**Question #1**

Let consider the Branch Prediction Mechanism based on the Branch History Table (BHT).

You are requested to

1. Explain the reasons why a Branch Prediction Unit is important in pipelined architectures
2. Describe the general architecture and behavior of a BHT
3. Detail the architecture and behavior of a BHT using a 2-bit saturating counter
4. Detail the architecture and behavior of a BHT using a (2,2) correlating predictor.

**Question #2**

Let consider a MIPS64 architecture including the following functional units (for each unit the number of clock periods to complete one instruction is reported):

* Integer ALU: 1 clock period
* Data memory: 1 clock period
* FP arithmetic unit: 2 clock periods (pipelined)
* FP multiplier unit: 4 clock periods (pipelined)
* FP divider unit: 8 clock periods (unpipelined)

You should also assume that

* The branch delay slot corresponds to 1 clock cycle, and the branch delay slot is not enabled
* Data forwarding is enabled
* The EXE phase can be completed out-of-order.

You should consider the following code fragment and, using the table in the following page (where each column corresponds to a clock period), and determine the pipeline behavior in each clock period, as well as the total number of clock periods required to execute the fragment, reporting the result in the right column in the table below. The value of the constant k is written in f5 before the beginning of the code fragment.

; \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\* MIPS64 \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

; for (i = 0; i < 10; i++) {

; v4[i] = v1[i]/v2[i] + v3[i]\*k;

; }

|  |  |  |
| --- | --- | --- |
| .data | comments | Clock cycles |
| V1: .double “10 values” |  |  |
| V2: .double “10 values” |  |  |
| V3: .double “10 values”  V4: .double “10 values” |  |  |
|  |  |
|  |  |
|  |  |
| .text |  |  |
| main: daddui r1,r0,0 | r1← pointer |  |
| daddui r2,r0,10 | r2 <= 20 |  |
| loop: l.d f1,v1(r1) | f1 <= v1[i] |  |
| l.d f2,v2(r1) | f2 <= v2[i] |  |
| l.d f3,v3(r1) | f3 <= v3[i] |  |
| mul.d f5,f3,f4 | f5 <= v3[i]\*k |  |
| div.d f6, f1, f2 | f6 <= v1[i] / v2[i] |  |
| add.d f7, f6, f5 | f7 <= v3[i]\*k + v1[i] / v2[i] |  |
| s.d f7,v4(r1) | v4[i] <= f7 |  |
| daddui r1,r1,8 | r1 <= r1 + 8 |  |
| daddi r2,r2,-1 | r2 <= r2 - 1 |  |
| bnez r2,loop |  |  |
| halt |  |  |
| total |  |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| daddui r1,r0,0 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| daddui r2,r0,10 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| l.d f1,v1(r1) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| l.d f2,v2(r1) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| l.d f3,v3(r1) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| mul.d f5,f3,f4 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| div.d f6, f1, f2 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| add.d f7, f6, f5 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| s.d f7,v4(r1) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| daddui r1,r1,8 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| daddi r2,r2,-1 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| bnez r2,loop |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| halt |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |