PROJECT 2

EE739: - Processor Design

Department of Electrical Engineering

(IIT Bombay)

Submitted By: -

Harshad Bhausaheb Ugale (20307R008)

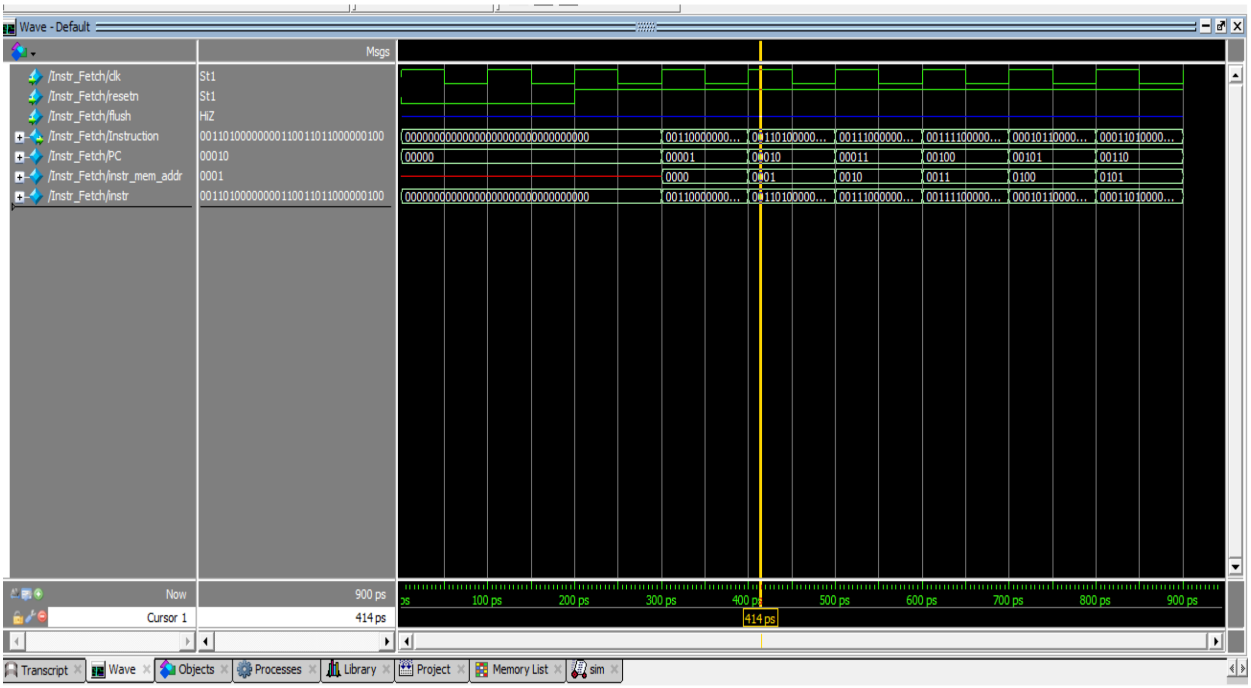
Mahesh Shahaji Patil (20307R010)

Introduction: -

Here, in this project we have implemented 2-way fetch superscalar processor which is 16-bit computer with 8 registers. We fetch two instructions at a time in the Fetch Unit. We then decode the instructions two at a time and pass the control bits to the Dispatch Unit. The Dispatch Unit then passes the instructions to the respective Reservation Stations for the ALU, Memory units. The Reservation Station manages the dispatching of the instructions stored in its buffer to the respective execution units. The outputs of the execution unit are then next fed to the storage buffer.

Instruction Fetch: -

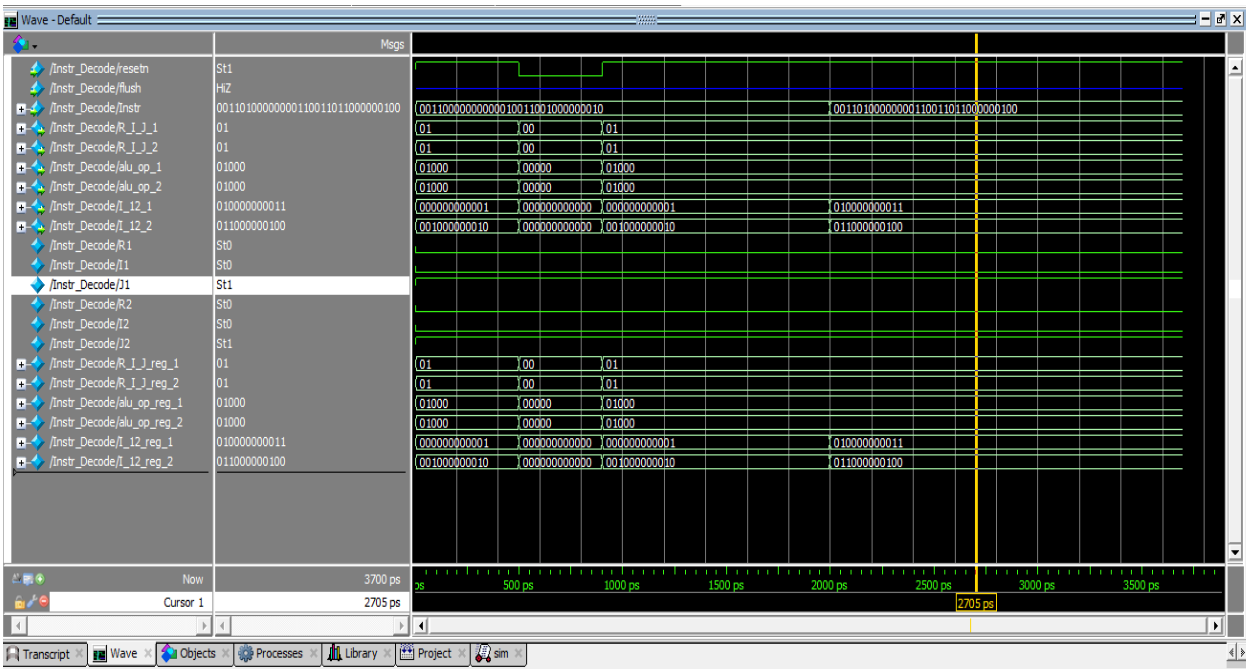
The Fetch Unit requires an input of the Program Counter. This Program Counter is fed to the Fetch Unit via a Multiplexer which is responsible for selecting the next program counter. The two instructions each of 16-bit wide have been fetched at a time.



	Msgs
/Instr_Fetch/clk	St1
/Instr_Fetch/resetn	St1
/Instr_Fetch/flush	HiZ
/Instr_Fetch/Instruction	00110100000000011001101100000000100
/Instr_Fetch/PC	00010
/Instr_Fetch/instr_mem_addr	0001
/Instr_Fetch/instr	00110100000000011001101100000000100
Now	900 ps
Cursor 1	414 ps

Instruction Decode: -

The Decode Stage is responsible to decode the instructions and send the corresponding register data and the architectural register tags for the destination and the operand registers along with the immediate operands (if any). It also sends control bits to be used by the different stages further in the pipeline.



Wave - Default

	Msgs
/Instr_Decode/resetn	St1
/Instr_Decode/flush	HiZ
/Instr_Decode/Instr	00110100000000110011011000000100
/Instr_Decode/R_I_J_1	01
/Instr_Decode/R_I_J_2	01
/Instr_Decode/alu_op_1	01000
/Instr_Decode/alu_op_2	01000
/Instr_Decode/I_12_1	010000000011
/Instr_Decode/I_12_2	011000000100
/Instr_Decode/R1	St0
/Instr_Decode/I1	St0
/Instr_Decode/J1	St1
/Instr_Decode/R2	St0
/Instr_Decode/I2	St0
/Instr_Decode/J2	St1
/Instr_Decode/R_I_J_reg_1	01
/Instr_Decode/R_I_J_reg_2	01
/Instr_Decode/alu_op_reg_1	01000
/Instr_Decode/alu_op_reg_2	01000
/Instr_Decode/I_12_reg_1	010000000011
/Instr_Decode/I_12_reg_2	011000000100
Now	3700 ps
Cursor 1	2705 ps

Dispatch Stage: -

The Dispatch Stage is crucial for the Superscalar processor architecture. This stage is responsible for dispatching the instructions coming to it. Dispatch stage receives the decoded instruction from the decode stage. In the case of 2- way fetch superscalar, the dispatch stage receives two decoded instructions from decode stage. Each instruction has associated control signals and register Ids or immediate operand. The dispatch stage resolves the false dependencies by using register renaming. As the reservation stations are decentralized, dispatch unit sends the instruction to appropriate reservation station. Dispatch stage receives instruction, operands, control bits, source and destination registers from decode stage. Dispatch receives 2 instructions from decode, in each clock cycle. Dispatch unit sends each instruction along with its associated control signals, operands (or tag of operand), operand validity bits, tag of destination to the correct reservation station.

