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| **Architetture dei Sistemi di Elaborazione 02GOLOV** | **Computer Architectures 02LSEYG** |
| **Laboratory**  **0x02** | **Expected delivery of lab\_02.zip including:**  **- program\_1.s**  **- lab\_02.pdf (fill and export this file to pdf)** |
| **Delivery date 23/10/2025** | |

All the previous steps for compiling the source code, simulating with gem5 and visualizing the pipeline have been collected into a workspace available at:

<https://github.com/cad-polito-it/ase_riscv_gem5_sim>

To create your simulation workspace, you can run the following git commands:

* For HTTPS clone:

**~/my\_gem5Dir$** git clone <https://github.com/cad-polito-it/ase_riscv_gem5_sim.git>

* For SSH:

**~/my\_gem5Dir$** git clone git@github.com:cad-polito-it/ase\_riscv\_gem5\_sim.git

If you wish to install on your machine the tools (without using the VM or LABINF’s PCs) the repository contains information (and scripts) on installing the necessary tools out of the box (and generate a *setup\_default* file accordingly). See [README](https://github.com/cad-polito-it/ase_riscv_gem5_sim/blob/main/README.md)

**IMPORTANT:** The repository contains three *setup\_default* files:

* *setup\_default*: an example of out of box installation and different tool paths.
* *setup\_default.vm*: tool paths used in the virtual machines.
* *setup\_default.labinf*: tool paths used in the LABINF machines.

Follow the HOWTO instructions available on the GitHub Repository for simulating a program. You simply run the following command:

**~/ase\_riscv\_gem5\_sim$ ./simulate.sh**

And select the program you want to simulate and see on the pipeline visualizer.

A useful list of RISC-V instructions can be found at:

<https://msyksphinz-self.github.io/riscv-isadoc/#_rv32i_rv64i_instructions>

* Exercise 1

The riscv\_in\_order\_hen\_patt.py (in the gem5 folder inside the workspace) file contains the pipeline configuration. Here you can modify the operation latency and the issue latency of integer and floating-point functional units (ALU, Multiplier, Divider).

You must configure the Gem5 simulator with the ***Initial Configuration***as described below:

**INTEGER\_ALU\_LATENCY = 1**

**INTEGER\_MUL\_LATENCY = 1**

**INTEGER\_DIV\_LATENCY = 1**

**FLOAT\_ALU\_LATENCY = 8**

**FLOAT\_MUL\_LATENCY = 24**

**FLOAT\_DIV\_LATENCY = 42**

Write an assembly program (**program\_1.s**) for the *RISCV* architecture described before being able to implement the following high-level code:

for (i = 31; i >= 0; i--) {

v4[i] = v1[i]\*v1[i] – v2[i];

v5[i] = v4[i]/v3[i] – v2[i];

v6[i] = (v4[i]-v1[i])\*v5[i];

}

Assume that the vectors v1[], v2[], and v3[] have been previously allocated in memory and contain 32 single-precision **floating-point values;** also assume that v3[] doesnot contain any ‘0’. Additionally, the vectors v4[], v5[], v6[] are empty vectors allocated in memory.

**Calculate** the data memory footprint of your program:

|  |  |
| --- | --- |
| **Data** | **Number of bytes** |
| **V1** | 128 |
| **V2** | 128 |
| **V3** | 128 |
| **V4** | 128 |
| **V5** | 128 |
| **V6** | 128 |
| **Total** | 768 |

* + - Calculate the CPU performance equation (CPU time) of the above program by assuming a clock frequency of 15 MHz:

By definition:

* + - * CPI*i* is equal to the number of clock cycles required by the related functional unit to execute the instruction (EX stage);
      * IC*i* is the number of times an instruction is repeated in the referenced source code.
    - Recalculate the CPU performance equation assuming that you can triple the speed of just one unit at a time:
      1. FP multiplier (MUL) unit latency: 24 à 8 clock cycles
      2. FP divider (DIV) unit latency: 42 à 14 clock cycles

Table 1: Calculate the CPU time ***by hand***

|  |  |  |  |
| --- | --- | --- | --- |
|  | Initial CPU time (a) | CPU time  (b – MUL speeded up) | CPU time  (c – DIV speeded up) |
| program\_1.s | 0,0002782 | 0,000208 | 0,000216533 |

* + - Using the simulator, calculate the CPU time again and fill in the following table:

Table 2: Collect the CPU time ***using the simulator***

|  |  |  |  |
| --- | --- | --- | --- |
|  | Initial CPU time (a) | CPU time  (b – MUL speeded up) | CPU time  (c – DIV speeded up) |
| program\_1.s | 0,0002491 | 0,0001808 | 0,0001893 |

Are there any differences? If so, where and why? If not, please provide some comments in the box below:

|  |
| --- |
| Your answer: All values computed by hand are higher than those computed by the simulator. This discrepancy occurs because the manual calculations do not account for the parallelization and pipelining that occur in the simulator, which allow multiple instructions to execute simultaneously and thus improve execution speed. |

* Exercise 2

Using the Gem5 simulator, validate experimentally the Amdahl’s law, defined as follows:



1. Using the program developed before **program\_1.s**
2. Modify the processor architectural parameters related (in riscv\_in\_order\_hen\_patt.py ) to multicycle instructions latency in the following way:

**Configuration 1:**

**INTEGER\_ALU\_LATENCY = 1**

**INTEGER\_MUL\_LATENCY = 1**

**INTEGER\_DIV\_LATENCY = 1**

**FLOAT\_ALU\_LATENCY = 6**

**FLOAT\_MUL\_LATENCY = 20**

**FLOAT\_DIV\_LATENCY = 38**

**Configuration 2:**

**INTEGER\_ALU\_LATENCY = 1**

**INTEGER\_MUL\_LATENCY = 1**

**INTEGER\_DIV\_LATENCY = 1**

**FLOAT\_ALU\_LATENCY = 4**

**FLOAT\_MUL\_LATENCY = 16**

**FLOAT\_DIV\_LATENCY = 30**

**Configuration 3:**

**INTEGER\_ALU\_LATENCY = 1**

**INTEGER\_MUL\_LATENCY = 1**

**INTEGER\_DIV\_LATENCY = 1**

**FLOAT\_ALU\_LATENCY = 2**

**FLOAT\_MUL\_LATENCY = 4**

**FLOAT\_DIV\_LATENCY = 8**

Compute both manually (using the Amdahl’s Law) and with the simulator the speed-up for any one of the previous processor configurations. Compare the obtained results and complete the following table.

Table 5: **program\_1.s speed-up computed *by hand and by simulation***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Proc. Config.**    **Speed-up comp.** | Initial config.  [c.c.] | Config. 1  [c.c.] | Config. 2  [c.c.] | Config. 3  [c.c.] |
| ***By hand*** | 1 | 1,137222737 | 1,3790204 | 2,65558207 |
| ***By simulation*** | 1 | 1,11710384 | 1,31510945 | 2,4938747 |