**Question 1**

Let consider the *Hazards* that may arise in a pipelined processor. You are requested to

1. List the different types of Hazards, detailing in particular the different categories of Data Hazards
2. Describe for every type and category an example where the Hazard happens
3. Identify the corresponding data dependency (for Data Hazards, only).

**Question 2**

Let consider a MIPS architecture using a *Branch History Table* (BHT) composed of 8 1-bit entries. Let assume that this architecture executes the following code, which computes the number of equal non-null elements placed in the same position in 2 vectors V1 and V2, each composed of 5 integer elements, and then writes the result in the variable Res. For ever instruction the hexadecimal address of the memory cell storing the instruction is reported.

Assuming that when the execution of the code fragment the BHT is full of null values (corresponding to the prediction Not Taken) you are asked to compute:

* The number of mispredicted branches during the execution of the fragment
* The BHT content when the execution finishes (using the table reported in the next page).

For all computation we suggest the usage of the table in the next page.

V1: .word 0, 2, 4, 6, 8 # vector V1

V2: .word 0, 1, 3, 6, 0 # vector V2

Res: .word 0 # result

…

0x0020 and $t3, $0, $0 # initialize index

0x0024 and $t4, $0, $0 # initialize counter of equal non-null elements

0x0028 lab1: lw $t0, V1($t3) # load first element from V1

0x002c lw $t1, V2($t3) # load first element from V2

0x0030 bne $t0, $t1, lab2 # compare for equal value

0x0034 beq $t0, $0, lab2 # compare for non-null value

0x0038 add $t4, $t4, 1 # increment counter

0x003c lab2: add $t3, $t3, 4 # increment index

0x0040 bne $t3, 16, lab1 # repeat

0x0044 sw $t4, Res # store result

…

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | Iteration #1 | | Iteration #2 | | Iteration #3 | | Iteration #4 | | Iteration #5 | |
|  | | prediction | result | prediction | result | prediction | result | prediction | result | prediction | result |
|  | and $t3, $0, $0 |  |  |  |  |  |  |  |  |  |  |
|  | and $t4, $0, $0 |  |  |  |  |  |  |  |  |  |  |
| lab1: | lw $t0, V1($t3) |  |  |  |  |  |  |  |  |  |  |
|  | lw $t1, V2($t3) |  |  |  |  |  |  |  |  |  |  |
|  | bne $t0, $t1, lab2 |  |  |  |  |  |  |  |  |  |  |
|  | beq $t0, $0, lab2 |  |  |  |  |  |  |  |  |  |  |
|  | add $t4, $t4, 1 |  |  |  |  |  |  |  |  |  |  |
| lab2: | add $t3, $t3, 4 |  |  |  |  |  |  |  |  |  |  |
|  | bne $t3, 16, lab1 |  |  |  |  |  |  |  |  |  |  |
|  | sw $t4, Res |  |  |  |  |  |  |  |  |  |  |

**HBT  
Final content**

|  |  |
| --- | --- |
| Entry 0 |  |
| Entry 1 |  |
| Entry 2 |  |
| Entry 3 |  |
| Entry 4 |  |
| Entry 5 |  |
| Entry 6 |  |
| Entry 7 |  |