DUE IN CLASS

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2.1 Simple execution, without data forwarding techniques

e) [Clock cycles	18	Instructions	6	Average CPI	3.0	
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f)	Clock cycles	174	S
	Instructions	61	
	Average CPI	2.852	

Stalls: - Data	101
- Structural	0
- Branch Taken	8

g) The branch policy adopted is Fredict Not Taken: whenever a branch instruction is executed, it has already fetched the next sequential. instruction. If the branch is not taken, the sequential instruction continues to be executed. However, if the branch is taken, the execution of the sequential instruction is cancelled and proceeds to execute the instruction with the address present in the branch instruction.

2.2 Application of data forwarding techniques

Clock cycles	136
Instructions	61
Average CPI	2.230

Stalls:	- Data	63
	- Structural	9
	- Branch Taken	8

2.3 Source code optimization: minimization of data and structural hazards

a) Attach a copy of the new assembly program. On dedicated page. (further)

Clock cycles	118
Instructions	61
Average CPI	1.934

Stalls: - Data	36
- Structural	9
- Branch Taken	9

2.4 Source code optimization: loop unrolling

a) Attach a copy of the new assembly program. On dedicated page. (further)

c)	Clock cycles	100
	Instructions	43
	Assess CDI	

Stalls: - Data	42
- Structural	9
- Branch Taken	2

d)

2.5 Source code optimization: branch delay slot

a) Attach a copy of the new assembly program. On dedicated page. (further)

d)

Clock cycles	101
Instructions	61
Average CPI	1.656

Stalls: - Data	27
- Structural	9
- Branch Taken	0

e)

40 39

38 37 35 36 22 23 24 25 26 27 28 29 30 31 32 33 34 (z , z) Table 1: Pipeline time diagram, with data forwarding techniques. 21 20 10 11 12 13 14 15 16 17 18 19 3 FPX XX 6 œ 6 7 1 Pu 512 O(ST) FDXMW 1 2 3 4 dedd 19 49, \$12 5w 39, mel+ (50) \$6, 85 la daddi 15, 15, 1 Suddi \$1, \$7, 8 duel 512, 512, 89 INSTRUCTIONS Suc

Lab. I - Page 9 of 13

Table 2: Pipeline time diagram, with minimization techniques to reduce the data and structural hazards.

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Table 3: Pipeline time diagram: usage of loop unrolling minimization techniques to reduce the control hazards.

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Table 4: Pipeline time diagram: usage of branch delay slot techniques to reduce the control hazards.

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(+ 2

4

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 35 37 38 39 Table 5: Pipeline time diagram, without data forwarding techniques. FDXAN FVVXX MXAM XXXX X X FDDDX F D X M W L L Anul \$12, 512, 59 ded 59, 59, \$12 6 bne 56, 55, Reep SN 39, mult (30) dodd: 55,55,1 5 dedti 51,51, 8 lw \$12, 0(\$1) INSTRUCTIONS 4

```
2.3 a)
```

```
.data
1
    A:
                             1, 3, 1, 6, 4
                      .word
                      .word 2, 4, 3, 9, 5
3
    mult:
             .word
                     A
5
6
             . code
                                    ; *A[0]
             daddi
7
                     $1, $0, A
                     $5, $0, 1
                                    ; $5 = 1 ;; i
; $6 = N ;; N = 10
8
             daddi
                     $6, $0, 10
9
             daddi
10
             1w
                      $9, 0($1)
                                    ; $9 = A[0] ;; mult
11
             daddi
                     $1, $1, 8
12
13
     loop:
             lw
                      $12, 0($1)
                                    ; $12 = A[i]
14
             daddi
                      $5, $5, 1
                                    ; i++
                                    ; $12 = $12*$9 ;; $12 = A[i]*mult
             dmul
                      $12, $12, $9
15
16
             daddi
                      $1, $1, 8
17
             dadd
                      $9, $9, $12
                                     ; $9 = $9 + $12 ;; mult = mult + A[i] = mult
18
             bne
                      $6, $5, loop
                                    ; Exit loop if i == N
19
20
                      $9, mult($0) ; Store result
             halt
21
22
23
     ;; Expected result: mult = f6180 (hex), 1008000 (dec)
24
```

2.4 a)

```
. data
       A:
                                .word
                                            1, 3, 1, 6, 4
 2 3 4
                                .word
                                           2, 4, 3, 9, 5
       mult:
                   .word
 5 6 7
                               $1, $0, A
$5, $0, 1
$6, $0, 10
$9, 0($1)
                                                      : *A[0]
                                                      ; $5 = 1 ;; i
; $6 = N ;; N = 10
; $9 = A[0] ;; mult
 8
 9
10
                   daddi
11
                               $1, $1, 8
12
13
       loop:
                                $12, 0($1)
$13, 8($1)
                                                      ; $12 = A[i]
; $13 = A[i+1]
14
                    lw
                                $12, $12, $9
$14, 16($1)
$9, $9, $12
                                                     ; $12 = $12*$9 ;; $12 = A[i]*mult
; $14 = A[i+2]
; $9 = $9 + $12 ;; mult = mult + A[i]*mult
16
                    lw
dadd
17
18
19
20
                               $5, $5, 3
$13, $13, $9
                                                     ; $13 = $13*$9 ;; $13 = A[i+1]*mult
; $9 = $9 + $13 ;; mult = mult + A[i+1]*mult
21
22
                                $9, $9, $13
23
24
                                $1, $1, 24
                    dmul
dadd
                               $14, $44, $9 ; $14 = $14*$9 ;; $14 = A[i+2]*mult
$9, $9, $14 ; $9 = $9 + $14 ;; mult = mult + A[i+2]*mult
25
26
27
                               $6, $5, loop ; Exit loop if i = N
28
                   bne
29
                                $9, mult($0) ; Store result
30
                   sw
halt
31
32
       ;; Expected result: mult = f6180 (hex), 1008000 (dec)
33
```

2.5 a)

```
. data
       A:
                            .word
                                     1, 3, 1, 6, 4
                            .word
                                     2, 4, 3, 9, 5
       mult:
                 .word
 5
 6
                           $1, $0, A
$5, $0, 1
$6, $0, 10
$9, 0($1)
                  daddi
                                              ; *A[0]
                                              ; $5 = 1 ;; i
; $6 = N ;; N = 10
; $9 = A[0] ;; mult
  8
 9
10
                           $1. $1. B
12
                 lw
                                               ; $12 = A[i]
13
       loop:
                 daddi
dmul
daddi
                           $5, $5, 1
$12, $12, $9
$1, $1, 8
$6, $5, loop
                                               ; 1++
14
                                              ; $12 = $12*$9 ;; $12 = A[i]*mult
15
16
17
                 bne
                                              ; Exit loop if i == N
18
                 dadd
                           $9, $9, $12
                                              ; $9 = $9 + $12 ;; mult = mult * A[i]*mult
19
                           $9, mult($0) ; Store result
20
21
22
      ;; Expected result: mult = f6180 (hex), 1008000 (dec)
23
```