Computer Architecture - tutorial 3

# Context, Objectives and Organization

Supplements material from Lecture 5 (Handling hazards).

The goals of the quantitative exercises in this tutorial are: to obtain familiarity with the process of identifying hazards (E1), and to review and apply the operation of different types of branch predictors (E2).

# E1: individual – 10 mins

*Problem*

Consider the following MIPS code fragments, each containing two instructions. For each code fragment identify the type of hazard that exists between the two instructions and the registers involved.

**a.**

|  |  |  |  |
| --- | --- | --- | --- |
| LD | R1, | 0(R2) | |
| DADD | R3, | R1, | R2 |
| **b.** |  |  |  |
| MULT | R1, | R2, | R3 |
| DADD | R1, | R2, | R3 |
| **c.** |  |  |  |
| MULT | R1, | R2, | R3 |
| MULT | R4, | R5, | R6 |
| **d.** |  |  |  |
| DADD | R1, | R2, | R3 |

SD 2000(R0), R1

**e.**

## DADD R1, R2, R3 SD 2000(R1), R4

*Solution*

1. Hazard – RAW (Read After Write): DADD requires the value of R1 before LD writes it, therefore a potential hazard.
2. Hazard – WAW (Write After Write): Both instructions write to R1.
3. Hazard - Structural hazard for multiplier. If the MULT unit is not pipelined.
4. Hazard - RAW: SD requires (in MEM stage) the value of R1 that DADD produces.
5. Hazard - RAW: sd requires (in ALU stage) the value of R1 computed by DADD

# E2: groups of 2 – 15 minutes

*Problem*

1. Explain the behaviour of a 2-bit saturating counter branch predictor. Show the state of the predictor and the transition for each outcome of the branch.
2. Consider the following code:

for (i=0; i<N; i++) if (x[i] == 0)

y[i] = 0.0;

else

y[i] = y[i]/x[i];

Assume that the assembly code generated is then:

loop: L.D F1, 0(R2)

## L.D F2, 0(R3)

BNEZ F1, else ADD.D F2, F0, F0

BEZ R0, fall else: DIV.D F2, F2, F1 fall: DADDI R2, R2, 8

## DADDI R3, R3, 8 DSUBI R1, R1, 1

S.D -8(R3), F2

BNEZ R1, loop

where:

* + the value of N is already stored in R1
  + the base addresses for x and y are stored in R2 and R3, respectively
  + register F0 contains the value 0
  + register R0 (always) contains the value 0

Assuming that every other element of x has the value 0, starting with the first one, show the outcomes of predictions when a 2-bit saturating counter is used to predict the inner branch BNEZ F1, else. Assume that the initial value of the counter is 00.

***Solution***

1. **2-bit saturating counter branch predictor**

|  |  |  |  |
| --- | --- | --- | --- |
| CURRENT COUNTER VALUE | PREDICTION | ACTUAL OUTCOME | NEW COUNTER VALUE |
| 00 | NT | NT | 00 |
| 00 | NT | T | 01 |
| 01 | NT | NT | 00 |
| 01 | NT | T | 10 |
| 10 | T | NT | 01 |
| 10 | T | T | 11 |
| 11 | T | NT | 10 |
| 11 | T | T | 11 |

1. **2-bit counter prediction rate**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Iteration | current counter value | prediction | actual outcome | new counter value |
| 1 | 00 | NT | NT | 00 (hit) |
| 2 | 00 | NT | T | 01 (miss) |
| 3 | 01 | NT | NT | 00 (hit) |
| 4 | 00 | NT | T | 01 (miss) |
| 5 | 0 | T | NT | 01 (miss) |