Single-Cycle RISC-V Processor With One Level Cache Memory

Introduction

RISC V is RISC Processor

RISC V Operates on 32- bit Data

RISC V has 32-bit 32 register in register file

RISC V Processor Microarchitecture

<u>Processor Design Includes Main Modules:</u>

Data Path

Control Unit

Then integrate it with Cache System

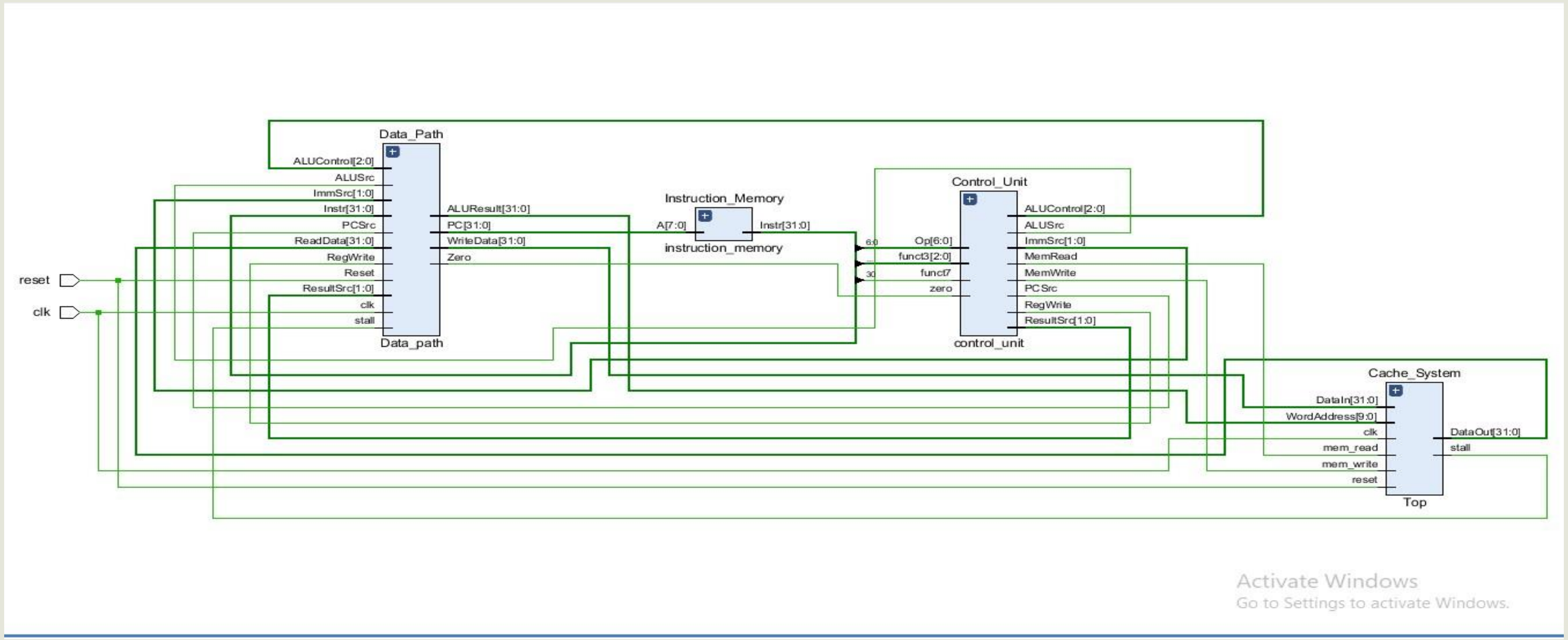
<u>-Our Design Covers instructions:</u>

Lw , Sw

R-Type ,I-Type

Beq , jal

RISC V Schematic

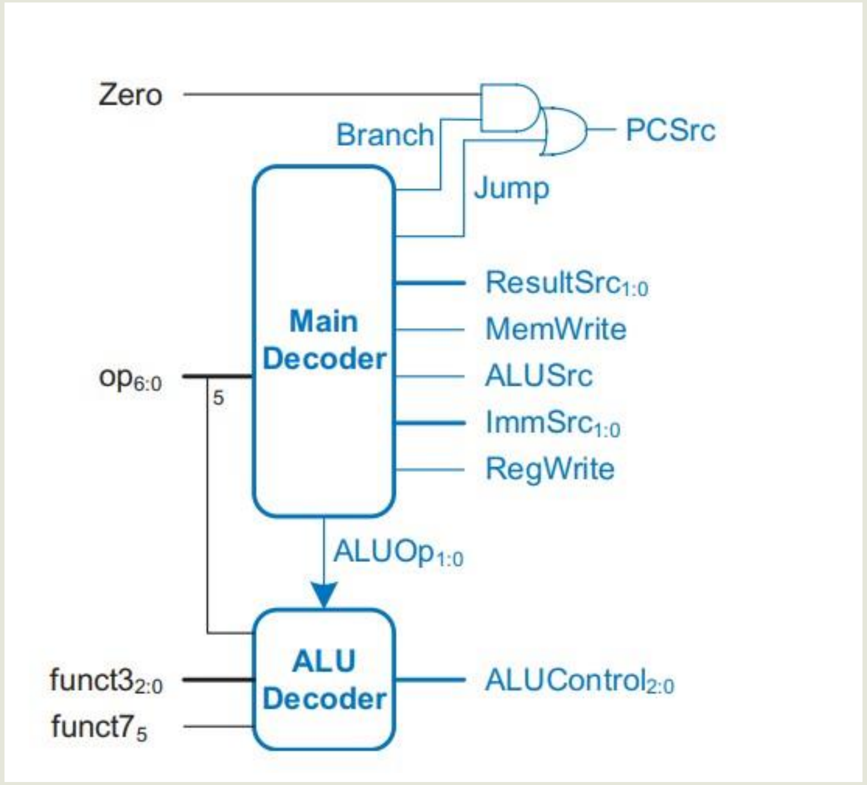


Activate Windows
Go to Settings to activate Windows.

RISC V Processor Microarchitecture

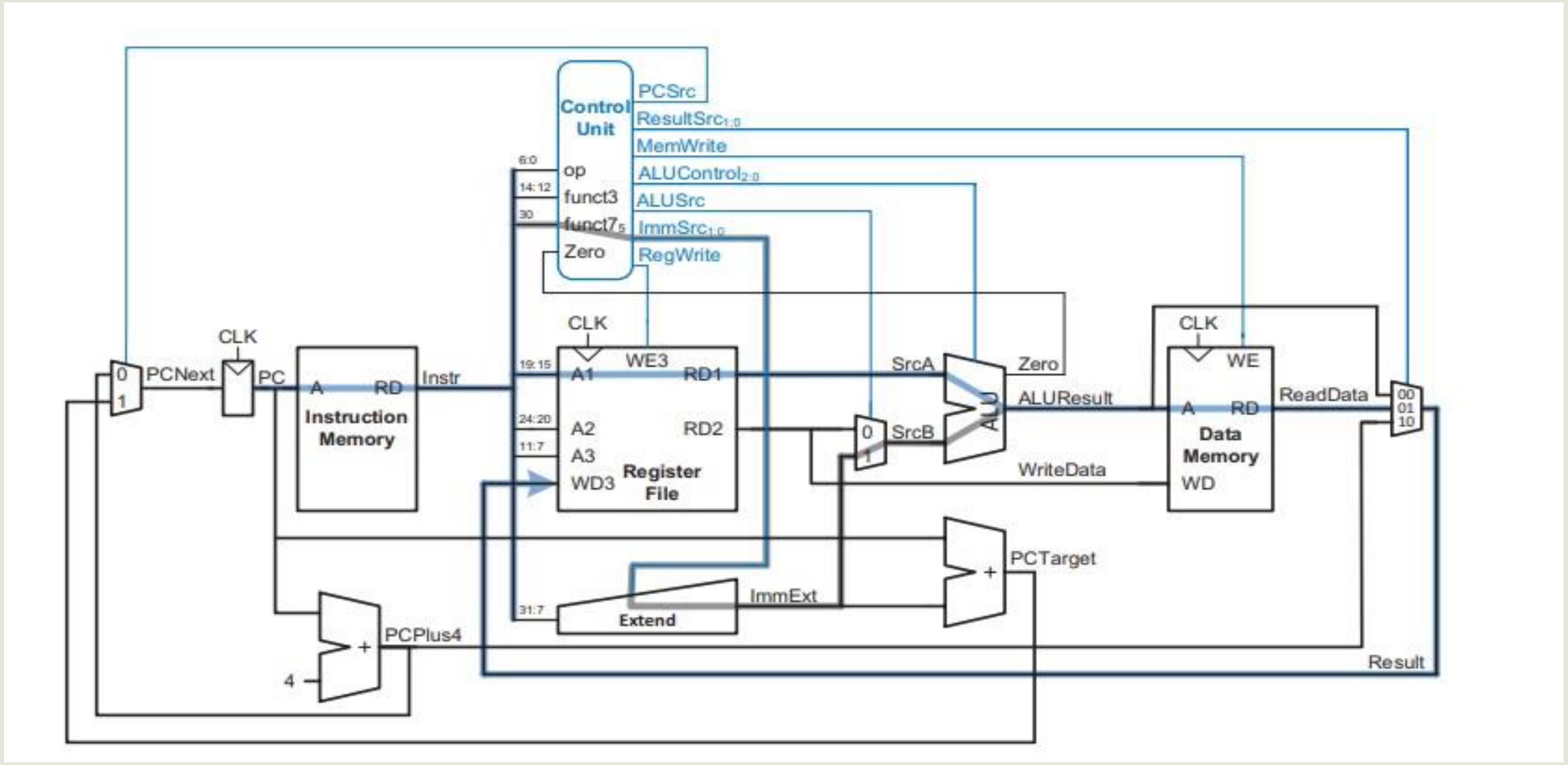
Control Unit:

