Considerando il processore MIPS64 e l’architettura descritta in seguito:

|  |  |  |
| --- | --- | --- |
| * + Integer ALU: 1 clock cycle   + Data memory: 1 clock cycle   + FP multiplier unit: pipelined 7 stages | * + FP arithmetic unit: pipelined 3 stages   + FP divider unit: not pipelined unit that requires 7 clock cycles   + branch delay slot: 1 clock cycle, and the branch delay slot disabled | * + forwarding enabled   + it is possible to complete instruction EXE stage in an out-of-order fashion. |

Usando il frammento di codice riportato, si calcoli il tempo di esecuzione dell’intero programma in colpi di clock e si completi la seguente tabella.

; for (i = 0; i < 100; i++) {

; v5[i] = v1[i]/v2[i];

; v6[i] = (v1[i]\*v2[i])/v3[i] + v4[i];

;}

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| .data |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Clock  cycles |
| V1: .double “100 values” |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| V2: .double “100 values” |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| V3: .double “100 values”  …  V5: .double “100 zeros” |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| V4: .double “100 values” |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| V5: .double “100 values” |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| V6: .double “100 values” |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| .text |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| main: daddui r1,r0,0 | F | D | E | M | W |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 5 |
| daddui r2,r0,100 |  | F | D | E | M | W |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |
| loop: l.d f1,v1(r1) |  |  | F | D | E | M | W |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |
| l.d f2,v2(r1) |  |  |  | F | D | E | M | W |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |
| div.d f5,f1,f2 |  |  |  |  | F | D | s | : | : | : | : | : | : | : | M | W |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 8 |
| s.d f5,v5(r1) |  |  |  |  |  | F | s | D | E | s | s | s | s | s | S | M | W |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |
| l.d f3,v3(r1) |  |  |  |  |  |  |  | F | D | s | s | s | s | s | S | E | M | W |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |
| l.d f4,v4(r1) |  |  |  |  |  |  |  |  | F | s | s | s | s | s | s | D | E | M | W |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 1 |
| mul.d f6,f1,f2 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | F | D | x | x | x | x | x | x | x | M | W |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | 7 |
| div.d f7,f6,f3 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | F | D | s | s | s | s | s | s | : | : | : | : | : | : | : | M | W |  |  |  |  |  |  |  |  |  |  | 7 |
| add.d f7,f7,f4 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | F | s | s | s | s | s | s | D | s | s | s | s | s | s | + | + | + | M | W |  |  |  |  |  |  |  | 3 |
| s.d f7,v6(r1) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | F | s | s | s | s | s | s | D | E | s | S | M | W |  |  |  |  |  |  | 1 |
| daddi r2,r2,-1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | F | D | s | S | E | M | W |  |  |  |  |  | 1 |
| daddui r1,r1,8 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | F | s | S | D | E | M | W |  |  |  |  | 1 |
| bnez r2,loop |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | F | D | E | M | W |  |  |  | 1 |
| Halt |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | F | D | E | M | W |  |  | 1 |
| Total |  |  |  |  | =6+35\*100=3506 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 3506 |

**Domanda 2**

Si consideri una BHT di 1K elementi con contatori di saturazione a 2 bit. Usando il frammento di codice proposto, si calcoli lo stato finale della BHT al completamento dell’esecuzione del programma proposto. Si calcoli inoltre, la *misprediction rate* complessiva. Lo stato iniziale della BPU è indicato nella tabella.

Assunzioni generali:

* R10 è il registro di controllo del loop ed è inizializzato a 100
* R3 e R7 sono registro di riferimento con valore 10
* R2 e R6 sono i registri in ingresso
  + R2 riceve un valore sempre maggiore a 10
  + R6 riceve un valore sempre minore a 10
* Gli altri registri sono inizializzati a 0.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Address** | **Instruction** | | **BHT (2-bit)** | **Prediction** | **misP. counter** |
| **0x0000** | **L0:** | **…** |  |  |  |
| **…** | ; | ***Reading input values*** |  |  |  |
| **0x0010** |  | **SLT R1, R2, R3** | 2 | T |  |
| **0x0014** |  | **BEQZ R1, L1** | 2-3 | T | 0 |
| **0x0018** |  | **DADDI R11, R0, 10** | 2 | T |  |
| **0x001C** | **L1:** | **SLT R4, R6, R7** | 2 | T |  |
| **0x0020** |  | **BEQZ R4, L2** | 2-1-0 | T | 1 |
| **0x0024** |  | **DADDI R12, R0, 10** | 2 | T |  |
| **0x0028** | **L2:** | **SLT R5, R2, R6** | 2 | T |  |
| **0x002C** |  | **BEQZ R5, L3** | 2-3 | T | 0 |
| **0x0030** |  | **DADDI R13, R0, 10** | 2 | T |  |
| **0x0038** | **L3:** | **DADD R14, R13, R12** | 2 | T |  |
| **0x003C** |  | **DADD R14, R14, R11** | 2 | T |  |
| **0x0040** |  | **SLT R5, R6, R14** | 2 | T |  |
| **0x0044** |  | **BEQZ R5, L4** | 2-1-0 | T | 1 |
| **0x0048** |  | **DADDI R15, R0, 10** | 2 | T |  |
| **0x004C** | **L4:** | **…** | 2 | T |  |
| **0x0050** |  | **DADDI R10, R10, #-1** | 2 | T |  |
| **0x0054** |  | **BNEZ R10, L0** | 3 | T | 0-..-0-..-1 |
| **0x0058** |  |  |  |  |  |
|  |  |  |  |  |  |

Note:

SLT R1,R2,R3 ;IF (R2 < R3) R1 🡨 1

;ELSE R1 🡨 0

MISPREDICTION RATE = 3/500