 nop, 然后执行异常处理程序

(4) 我们可以设计一个新指令。异常被触发时, ID/EX 注册。指令将获取异常处理程序的地址。如果 IF/ID 信号 = 0, 则产生 nops。则 ID/EX 寄存器多路复用器的信号是 1

(5) 均与(4)相同, 除了我们使用 cause register 来计算内存地址

## 4.18 (1)

li \$r5, 0

LOOP: beq \$r5, \$r6, DONE

sll \$r10, \$r5, 2

add \$r11, \$r1, \$r10

lw \$r12, 0(\$r11)

lw \$r10, 4(\$r11)

sub \$r12, \$r12, \$r10

sll \$r10, \$r5, 2

add \$r11, \$r2, \$r10

sw \$r12, 0(\$r11)

addi \$r5, \$r5, 2

j LOOP

DONE:

## (2)

Instructions	Pipeline
ADD R5,R0,R0	IF ID EX ME WB
BEQ R5,R6,End	IF ID ** EX ME WB
ADD R10,R5,R1	IF ** ID EX ME WB
LW R11,0(R10)	IF ** ID ** EX ME WB
LW R10,1(R10)	IF ** ID ** EX ME WB
SUB R10,R11,R10	IF ** ID ** ** EX ME WB
ADD R11,R5,R2	IF ** ** ID EX ME WB
SW R10,0(R11)	IF ** ** ID ** EX ME WB
ADDI R5,R5,2	IF ** ID EX ME WB
BEW R0,R0,Again	IF ** ID ** EX ME WB
BEQ R5,R6,End	IF ** ID EX ME WB
ADD R10,R5,R1	IF ** ID ** EX ME WB
LW R11,0(R10)	IF ** ID EX ME WB
LW R10,1(R10)	IF ** ID ** EX ME WB
SUB R10,R11,R10	IF ** ID ** EX ME WB
ADD R11,R5,R2	IF ** ID ** ** EX ME WB
SW R10,0(R11)	IF ** ** ID EX ME WB
ADDI R5,R5,2	IF ** ** ID EX ME WB
BEW R0,R0,Again	IF ID EX ME WB
BEQ R5,R6,End	IF ID ** EX ME WB

(3)

<pre> ADD R5,R0,R0 Again: ADD R10,R5,R1       BEQ R5,R6,End       LW  R11,0(R10)       ADD R12,R5,R2       LW  R10,1(R10)       ADDI R5,R5,2       SUB R10,R11,R10       SW  R10,0(R12)       BEQ R0,R0,Again End: </pre>	Note that we are now computing a+i before we check whether we should continue the loop. This is OK because we are allowed to "trash" R10. If we exit the loop one extra instruction is executed, but if we stay in the loop we allow both of the memory instructions to execute in parallel with other instructions
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(4)

Instructions	Pipeline
ADD R5,R0,R0	IF ID EX ME WB
ADD R10,R5,R1	IF ID ** EX ME WB
BEQ R5,R6,End	IF ** ID EX ME WB
LW R11,0(R10)	IF ** ID EX ME WB
ADD R12,R5,R2	IF ID EX ME WB
LW R10,1(R10)	IF ID EX ME WB
ADDI R5,R5,2	IF ID EX ME WB
SUB R10,R11,R10	IF ID ** EX ME WB
SW R10,0(R12)	IF ** ID EX ME WB
BEQ R0,R0,Again	IF ** ID EX ME WB
ADD R10,R5,R1	IF ** ID EX ME WB
BEQ R5,R6,End	IF ** ID ** EX ME WB
LW R11,0(R10)	IF ** ID EX ME WB
ADD R12,R5,R2	IF ** ID EX ME WB
LW R10,1(R10)	IF ID EX ME WB
ADDI R5,R5,2	IF ID EX ME WB
SUB R10,R11,R10	IF ID ** EX ME WB
SW R10,0(R12)	IF ID ** EX ME WB
BEQ R0,R0,Again	IF ** ID EX ME WB
ADD R10,R5,R1	IF ** ID ** EX ME WB
BEQ R5,R6,End	IF ** ID EX ME WB

(5)

CPI for 1-issue	CPI for 2-issue	Speedup
1.11 (10 cycles per 9 instructions). There is 1 stall cycle in each iteration due to a data hazard between the second LW and the next instruction (SUB).	1.06 (19 cycles per 18 instructions). Neither of the two LW instructions can execute in parallel with another instruction, and SUB stalls because it depends on the second LW. The SW instruction executes in parallel with ADDI in even-numbered iterations.	1.05

(6)

CPI for 1-issue	CPI for 2-issue	Speedup
1.11	0.83 (15 cycles per 18 instructions). In all iterations, SUB is stalled because it depends on the second LW. The only instructions that execute in odd-numbered iterations as a pair are ADDI and BEQ. In even-numbered iterations, only the two LW instruction cannot execute as a pair.	1.34

4.19 (1)  $140 \text{ pJ} + 2 \times 70 \text{ ps} + 60 \text{ pJ} = 340 \text{ pJ}$

(2)  $140 + 2 \times 70 + 60 + 140 = 480 \text{ pJ}$

(3)  $140 + 70 + 60 + 140 = 410 \text{ pJ}$

$\frac{410}{480} = 0.854$

$1 - 0.854 = 0.146 = 14.6\%$

(4) before : 250 ps

after : 无改变 (由于  $150 \text{ ps} + 90 \text{ ps} < 250 \text{ ps}$ )

(5) 这个改变不会引起任何问题。根据流水线设计的主要原则, 时钟周期时间必须等于最慢的延迟时间。因此, 这种变化不会导致时钟周期的变化 (仍为 250 ps)

(b) I-Mem active energy : 140 pJ

I-Mem Latency : 200 ps

Clock cycle time : 250 ps

Total I-Mem energy :  $140 \text{ pJ} + 50 \text{ ps} \cdot 0.1 \cdot 140 \text{ pJ} / 200 \text{ ps} = 143.5 \text{ pJ}$

Idle energy % :  $3.5 \text{ pJ} / 143.5 \text{ pJ} = 2.44\%$