Reservation Station: -

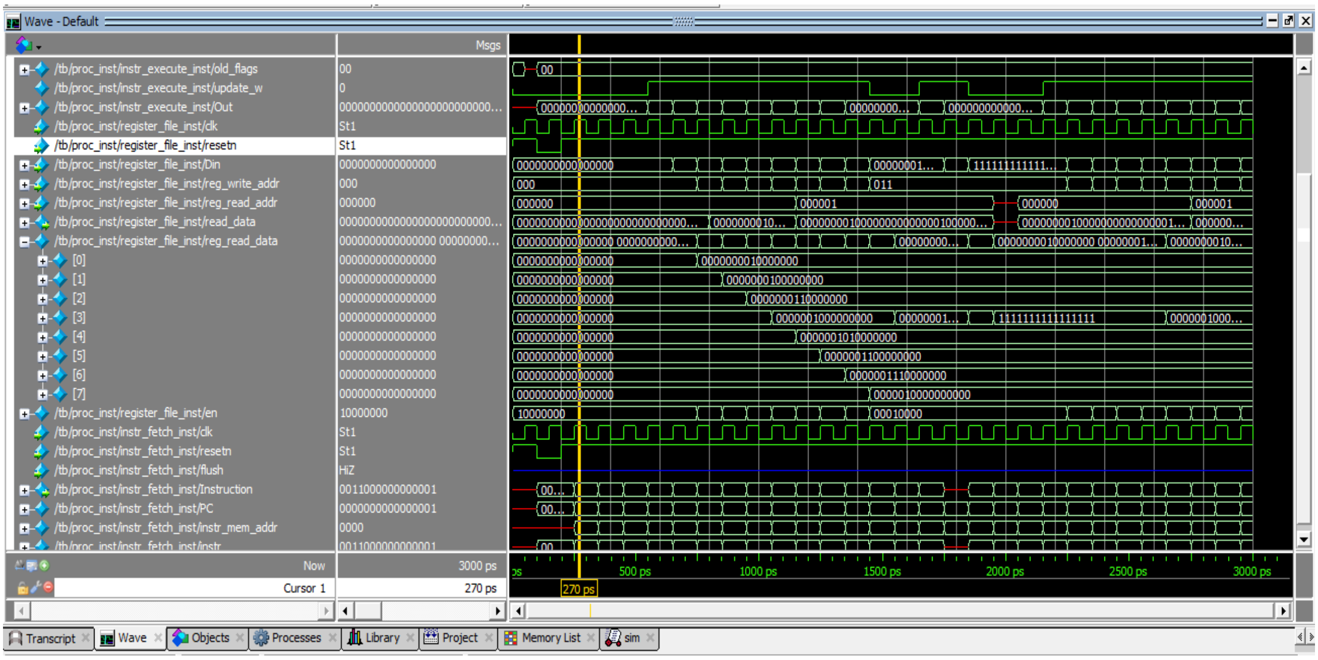
Instructions wait in the reservation station till their operands are ready. We have designed decentralized reservation stations, with each execution unit having its own reservation station. Thus, there are 2 reservation stations, one each for ALU, Memory units. The reservation station sends the instruction to execution unit once its operands are ready. Each reservation gets the instruction, control bits, operands, operand validity bits, tag of destination register of the instruction from the dispatch stage. Reservation station sends the instruction, control bits, destination register tag to the execution unit. The instruction, control bits and operands are used by the execution units as desired.

Execution: -

In this stage the execution of the instruction takes place according to the operands defined in the instruction like whether it is ADD, ADC, NDU, LHI, LW, SW, etc. and the results have been produced. The execution stage contains mostly the ALU & Memory operations.

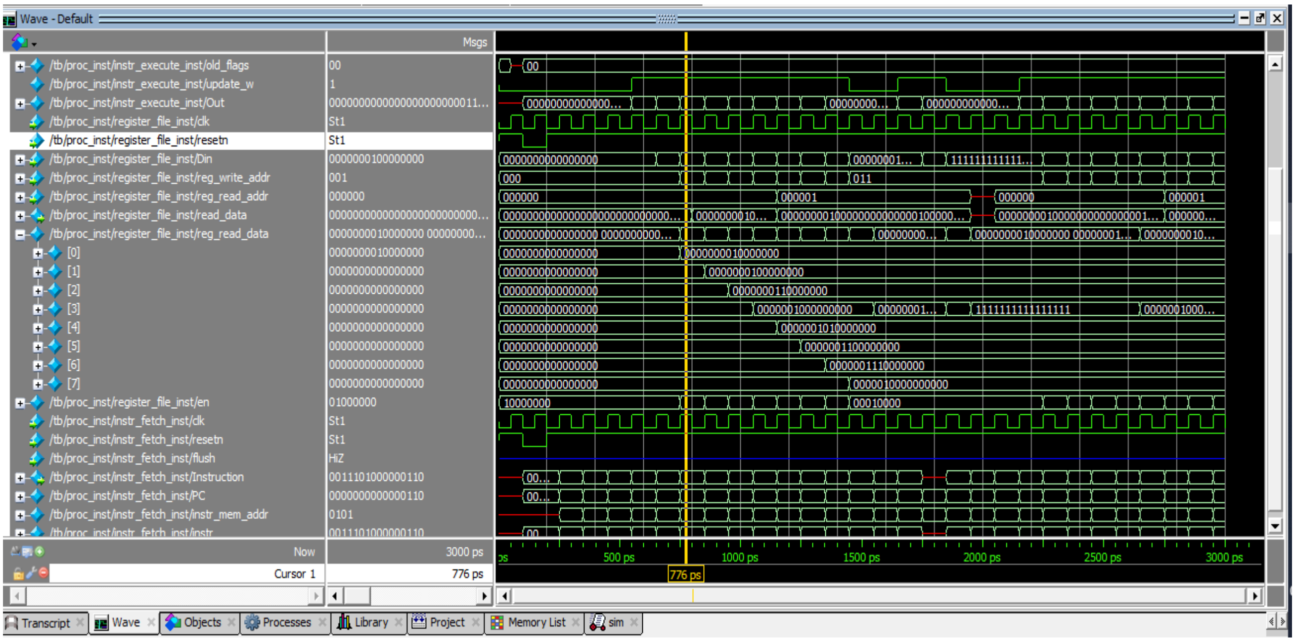
LHI R0, 000000001 (1st Instruction From program_instr.hex)

Input: -



```
/tb/proc_inst/instr_execute_inst/old_flags          00
/tb/proc_inst/instr_execute_inst/update_w           0
/tb/proc_inst/instr_execute_inst/Out                0000000000000000000000000...
/tb/proc_inst/register_file_inst/clk                St1
/tb/proc_inst/register_file_inst/resetn             St1
/tb/proc_inst/register_file_inst/Din                0000000000000000
/tb/proc_inst/register_file_inst/reg_write_addr     000
/tb/proc_inst/register_file_inst/reg_read_addr      000000
/tb/proc_inst/register_file_inst/read_data          0000000000000000000000000...
/tb/proc_inst/register_file_inst/reg_read_data      0000000000000000 00000000...
  [0]                                               0000000000000000
  [1]                                               0000000000000000
  [2]                                               0000000000000000
  [3]                                               0000000000000000
  [4]                                               0000000000000000
  [5]                                               0000000000000000
  [6]                                               0000000000000000
  [7]                                               0000000000000000
/tb/proc_inst/register_file_inst/en                 10000000
/tb/proc_inst/instr_fetch_inst/clk                  St1
/tb/proc_inst/instr_fetch_inst/resetn               St1
/tb/proc_inst/instr_fetch_inst/flush                HiZ
/tb/proc_inst/instr_fetch_inst/Instruction          0011000000000001
/tb/proc_inst/instr_fetch_inst/PC                   0000000000000001
/tb/proc_inst/instr_fetch_inst/instr_mem_addr       0000
/tb/proc_inst/instr_fetch_inst/instr                0011000000000001
Now                                                 3000 ps
Cursor 1                                            270 ps
```

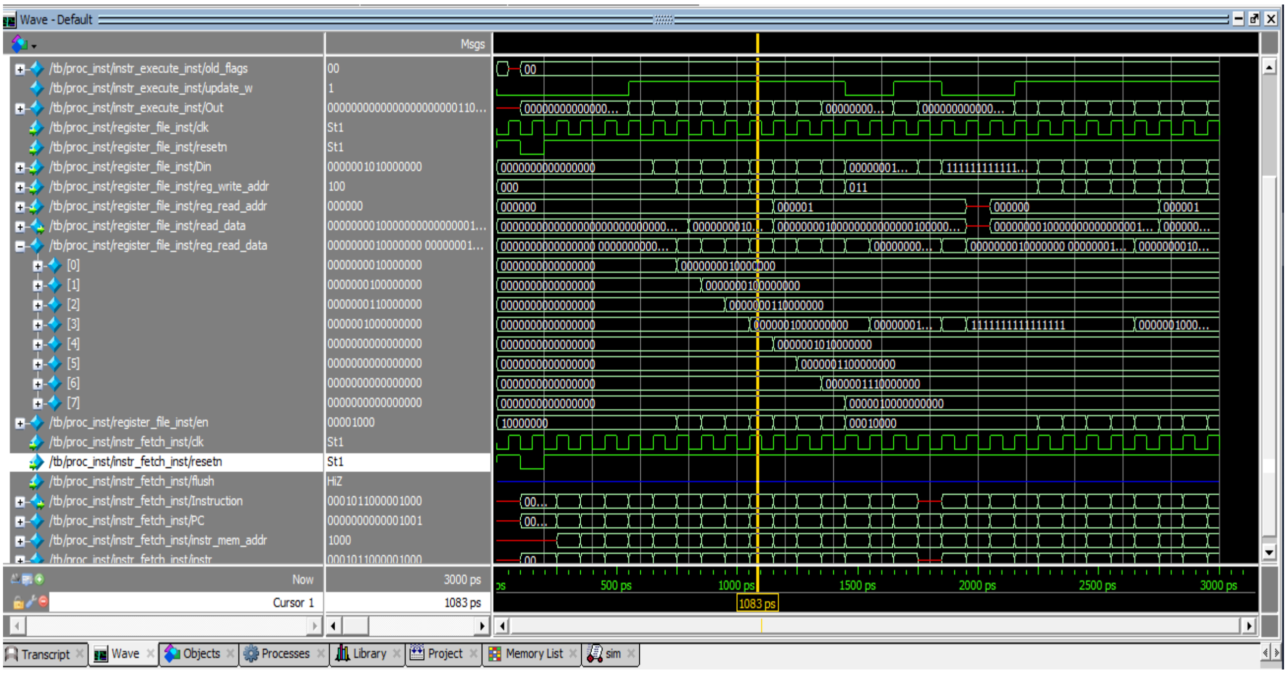
Output: -



	Msgs
/tb/proc_inst/instr_execute_inst/old_flags	00
/tb/proc_inst/instr_execute_inst/update_w	1
/tb/proc_inst/instr_execute_inst/Out	000000000000000000000011...
/tb/proc_inst/register_file_inst/clk	St1
/tb/proc_inst/register_file_inst/resetn	St1
/tb/proc_inst/register_file_inst/Din	0000000100000000
/tb/proc_inst/register_file_inst/reg_write_addr	001
/tb/proc_inst/register_file_inst/reg_read_addr	000000
/tb/proc_inst/register_file_inst/read_data	000000000000000000000000...
/tb/proc_inst/register_file_inst/reg_read_data	0000000010000000 00000000...
[0]	0000000010000000
[1]	0000000000000000
[2]	0000000000000000
[3]	0000000000000000
[4]	0000000000000000
[5]	0000000000000000
[6]	0000000000000000
[7]	0000000000000000
/tb/proc_inst/register_file_inst/en	01000000
/tb/proc_inst/instr_fetch_inst/clk	St1
/tb/proc_inst/instr_fetch_inst/resetn	St1
/tb/proc_inst/instr_fetch_inst/flush	HiZ
/tb/proc_inst/instr_fetch_inst/Instruction	0011101000000110
/tb/proc_inst/instr_fetch_inst/PC	0000000000000110
/tb/proc_inst/instr_fetch_inst/instr_mem_addr	0101
/tb/proc_inst/instr_fetch_inst/instr	0011101000000110
Now	3000 ps
Cursor 1	776 ps

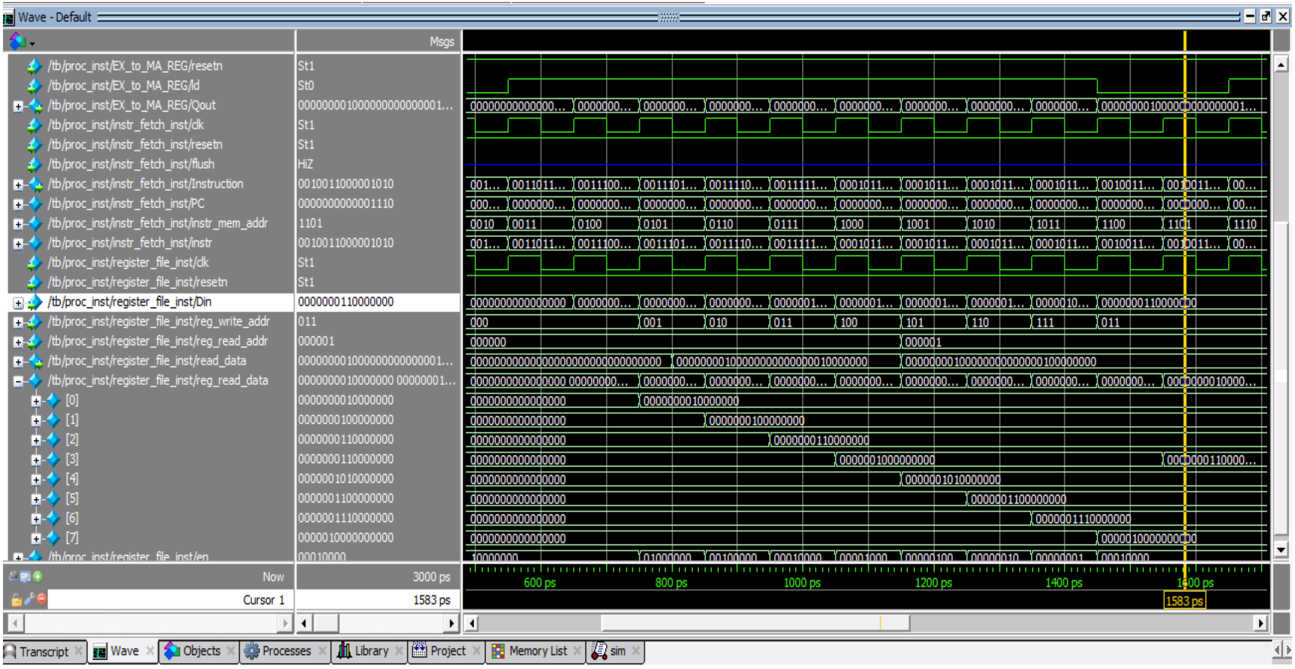
ADD R3, R0, R1 Instruction: -

Input: -



	Msgs
/tb/proc_inst/instr_execute_inst/old_flags	00
/tb/proc_inst/instr_execute_inst/update_w	1
/tb/proc_inst/instr_execute_inst/Out	000000000000000000000110...
/tb/proc_inst/register_file_inst/clk	St1
/tb/proc_inst/register_file_inst/resetn	St1
/tb/proc_inst/register_file_inst/Din	0000001010000000
/tb/proc_inst/register_file_inst/reg_write_addr	100
/tb/proc_inst/register_file_inst/reg_read_addr	000000
/tb/proc_inst/register_file_inst/read_data	00000000100000000000000001...
/tb/proc_inst/register_file_inst/reg_read_data	0000000010000000 00000001...
[0]	0000000010000000
[1]	0000000100000000
[2]	0000000110000000
[3]	0000001000000000
[4]	0000000000000000
[5]	0000000000000000
[6]	0000000000000000
[7]	0000000000000000
/tb/proc_inst/register_file_inst/en	00001000
/tb/proc_inst/instr_fetch_inst/clk	St1
/tb/proc_inst/instr_fetch_inst/resetn	St1
/tb/proc_inst/instr_fetch_inst/flush	HiZ
/tb/proc_inst/instr_fetch_inst/Instruction	0001011000001000
/tb/proc_inst/instr_fetch_inst/PC	0000000000001001
/tb/proc_inst/instr_fetch_inst/instr_mem_addr	1000
/tb/proc_inst/instr_fetch_inst/instr	0001011000001000
Now	3000 ps
Cursor 1	1083 ps

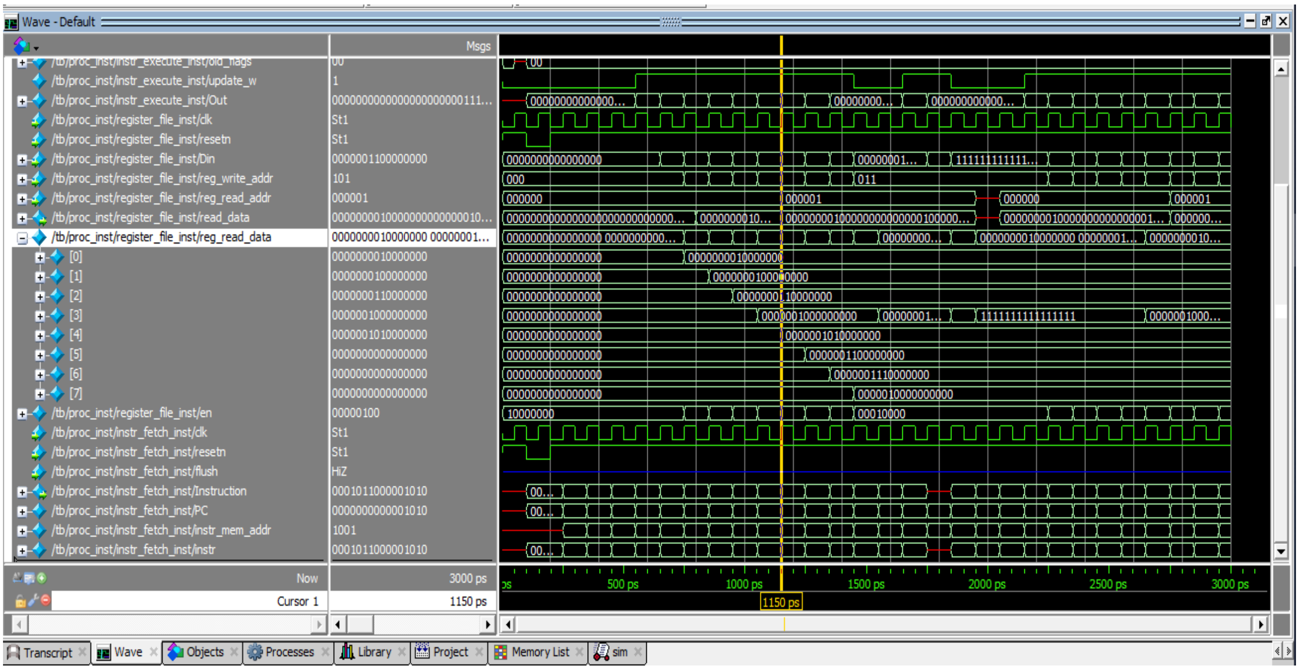
Output: -



```
Wave - Default
                                                   Msgs
/tb/proc_inst/EX_to_MA_REG/resetn                  St1
/tb/proc_inst/EX_to_MA_REG/ld                      St0
/tb/proc_inst/EX_to_MA_REG/Qout                    000000001000000000000001...
/tb/proc_inst/instr_fetch_inst/clk                 St1
/tb/proc_inst/instr_fetch_inst/resetn              St1
/tb/proc_inst/instr_fetch_inst/flush               HiZ
/tb/proc_inst/instr_fetch_inst/Instruction         0010011000001010
/tb/proc_inst/instr_fetch_inst/PC                  0000000000001110
/tb/proc_inst/instr_fetch_inst/instr_mem_addr      1101
/tb/proc_inst/instr_fetch_inst/instr               0010011000001010
/tb/proc_inst/register_file_inst/clk               St1
/tb/proc_inst/register_file_inst/resetn            St1
/tb/proc_inst/register_file_inst/Din               0000000110000000
/tb/proc_inst/register_file_inst/reg_write_addr    011
/tb/proc_inst/register_file_inst/reg_read_addr     000001
/tb/proc_inst/register_file_inst/read_data         000000001000000000000001...
/tb/proc_inst/register_file_inst/reg_read_data     0000000010000000 00000001...
  [0]                                              0000000010000000
  [1]                                              0000000100000000
  [2]                                              0000000110000000
  [3]                                              0000000110000000
  [4]                                              0000001010000000
  [5]                                              0000001100000000
  [6]                                              0000001110000000
  [7]                                              0000010000000000
/tb/proc_inst/register_file_inst/en                00010000
Now                                                3000 ps
Cursor 1                                           1583 ps
```

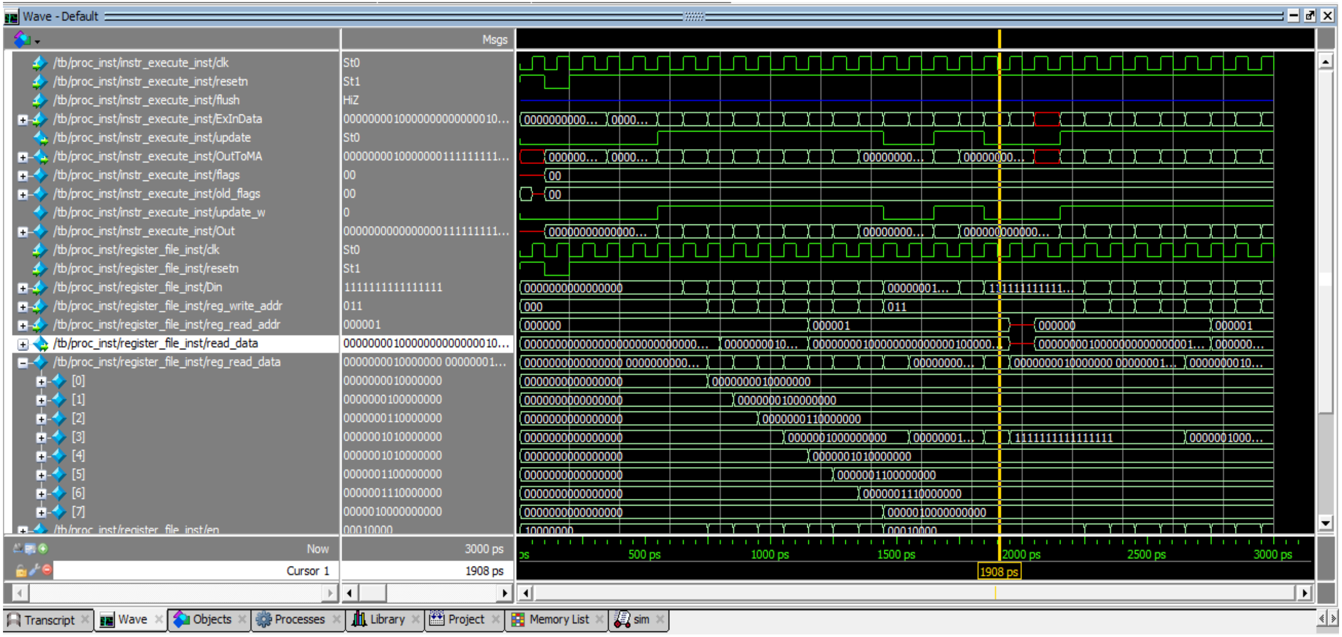
ADC R4, R0, R1 Instruction: -

Input: -



```
Wave - Default
                                                   Msgs
/tb/proc_inst/instr_execute_inst/old_flags         00
/tb/proc_inst/instr_execute_inst/update_w          1
/tb/proc_inst/instr_execute_inst/Out               0000000000000000000000111...
/tb/proc_inst/register_file_inst/clk               St1
/tb/proc_inst/register_file_inst/resetn            St1
/tb/proc_inst/register_file_inst/Din               0000001100000000
/tb/proc_inst/register_file_inst/reg_write_addr    101
/tb/proc_inst/register_file_inst/reg_read_addr     000001
/tb/proc_inst/register_file_inst/read_data         000000001000000000000010...
/tb/proc_inst/register_file_inst/reg_read_data     0000000010000000 00000001...
  [0]                                              0000000010000000
  [1]                                              0000000100000000
  [2]                                              0000000110000000
  [3]                                              0000001000000000
  [4]                                              0000001010000000
  [5]                                              0000000000000000
  [6]                                              0000000000000000
  [7]                                              0000000000000000
/tb/proc_inst/register_file_inst/en                00000100
/tb/proc_inst/instr_fetch_inst/clk                 St1
/tb/proc_inst/instr_fetch_inst/resetn              St1
/tb/proc_inst/instr_fetch_inst/flush               HiZ
/tb/proc_inst/instr_fetch_inst/Instruction         0001011000001010
/tb/proc_inst/instr_fetch_inst/PC                  0000000000001010
/tb/proc_inst/instr_fetch_inst/instr_mem_addr      1001
/tb/proc_inst/instr_fetch_inst/instr               0001011000001010
Now                                                3000 ps
Cursor 1                                           1150 ps
```

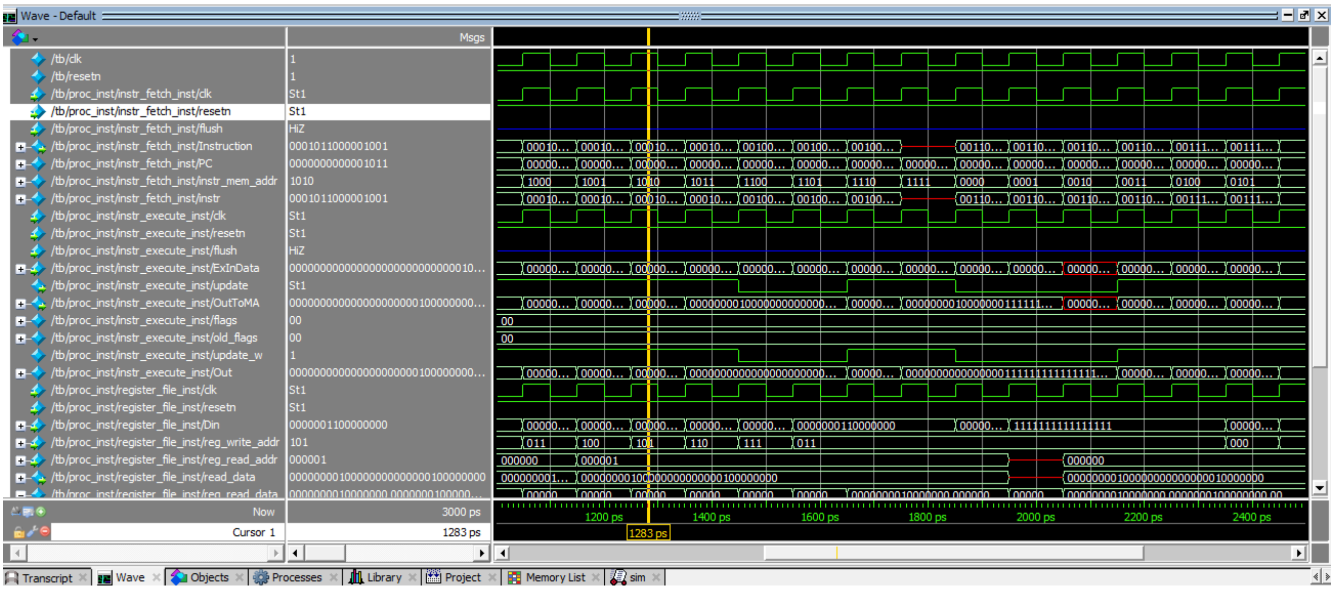
Output: -



	Msgs
/tb/proc_inst/instr_execute_inst/clk	St0
/tb/proc_inst/instr_execute_inst/resetn	St1
/tb/proc_inst/instr_execute_inst/flush	HiZ
/tb/proc_inst/instr_execute_inst/ExInData	00000000100000000000000010...
/tb/proc_inst/instr_execute_inst/update	St0
/tb/proc_inst/instr_execute_inst/OutToMA	000000001000000011111111...
/tb/proc_inst/instr_execute_inst/flags	00
/tb/proc_inst/instr_execute_inst/old_flags	00
/tb/proc_inst/instr_execute_inst/update_w	0
/tb/proc_inst/instr_execute_inst/Out	0000000000000000111111111...
/tb/proc_inst/register_file_inst/clk	St0
/tb/proc_inst/register_file_inst/resetn	St1
/tb/proc_inst/register_file_inst/Din	1111111111111111
/tb/proc_inst/register_file_inst/reg_write_addr	011
/tb/proc_inst/register_file_inst/reg_read_addr	000001
/tb/proc_inst/register_file_inst/read_data	00000000100000000000000010...
/tb/proc_inst/register_file_inst/reg_read_data	0000000010000000 00000001...
[0]	0000000010000000
[1]	0000000100000000
[2]	0000000110000000
[3]	0000001010000000
[4]	0000001010000000
[5]	0000001100000000
[6]	0000001110000000
[7]	0000010000000000
/tb/proc_inst/register_file_inst/en	00010000
Now	3000 ps
Cursor 1	1908 ps

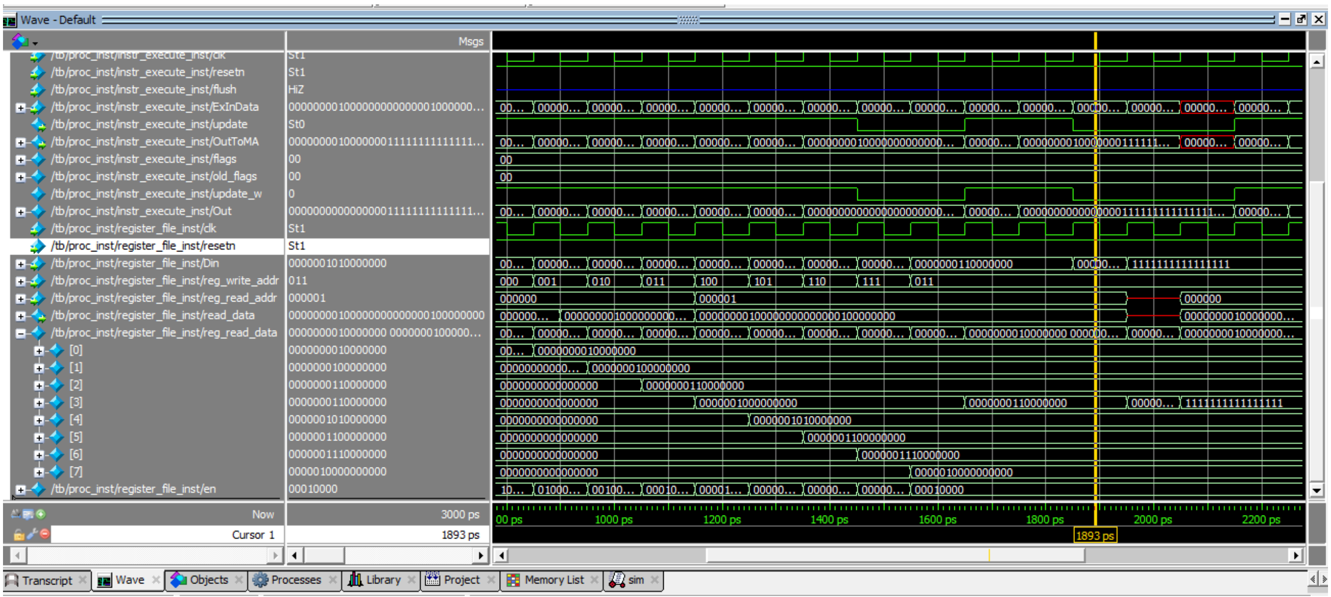
ADZ R5, R0, R1 Instruction: -

Input: -



	Msgs
/tb/clk	1
/tb/resetn	1
/tb/proc_inst/instr_fetch_inst/clk	St1
/tb/proc_inst/instr_fetch_inst/resetn	St1
/tb/proc_inst/instr_fetch_inst/flush	HiZ
/tb/proc_inst/instr_fetch_inst/Instruction	0001011000001001
/tb/proc_inst/instr_fetch_inst/PC	0000000000001011
/tb/proc_inst/instr_fetch_inst/instr_mem_addr	1010
/tb/proc_inst/instr_fetch_inst/instr	0001011000001001
/tb/proc_inst/instr_execute_inst/clk	St1
/tb/proc_inst/instr_execute_inst/resetn	St1
/tb/proc_inst/instr_execute_inst/flush	HiZ
/tb/proc_inst/instr_execute_inst/ExInData	0000000000000000000000000010...
/tb/proc_inst/instr_execute_inst/update	St1
/tb/proc_inst/instr_execute_inst/OutToMA	000000000000000000000100000000...
/tb/proc_inst/instr_execute_inst/flags	00
/tb/proc_inst/instr_execute_inst/old_flags	00
/tb/proc_inst/instr_execute_inst/update_w	1
/tb/proc_inst/instr_execute_inst/Out	000000000000000000000100000000...
/tb/proc_inst/register_file_inst/clk	St1
/tb/proc_inst/register_file_inst/resetn	St1
/tb/proc_inst/register_file_inst/Din	0000001100000000
/tb/proc_inst/register_file_inst/reg_write_addr	101
/tb/proc_inst/register_file_inst/reg_read_addr	000001
/tb/proc_inst/register_file_inst/read_data	00000000100000000000000100000000
/tb/proc_inst/register_file_inst/reg_read_data	0000000010000000 0000000100000...
Now	3000 ps
Cursor 1	1283 ps

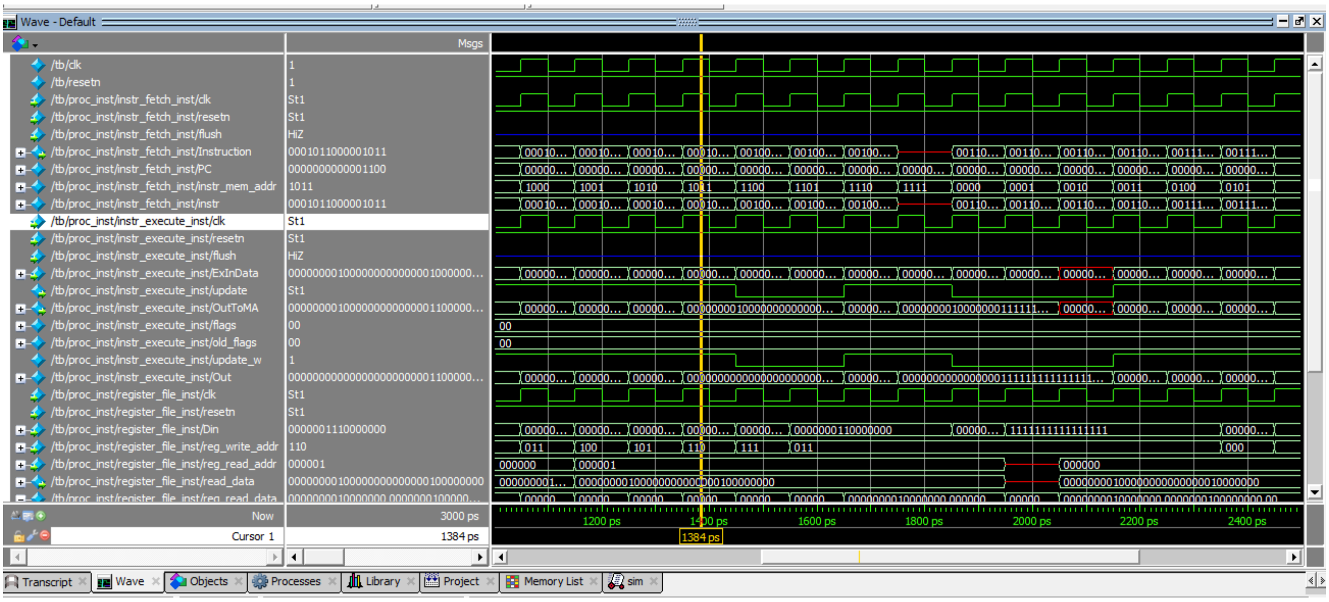
Output: -



Wave - Default	Msgs
/tb/proc_inst/instr_execute_inst/clk	St1
/tb/proc_inst/instr_execute_inst/resetn	St1
/tb/proc_inst/instr_execute_inst/flush	HiZ
/tb/proc_inst/instr_execute_inst/ExInData	00000000100000000000000001000000...
/tb/proc_inst/instr_execute_inst/update	St0
/tb/proc_inst/instr_execute_inst/OutToMA	0000000010000000111111111111111...
/tb/proc_inst/instr_execute_inst/flags	00
/tb/proc_inst/instr_execute_inst/old_flags	00
/tb/proc_inst/instr_execute_inst/update_w	0
/tb/proc_inst/instr_execute_inst/Out	000000000000000011111111111111...
/tb/proc_inst/register_file_inst/clk	St1
/tb/proc_inst/register_file_inst/resetn	St1
/tb/proc_inst/register_file_inst/Din	0000001010000000
/tb/proc_inst/register_file_inst/reg_write_addr	011
/tb/proc_inst/register_file_inst/reg_read_addr	000001
/tb/proc_inst/register_file_inst/read_data	00000000100000000000000100000000
/tb/proc_inst/register_file_inst/reg_read_data	0000000010000000 0000000100000...
[0]	0000000010000000
[1]	0000000100000000
[2]	0000000110000000
[3]	0000000110000000
[4]	0000001010000000
[5]	0000001100000000
[6]	0000001110000000
[7]	0000010000000000
/tb/proc_inst/register_file_inst/en	00010000
Now	3000 ps
Cursor 1	1893 ps

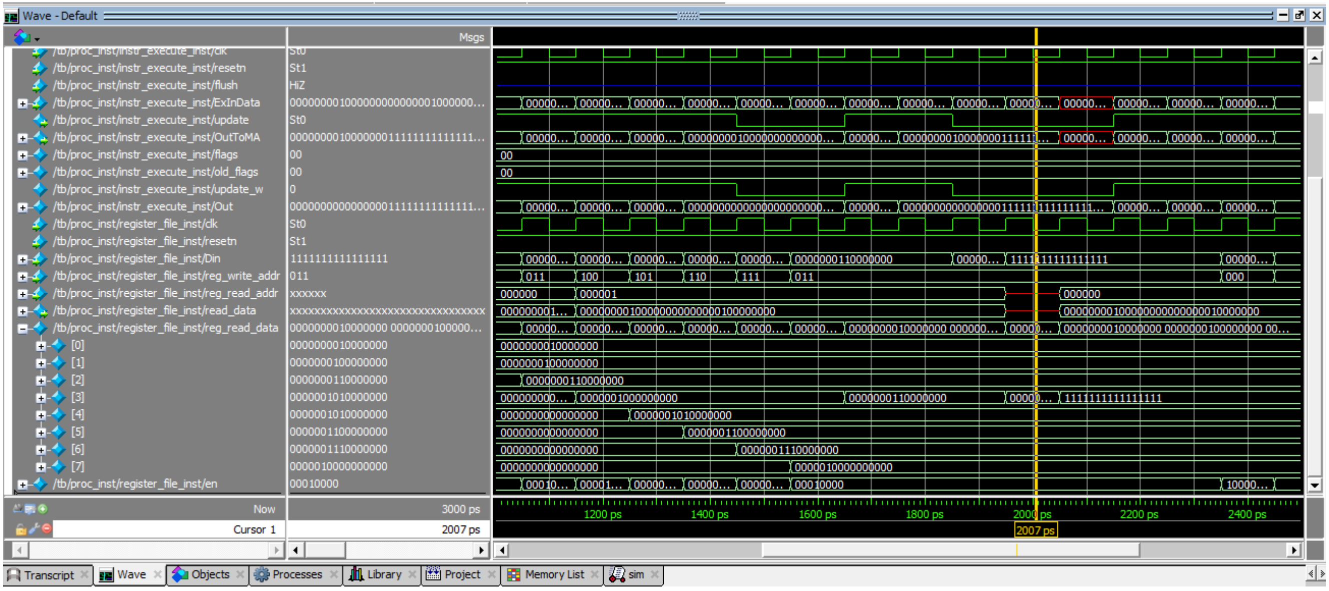
ADL R6, R0, R1 Instruction: -

Input: -



Wave - Default	Msgs
/tb/clk	1
/tb/resetn	1
/tb/proc_inst/instr_fetch_inst/clk	St1
/tb/proc_inst/instr_fetch_inst/resetn	St1
/tb/proc_inst/instr_fetch_inst/flush	HiZ
/tb/proc_inst/instr_fetch_inst/Instruction	0001011000001011
/tb/proc_inst/instr_fetch_inst/PC	0000000000001100
/tb/proc_inst/instr_fetch_inst/instr_mem_addr	1011
/tb/proc_inst/instr_fetch_inst/instr	0001011000001011
/tb/proc_inst/instr_execute_inst/clk	St1
/tb/proc_inst/instr_execute_inst/resetn	St1
/tb/proc_inst/instr_execute_inst/flush	HiZ
/tb/proc_inst/instr_execute_inst/ExInData	00000000100000000000000001000000...
/tb/proc_inst/instr_execute_inst/update	St1
/tb/proc_inst/instr_execute_inst/OutToMA	00000000100000000000000001100000...
/tb/proc_inst/instr_execute_inst/flags	00
/tb/proc_inst/instr_execute_inst/old_flags	00
/tb/proc_inst/instr_execute_inst/update_w	1
/tb/proc_inst/instr_execute_inst/Out	00000000000000000000000001100000...
/tb/proc_inst/register_file_inst/clk	St1
/tb/proc_inst/register_file_inst/resetn	St1
/tb/proc_inst/register_file_inst/Din	0000001110000000
/tb/proc_inst/register_file_inst/reg_write_addr	110
/tb/proc_inst/register_file_inst/reg_read_addr	000001
/tb/proc_inst/register_file_inst/read_data	00000000100000000000000100000000
/tb/proc_inst/register_file_inst/reg_read_data	0000000010000000 0000000100000...
Now	3000 ps
Cursor 1	1384 ps

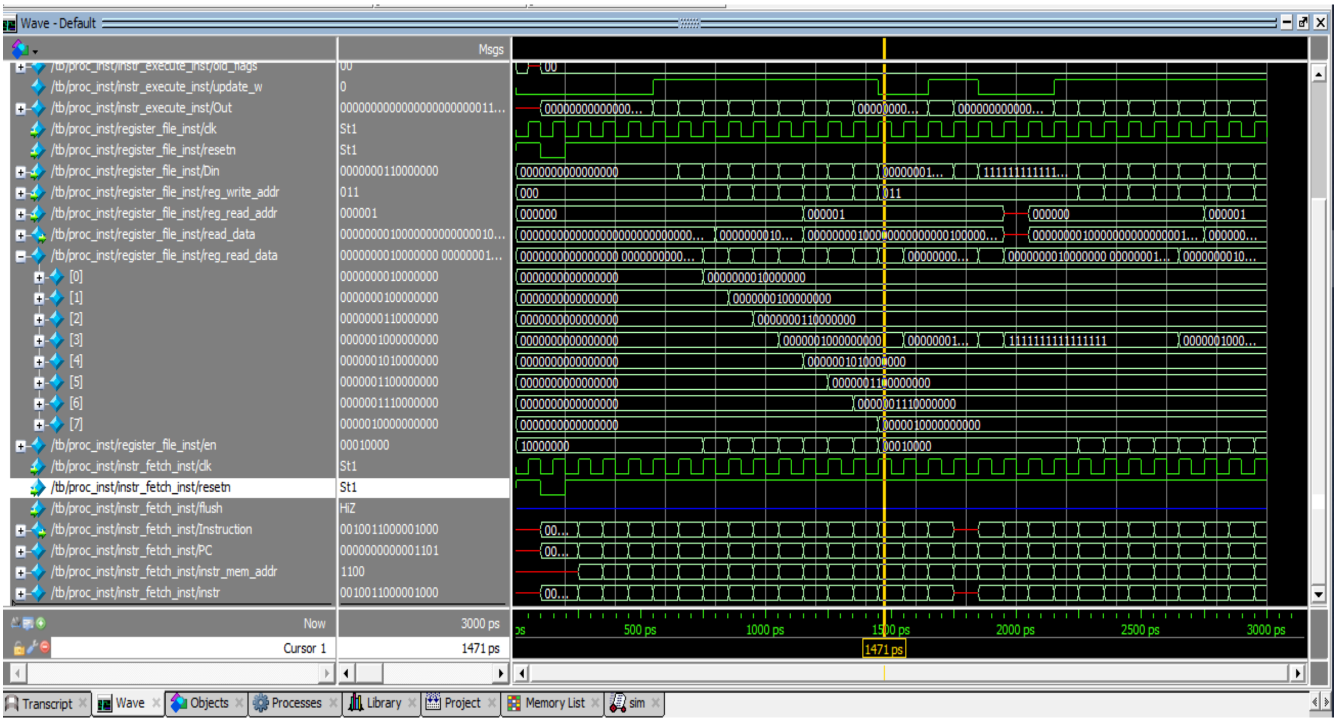
Output: -



```
Wave - Default                                          Msgs
/tb/proc_inst/instr_execute_inst/clk                    St0
/tb/proc_inst/instr_execute_inst/resetn                 St1
/tb/proc_inst/instr_execute_inst/flush                  HiZ
/tb/proc_inst/instr_execute_inst/ExInData               00000000100000000000000001000000...
/tb/proc_inst/instr_execute_inst/update                 St0
/tb/proc_inst/instr_execute_inst/OutToMA                00000000100000001111111111111...
/tb/proc_inst/instr_execute_inst/flags                  00
/tb/proc_inst/instr_execute_inst/old_flags              00
/tb/proc_inst/instr_execute_inst/update_w               0
/tb/proc_inst/instr_execute_inst/Out                    00000000000000001111111111111...
/tb/proc_inst/register_file_inst/clk                    St0
/tb/proc_inst/register_file_inst/resetn                 St1
/tb/proc_inst/register_file_inst/Din                    1111111111111111
/tb/proc_inst/register_file_inst/reg_write_addr         011
/tb/proc_inst/register_file_inst/reg_read_addr          xxxxxx
/tb/proc_inst/register_file_inst/read_data              xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
/tb/proc_inst/register_file_inst/reg_read_data          0000000010000000 0000000100000...
    [0]                                                 0000000010000000
    [1]                                                 0000000100000000
    [2]                                                 0000000110000000
    [3]                                                 0000001010000000
    [4]                                                 0000001010000000
    [5]                                                 0000001100000000
    [6]                                                 0000001110000000
    [7]                                                 0000010000000000
/tb/proc_inst/register_file_inst/en                     00010000
Now                                                     3000 ps
Cursor 1                                                2007 ps
```

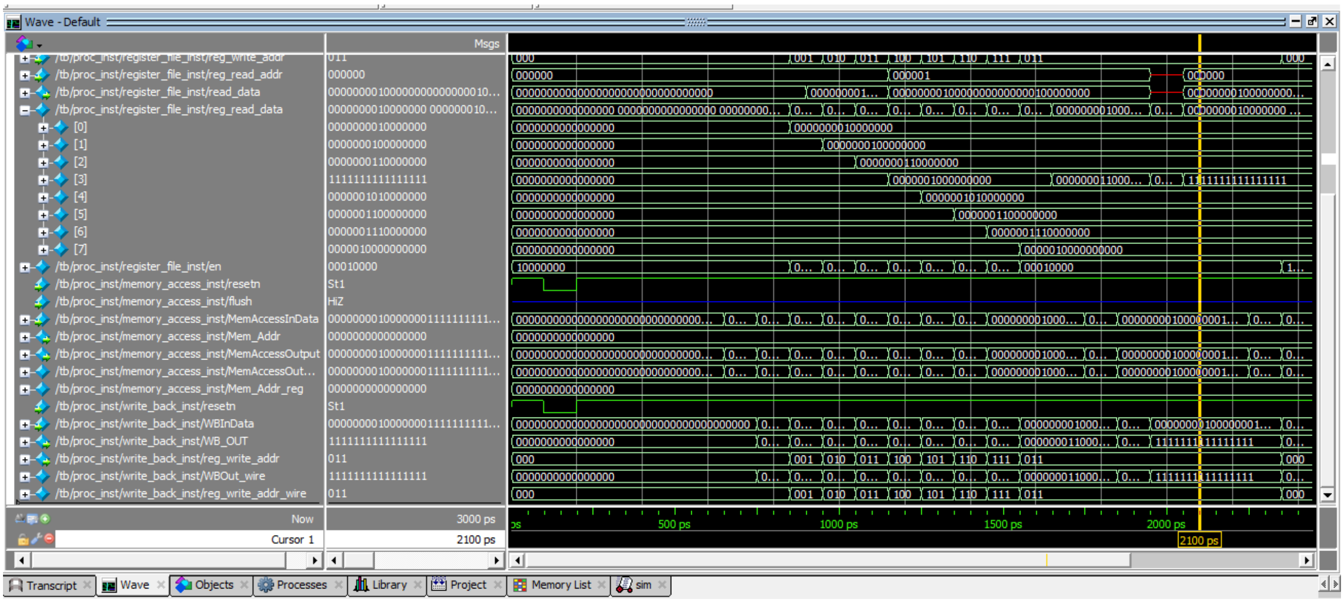
NDU R3, R0, R1 Instruction: -

Input: -



```
Wave - Default                                          Msgs
/tb/proc_inst/instr_execute_inst/old_flags              00
/tb/proc_inst/instr_execute_inst/update_w               0
/tb/proc_inst/instr_execute_inst/Out                    000000000000000000000011...
/tb/proc_inst/register_file_inst/clk                    St1
/tb/proc_inst/register_file_inst/resetn                 St1
/tb/proc_inst/register_file_inst/Din                    0000000110000000
/tb/proc_inst/register_file_inst/reg_write_addr         011
/tb/proc_inst/register_file_inst/reg_read_addr          000001
/tb/proc_inst/register_file_inst/read_data              00000000100000000000000010...
/tb/proc_inst/register_file_inst/reg_read_data          0000000010000000 00000001...
    [0]                                                 0000000010000000
    [1]                                                 0000000100000000
    [2]                                                 0000000110000000
    [3]                                                 0000001000000000
    [4]                                                 0000001010000000
    [5]                                                 0000001100000000
    [6]                                                 0000001110000000
    [7]                                                 0000010000000000
/tb/proc_inst/register_file_inst/en                     00010000
/tb/proc_inst/instr_fetch_inst/clk                      St1
/tb/proc_inst/instr_fetch_inst/resetn                   St1
/tb/proc_inst/instr_fetch_inst/flush                    HiZ
/tb/proc_inst/instr_fetch_inst/Instruction              0010011000001000
/tb/proc_inst/instr_fetch_inst/PC                       0000000000001101
/tb/proc_inst/instr_fetch_inst/instr_mem_addr           1100
/tb/proc_inst/instr_fetch_inst/instr                    0010011000001000
Now                                                     3000 ps
Cursor 1                                                1471 ps
```

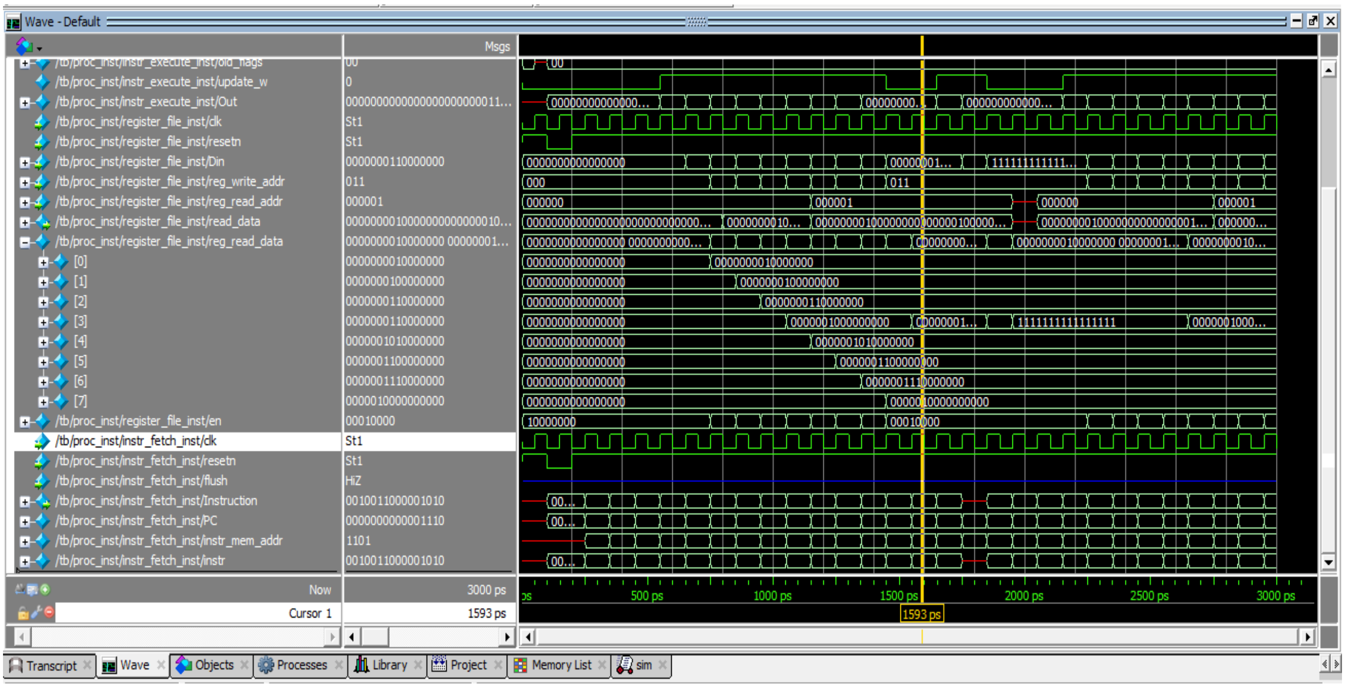
Output: -



```
/tb/proc_inst/register_file_inst/reg_write_addr            011
/tb/proc_inst/register_file_inst/reg_read_addr             000000
/tb/proc_inst/register_file_inst/read_data                 0000000010000000000000010...
/tb/proc_inst/register_file_inst/reg_read_data             0000000010000000 000000010...
    [0]                                                    0000000010000000
    [1]                                                    0000000100000000
    [2]                                                    0000000110000000
    [3]                                                    1111111111111111
    [4]                                                    0000001010000000
    [5]                                                    0000001100000000
    [6]                                                    0000001110000000
    [7]                                                    0000010000000000
/tb/proc_inst/register_file_inst/en                        00010000
/tb/proc_inst/memory_access_inst/resetn                    St1
/tb/proc_inst/memory_access_inst/flush                     HiZ
/tb/proc_inst/memory_access_inst/MemAccessInData           00000000100000001111111111...
/tb/proc_inst/memory_access_inst/Mem_Addr                  0000000000000000
/tb/proc_inst/memory_access_inst/MemAccessOutput           00000000100000001111111111...
/tb/proc_inst/memory_access_inst/MemAccessOut...           00000000100000001111111111...
/tb/proc_inst/memory_access_inst/Mem_Addr_reg              0000000000000000
/tb/proc_inst/write_back_inst/resetn                       St1
/tb/proc_inst/write_back_inst/WBInData                     00000000100000001111111111...
/tb/proc_inst/write_back_inst/WB_OUT                       1111111111111111
/tb/proc_inst/write_back_inst/reg_write_addr               011
/tb/proc_inst/write_back_inst/WBOut_wire                   1111111111111111
/tb/proc_inst/write_back_inst/reg_write_addr_wire          011
Now                                                        3000 ps
Cursor 1                                                   2100 ps
```

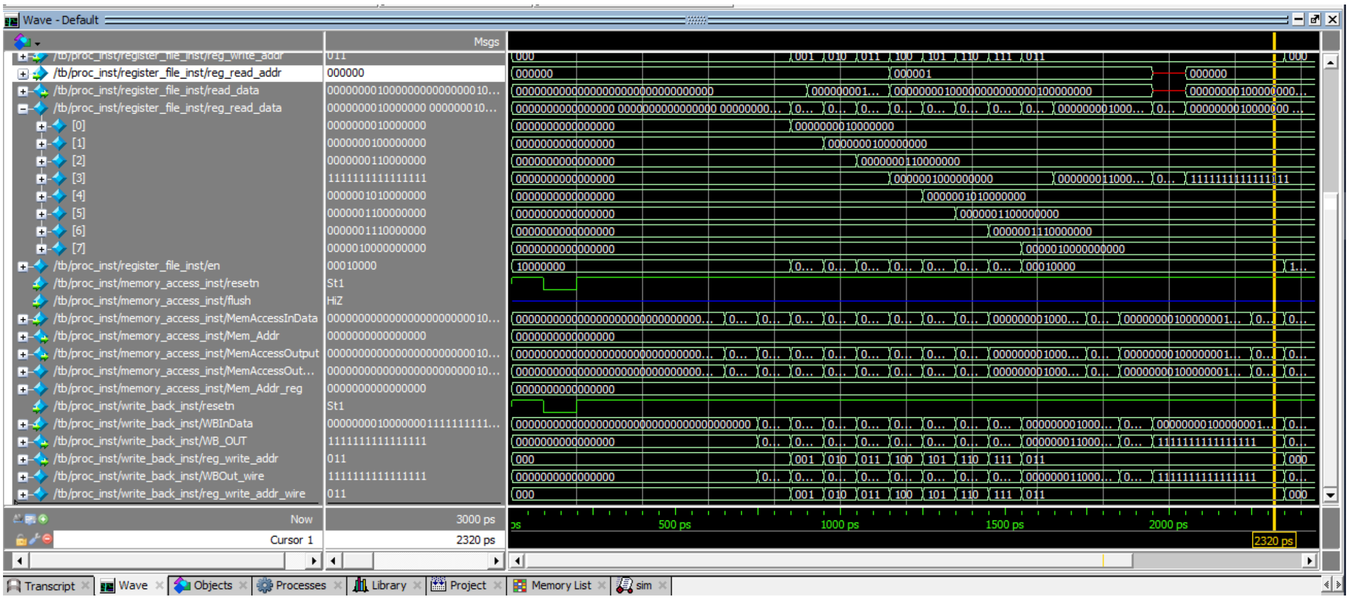
NDC R2, R0, R1 Instruction: -

Input: -



```
/tb/proc_inst/instr_execute_inst/old_flags                 00
/tb/proc_inst/instr_execute_inst/update_w                  0
/tb/proc_inst/instr_execute_inst/Out                       00000000000000000000000011...
/tb/proc_inst/register_file_inst/clk                       St1
/tb/proc_inst/register_file_inst/resetn                    St1
/tb/proc_inst/register_file_inst/Din                       0000000110000000
/tb/proc_inst/register_file_inst/reg_write_addr            011
/tb/proc_inst/register_file_inst/reg_read_addr             000001
/tb/proc_inst/register_file_inst/read_data                 0000000010000000000000010...
/tb/proc_inst/register_file_inst/reg_read_data             0000000010000000 00000001...
    [0]                                                    0000000010000000
    [1]                                                    0000000100000000
    [2]                                                    0000000110000000
    [3]                                                    0000000110000000
    [4]                                                    0000001010000000
    [5]                                                    0000001100000000
    [6]                                                    0000001110000000
    [7]                                                    0000010000000000
/tb/proc_inst/register_file_inst/en                        00010000
/tb/proc_inst/instr_fetch_inst/clk                         St1
/tb/proc_inst/instr_fetch_inst/resetn                      St1
/tb/proc_inst/instr_fetch_inst/flush                       HiZ
/tb/proc_inst/instr_fetch_inst/Instruction                 0010011000001010
/tb/proc_inst/instr_fetch_inst/PC                          0000000000001110
/tb/proc_inst/instr_fetch_inst/instr_mem_addr              1101
/tb/proc_inst/instr_fetch_inst/instr                       0010011000001010
Now                                                        3000 ps
Cursor 1                                                   1593 ps
```

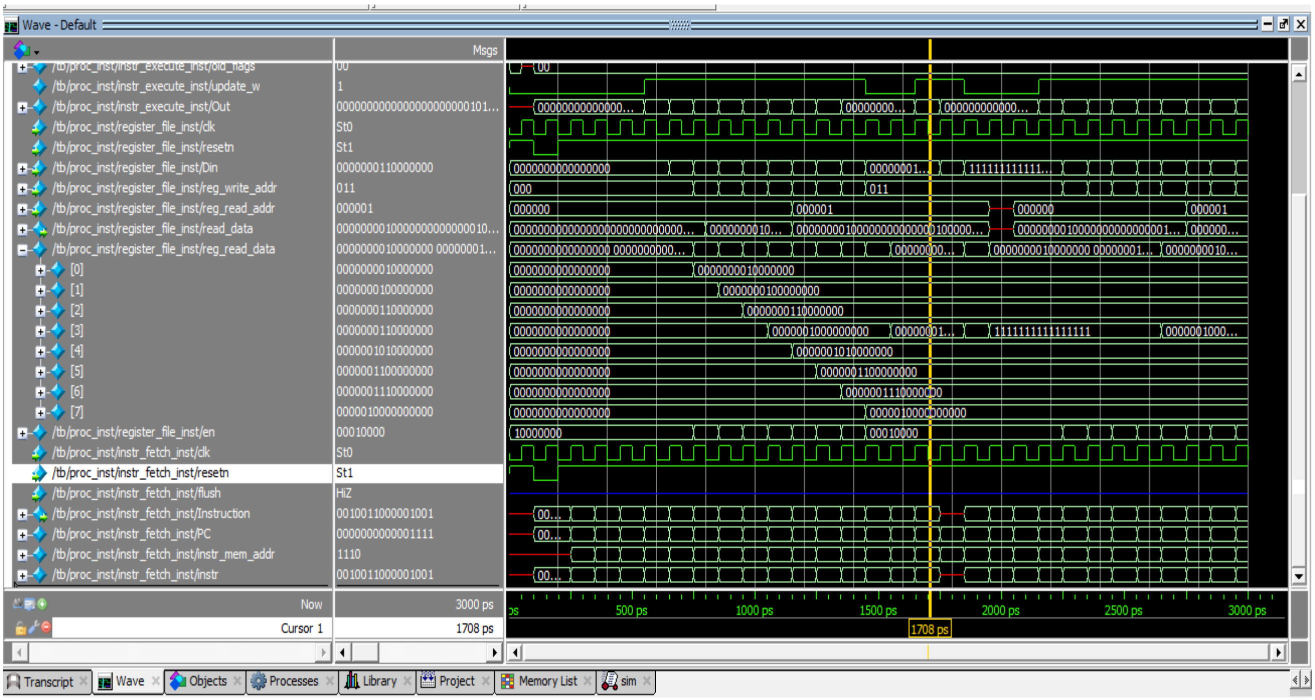
Output: -



```
/tb/proc_inst/register_file_inst/reg_write_addr        011
/tb/proc_inst/register_file_inst/reg_read_addr         000000
/tb/proc_inst/register_file_inst/read_data             00000000100000000000000010...
/tb/proc_inst/register_file_inst/reg_read_data         0000000010000000 000000010...
  [0]                                                  0000000010000000
  [1]                                                  0000000100000000
  [2]                                                  0000000110000000
  [3]                                                  1111111111111111
  [4]                                                  0000001010000000
  [5]                                                  0000001100000000
  [6]                                                  0000001110000000
  [7]                                                  0000010000000000
/tb/proc_inst/register_file_inst/en                    00010000
/tb/proc_inst/memory_access_inst/resetn                St1
/tb/proc_inst/memory_access_inst/flush                 HiZ
/tb/proc_inst/memory_access_inst/MemAccessInData       000000000000000000000000010...
/tb/proc_inst/memory_access_inst/Mem_Addr              0000000000000000
/tb/proc_inst/memory_access_inst/MemAccessOutput       000000000000000000000000010...
/tb/proc_inst/memory_access_inst/MemAccessOut...       000000000000000000000000010...
/tb/proc_inst/memory_access_inst/Mem_Addr_reg          0000000000000000
/tb/proc_inst/write_back_inst/resetn                   St1
/tb/proc_inst/write_back_inst/WBInData                 00000000100000001111111111...
/tb/proc_inst/write_back_inst/WB_OUT                   1111111111111111
/tb/proc_inst/write_back_inst/reg_write_addr           011
/tb/proc_inst/write_back_inst/WBOut_wire               1111111111111111
/tb/proc_inst/write_back_inst/reg_write_addr_wire      011
Now                                                    3000 ps
Cursor 1                                               2320 ps
```

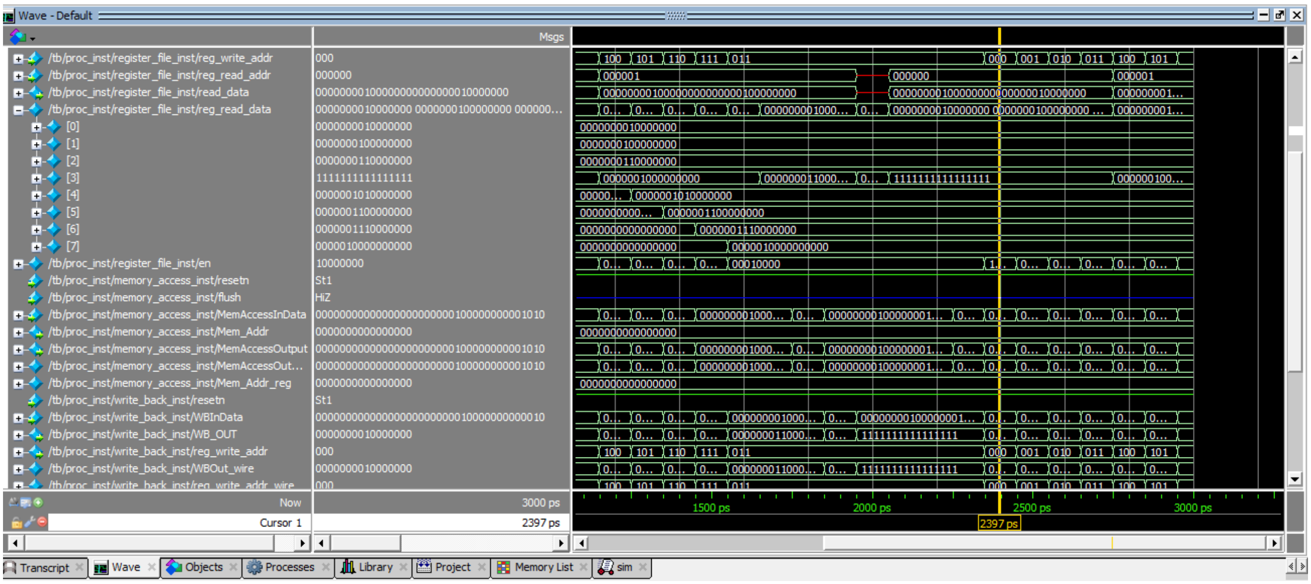
NDZ R4, R0, R1 Instruction: -

Input: -



```
/tb/proc_inst/instr_execute_inst/old_flags             00
/tb/proc_inst/instr_execute_inst/update_w              1
/tb/proc_inst/instr_execute_inst/Out                   00000000000000000000000101...
/tb/proc_inst/register_file_inst/clk                   St0
/tb/proc_inst/register_file_inst/resetn                St1
/tb/proc_inst/register_file_inst/Din                   0000000110000000
/tb/proc_inst/register_file_inst/reg_write_addr        011
/tb/proc_inst/register_file_inst/reg_read_addr         000001
/tb/proc_inst/register_file_inst/read_data             00000000100000000000000010...
/tb/proc_inst/register_file_inst/reg_read_data         0000000010000000 00000001...
  [0]                                                  0000000010000000
  [1]                                                  0000000100000000
  [2]                                                  0000000110000000
  [3]                                                  0000000110000000
  [4]                                                  0000001010000000
  [5]                                                  0000001100000000
  [6]                                                  0000001110000000
  [7]                                                  0000010000000000
/tb/proc_inst/register_file_inst/en                    00010000
/tb/proc_inst/instr_fetch_inst/clk                     St0
/tb/proc_inst/instr_fetch_inst/resetn                  St1
/tb/proc_inst/instr_fetch_inst/flush                   HiZ
/tb/proc_inst/instr_fetch_inst/Instruction             0010011000001001
/tb/proc_inst/instr_fetch_inst/PC                      0000000000001111
/tb/proc_inst/instr_fetch_inst/instr_mem_addr          1110
/tb/proc_inst/instr_fetch_inst/instr                   0010011000001001
Now                                                    3000 ps
Cursor 1                                               1708 ps
```

Output: -



```
/tb/proc_inst/register_file_inst/reg_write_addr          000
/tb/proc_inst/register_file_inst/reg_read_addr           000000
/tb/proc_inst/register_file_inst/read_data               00000000100000000000000010000000
/tb/proc_inst/register_file_inst/reg_read_data           0000000010000000 0000000100000000 000000...
    [0]                                                  0000000010000000
    [1]                                                  0000000100000000
    [2]                                                  0000000110000000
    [3]                                                  1111111111111111
    [4]                                                  0000001010000000
    [5]                                                  0000001100000000
    [6]                                                  0000001110000000
    [7]                                                  0000010000000000
/tb/proc_inst/register_file_inst/en                      10000000
/tb/proc_inst/memory_access_inst/resetn                  St1
/tb/proc_inst/memory_access_inst/flush                   HiZ
/tb/proc_inst/memory_access_inst/MemAccessInData         000000000000000000000001000000000001010
/tb/proc_inst/memory_access_inst/Mem_Addr                0000000000000000
/tb/proc_inst/memory_access_inst/MemAccessOutput         000000000000000000000001000000000001010
/tb/proc_inst/memory_access_inst/MemAccessOut...         000000000000000000000001000000000001010
/tb/proc_inst/memory_access_inst/Mem_Addr_reg            0000000000000000
/tb/proc_inst/write_back_inst/resetn                     St1
/tb/proc_inst/write_back_inst/WBInData                   000000000000000000000000100000000000010
/tb/proc_inst/write_back_inst/WB_OUT                     0000000010000000
/tb/proc_inst/write_back_inst/reg_write_addr             000
/tb/proc_inst/write_back_inst/WBOut_wire                 0000000010000000
/tb/proc_inst/write_back_inst/reg_write_addr_wire        000
Now                                                      3000 ps
Cursor 1                                                 2397 ps
```

Completion Stage: -

The Completion Stage is mainly concerned with memory writeback. Memory writeback occurs using the store buffer via a store commit signal upon the commit of a memory store instruction. Whenever a memory writeback needs to occur, a store commit signal is enabled and the Store Buffer location for that particular instruction (obtained from the memory unit itself upon execution) is sent to the Store Buffer wherein the data and the memory address stored at the sent location is written back to the memory. This data and memory address was stored into the Store Buffer by the Memory Unit upon successful execution.

Conclusion: -

We have designed and verified the 2-way fetch superscalar processor design which is 16-bit computer, 8 registers with 16-bit each and it has been optimized by performance.