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Lab 1 - Hazards

The formulas for the CPI's for the five stage pipeline due to RAW hazards in question 1 and question 2 as well as the derivations of the slowdowns are given below:

$$CPI_1 = \frac{insn + 2 * RAW}{insn} \qquad CPI_2 = \frac{insn + RAW_1 + 2 * RAW_2}{insn}$$

$$\%\ \text{drop}_1 = \frac{CPI_{new} - CPI_{old}}{CPI_{old}} * 100 \qquad \%\ \text{drop}_2 = \frac{CPI_{new} - CPI_{old}}{CPI_{old}} * 100$$

$$= \frac{\frac{insn+2*RAW}{insn} - \frac{insn}{insn}}{\frac{insn}{insn}} * 100 \qquad = \frac{\frac{insn+RAW_1+2*RAW_2}{insn} - \frac{insn}{insn}}{\frac{insn}{insn}} * 100$$

$$= \frac{2 * RAW}{insn} * 100 \qquad = \frac{RAW_1 + 2 * RAW_2}{insn} * 100$$

where:

$insn =$ number of instructions
$RAW =$ number of RAW hazards
$RAW_1 =$ number of RAW hazards causing 1-cycle stalls
$RAW_2 =$ number of RAW hazards causing 2-cycle stalls

The benchmark was compiled using: `ssbig-na-sstrix-gcc -O1 mbq1.c -o mbq1` The benchmark main loop runs 1 million times:

```
(1) addu    $4,$4,1
(2) addu    $5,$4,1
(3) lw      $8,16($sp)
(4) addi    $7,$8,1
(5) sw      $7,16($sp)
(6) addu    $3,$3,1
(7) slt     $2,$6,$3
(8) beq     $2,$0,$L5
```

There are 5 RAW hazards in these 8 instructions in the following places:

1. There is a RAW hazard at (2) because it has a dependency on $4. This dependency is a 2-cycle stall in the non-bypassing pipeline and a 1-cycle stall in the bypassing pipeline bypassing because the the value needed for $4 is ready by the end of the EXEC stage.
2. There is a RAW hazard at (4) because it has a dependency on $8. This dependency translates to a 2-cycle stall in both the bypassing and non-bypassing pipelines because the value needed for $8 will be ready at the end of the MEM stage.
3. There is a RAW hazard at (5) only in the non-bypassing pipeline. In the bypassing pipeline, even though (5) has a data dependency on $7, there is no hazard because the value in $7 is only needed in the MEM stage by instruction (5) and will be ready by the end of the EXEC stage in instruction (4).
4. There is a RAW hazard at (7) because it has a dependency on $3 which is a 2-cycle stall in the non-bypassing pipeline and a 1-cycle stall in the bypassing pipeline.
5. There is a RAW hazard at (8) because it has a dependency on $2. This dependency translates to a 2-cycle stall in the non-bypassing pipeline and a 1-cycle stall in the bypassing pipeline because the value needed for $2 will be ready by the end of the EXEC stage.

Therefore, the microbenchmark should generate CPI_1 and CPI_2 as follows:

$$CPI_1 = \frac{8 + 2 * 5}{8} \qquad CPI_2 = \frac{8 + 3 + 2 * 1}{8}$$

$$= 2.25 \qquad = 1.625$$

which are exactly the values measured by running `sim-safe mbq1`. The measurements from running `sim-safe /cad2/ece552f/benchmarks/gcc.eio` are:

$CPI_1, gcc = 1.6642$ $CPI_2, gcc = 1.3903$
$\%\ \text{drop}_1, gcc = 66.24$ $\%\ \text{drop}_2, gcc = 39.03$