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| **Architetture dei Sistemi di Elaborazione 02GOLOV** | Delivery date:  **9th November 2023** |
| **Laboratory**  **3** | Expected delivery of lab\_03.zip must include:   * program\_1\_a.s, program\_1\_b.s and program\_1\_c.s * this file compiled and if possible in pdf format. |

Please, configure the winMIPS64 simulator with the *Base Configuration* provided in the following:

* Immagine che contiene testo, schermata, Carattere, numero

  Description automatically generatedCode address bus: 12
* Data address bus: 12
* Pipelined FP arithmetic unit (latency): 3 stages
* Pipelined multiplier unit (latency): 8 stages
* divider unit (latency): not pipelined unit,

20 clock cycles

* Forwarding is enabled
* Branch prediction is disabled
* Branch delay slot is disabled
* *Integer ALU: 1 clock cycle*
* *Data memory: 1 clock cycle*
* *Branch delay slot: 1 clock cycle*.

1. Enhance the assembly program you created in the previous lab called **program\_1.s**:

int m=1 /\* 64 bit \*/

double k,p

for (i = 0; i < 64; i++){

if (i is even) {

p= v1[i] \* ((double)( m<< i)) /\*logic shift \*/

m = (int)p

} else {

/\* i is odd \*/

p= v1[i] / ((double)m\* i))

k = ((float)((int)v4[i]/ 2^i)

}

v5[i] = ((p \* v2[i]) + v3[i])+v4[i];

v6[i] = v5[i]/(k+v1[i]);

v7[i] = v6[i]\*(v2[i]+v3[i]);

}

* + 1. Detect manually the different data, structural and control hazards that provoke a pipeline stall
    2. Optimize the program by re-scheduling the program instructions in order to eliminate as many hazards as possible. Compute manually the number of clock cycles the new program (**program\_1\_a.s**) requires to execute, and compare the obtained results with the ones obtained by the simulator.
    3. Starting from **program\_1\_a.s**, enable the *branch delay slot* and re-schedule some instructions in order to improve the previous program execution time. Compute manually the number of clock cycles the new program (**program\_1\_b.s**) requires to execute, and compare the obtained results with the ones obtained by the simulator.
    4. Unroll 2 times the program (**program\_1\_b.s**), if necessary re-schedule some instructions and increase the number of used registers. Compute manually the number of clock cycles the new program (**program\_1\_c.s**) requires to execute, and compare the obtained results with the ones obtained by the simulator.

Complete the following table with the obtained results:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Program**    **Clock cycle computation** | **program\_1.s** | **program\_1\_a.s** | **program\_1\_b.s** | **program\_1\_c.s** |
| **By hand** | 6403 | 6403 | 6403 | 6467 |
| **By simulation** | 6599 | 5575 | 5576 | 6088 |

Collect the IPC (from the simulator) for different programs.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **program\_1.s** | **program\_1\_a.s** | **program\_1\_b.s** | **program\_1\_c.s** |
| **IPC** | 0.37 | 0.39 | 0.40 | 0.35 |

Compare the results obtained in point 1, and provide some explanation in the case the results are different.

Eventual explanation: