

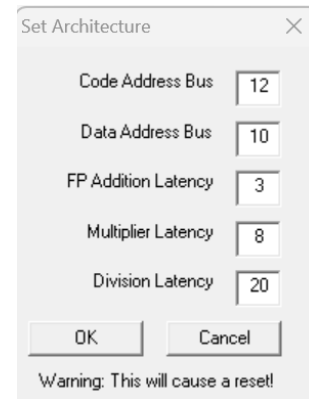
**Laboratory**  
**3**

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:

- Code 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 = ((double)((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]);

}
```

- a. Detect manually the different data, structural and control hazards that provoke a pipeline stall

- b. 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.
- c. 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.
- d. 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	<u>5133</u>	<u>4973</u>	<u>4910</u>	<u>3662</u>
By simulation	<u>5133</u>	<u>4973</u>	<u>4910</u>	<u>3662</u>

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	<u>0.349</u>	<u>0.362</u>	<u>0.373</u>	<u>0.440</u>

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

Eventual explanation: