

## CA HW 4

### ① Loop Unrolling and SW Pipelining

given LD  $\rightarrow$  any : 3 stalls

FPMUL  $\rightarrow$  any : 6 stalls

FPMUL  $\rightarrow$  ST : 5 stalls

INTALU  $\rightarrow$  BR : 2 stalls

INTALU  $\rightarrow$  any : 1 stall

BR  $\rightarrow$  1 delay slot

⇒ Schedule for default code :-

Loop : LD F2, 0(R1)

LD F4, 0(R2)

stall

stall

stall

MUL.D F2, F2, F4

stall

stall

stall

stall

stall

SD F2, 0(R1)

DADDUI R1, R1, #-8

DADDUI R2, R2, #-8

BNE R1, R3, LOOP

stall

∴ This takes a total of 17 cycles.

2) To minimize stalls, we can go for smart scheduling.

Loop: LD F2, 0(R1)  
LD F4, 0(R2)  
DADDUI R1, R1, #-8  
DADDUI R2, R2, #-8  
Stall  
MUL.D F2, F2, F4  
Stall  
Stall  
Stall  
Stall  
BNE R1, R3, Loop  
SD F2, 8(R1)

This requires a total of 12 cycles. Hence, compared to the default schedule, we can save 5 cycles per iteration.

3) default cycle = 17

no. of cycles worth of work = 4

loop overheads = 3

Hence the min unroll degree to eliminate stall cycles = 4

$\therefore 4 \times 4 + 3 = 19$  cycles.

Loop: LD F2, 0(R1)

LD F4, 0(R2)

LD F6, -8(R1)

LD F8, -8(R2)

LD F10, -16(R1)

LD F12, -16(R2)

LD F14, -24(R1)

LD F16, -24(R2)

MUL.D F2, F2, F4

MUL.D F6, F6, F8

MUL.D F10, F10, F12

MUL.D F14, F14, F16

DADDUI R1, R1, #-32

DADDUI R2, R2, #-32

SD F2, 32(R1)

SD F6, 24(R1)

SD F10, 16(R1)

BNE R1, R3, Loop

SD F14, 8(R1)

4) Software-pipelined version

Loop: SD F2, 16(R1)  
MUL.D F2, F2, F4  
LD F4, 0(R2)  
LD F2, 0(R1)  
DADDUI R2, R2, #-8  
BNE R1, R3, Loop  
DADDUI R1, R1, #-8

When this code executes, it won't experience any stalls. Since each instruction is executed in a cycle and ~~that~~ it feeds to an instruction in the next cycle as different instructions belonging to different cycle execute in the same iteration.

## ② Branch Predictors

Given: Tournament branch predictor.

$$\begin{aligned}\text{capacity of selector} &= 32K \times 3b \\ &= 98304b \\ &= 96kb\end{aligned}$$

$$\begin{aligned}\text{capacity of global predictor} &= 3b \times 2^{15} \\ &= 98304b \\ &= 96kb\end{aligned}$$

$$\begin{aligned}\text{capacity of local predictor} &= (12 \times 2^7) + (2^6 \times 2b) \\ &= 1536 + 131072 \\ &= 132608b \\ &= 129.5kb\end{aligned}$$

$$\begin{aligned}\text{Total capacity} &= 96 + 96 + 129.5 \\ &= \boxed{321.5Kb}\end{aligned}$$