Generates Control Signals.



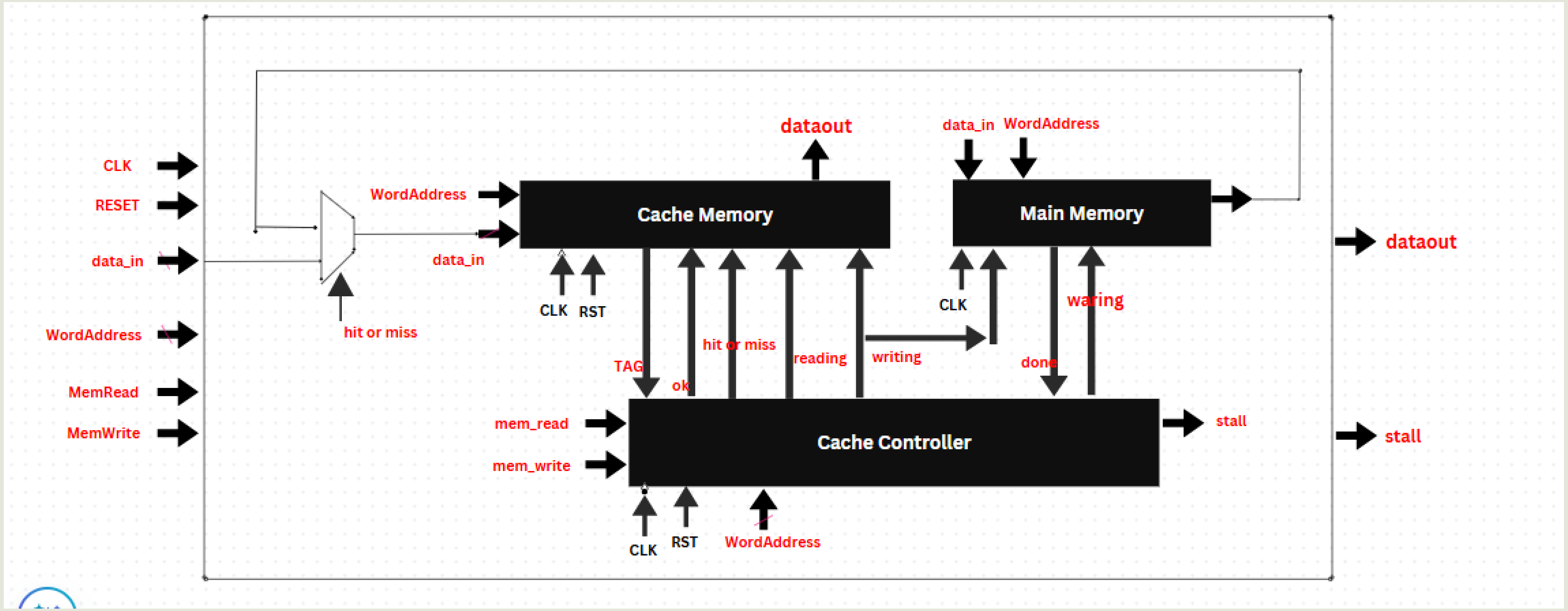
RISC V Processor Microarchitecture

Data Path:



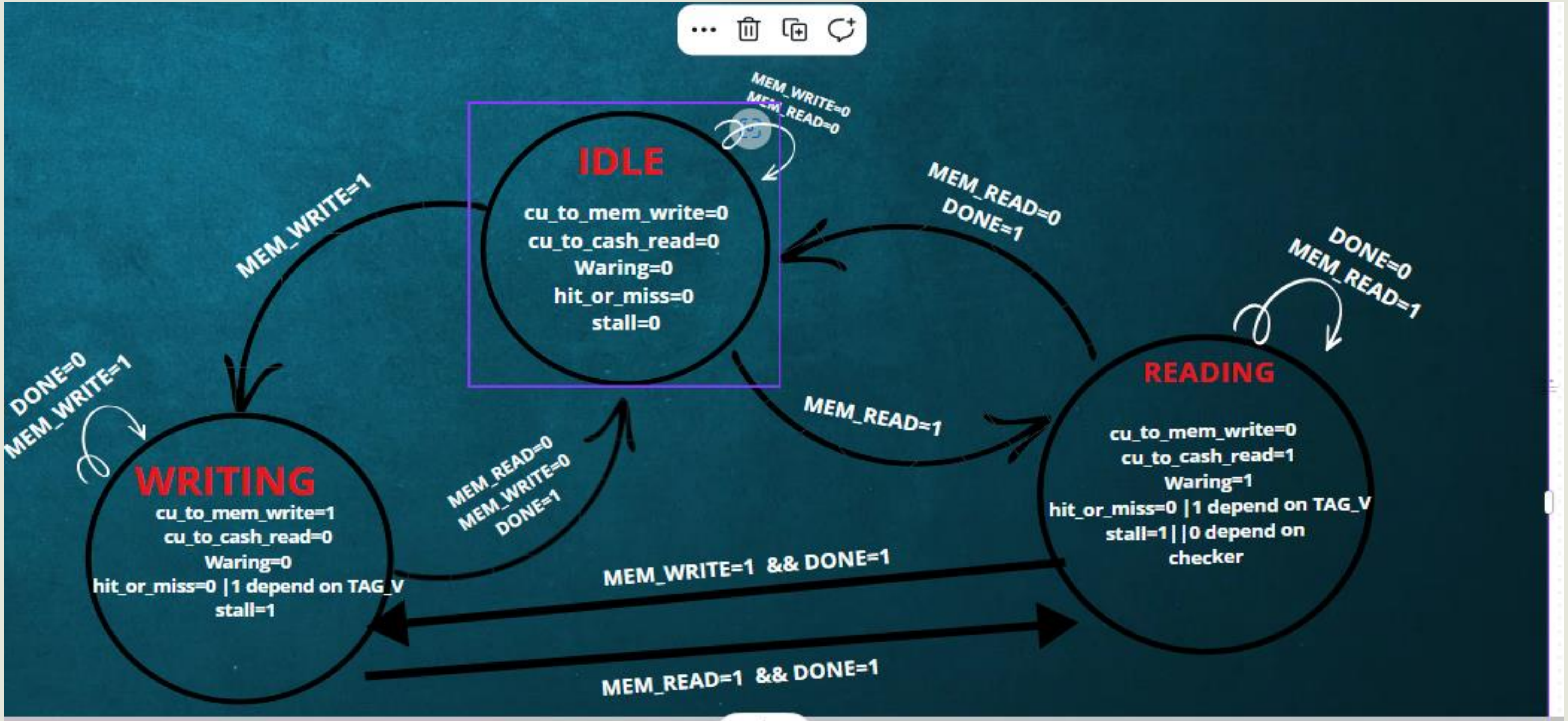
RISC V Processor Microarchitecture

Cache System:



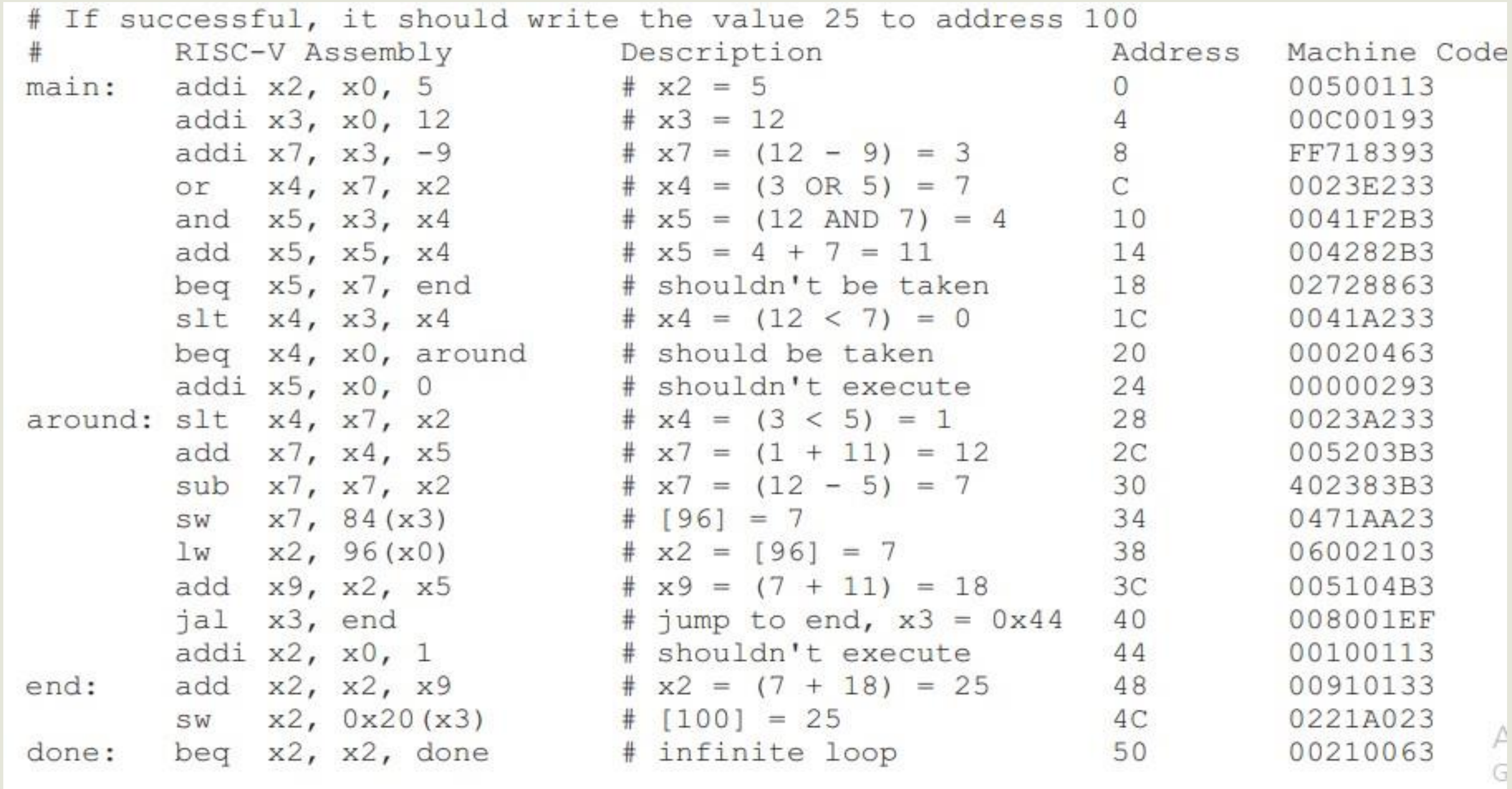
RISC V Processor Microarchitecture

FSM



RISC V Test Program

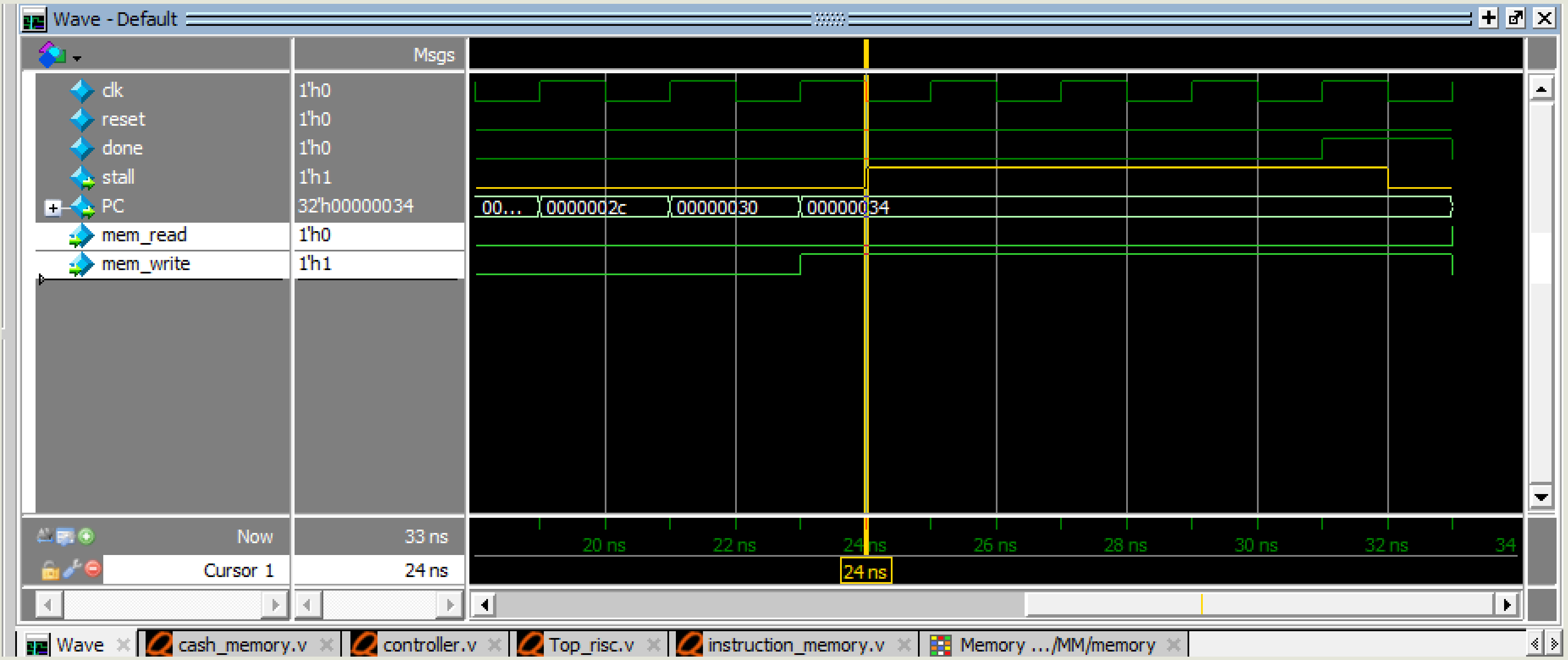
The Program writes the value 25 to address 100



```
# If successful, it should write the value 25 to address 100
#       RISC-V Assembly         Description                  Address   Machine Code
main:   addi x2, x0, 5          # x2 = 5                     0         00500113
        addi x3, x0, 12         # x3 = 12                    4         00C00193
        addi x7, x3, -9         # x7 = (12 - 9) = 3          8         FF718393
        or   x4, x7, x2         # x4 = (3 OR 5) = 7          C         0023E233
        and  x5, x3, x4         # x5 = (12 AND 7) = 4        10        0041F2B3
        add  x5, x5, x4         # x5 = 4 + 7 = 11            14        004282B3
        beq  x5, x7, end        # shouldn't be taken         18        02728863
        slt  x4, x3, x4         # x4 = (12 < 7) = 0          1C        0041A233
        beq  x4, x0, around     # should be taken            20        00020463
        addi x5, x0, 0          # shouldn't execute          24        00000293
around: slt  x4, x7, x2         # x4 = (3 < 5) = 1           28        0023A233
        add  x7, x4, x5         # x7 = (1 + 11) = 12         2C        005203B3
        sub  x7, x7, x2         # x7 = (12 - 5) = 7          30        402383B3
        sw   x7, 84(x3)         # [96] = 7                   34        0471AA23
        lw   x2, 96(x0)         # x2 = [96] = 7              38        06002103
        add  x9, x2, x5         # x9 = (7 + 11) = 18         3C        005104B3
        jal  x3, end            # jump to end, x3 = 0x44     40        008001EF
        addi x2, x0, 1          # shouldn't execute          44        00100113
end:    add  x2, x2, x9         # x2 = (7 + 18) = 25         48        00910133
        sw   x2, 0x20(x3)       # [100] = 25                 4C        0221A023
done:   beq  x2, x2, done       # infinite loop              50        00210063
```

Simulation Results

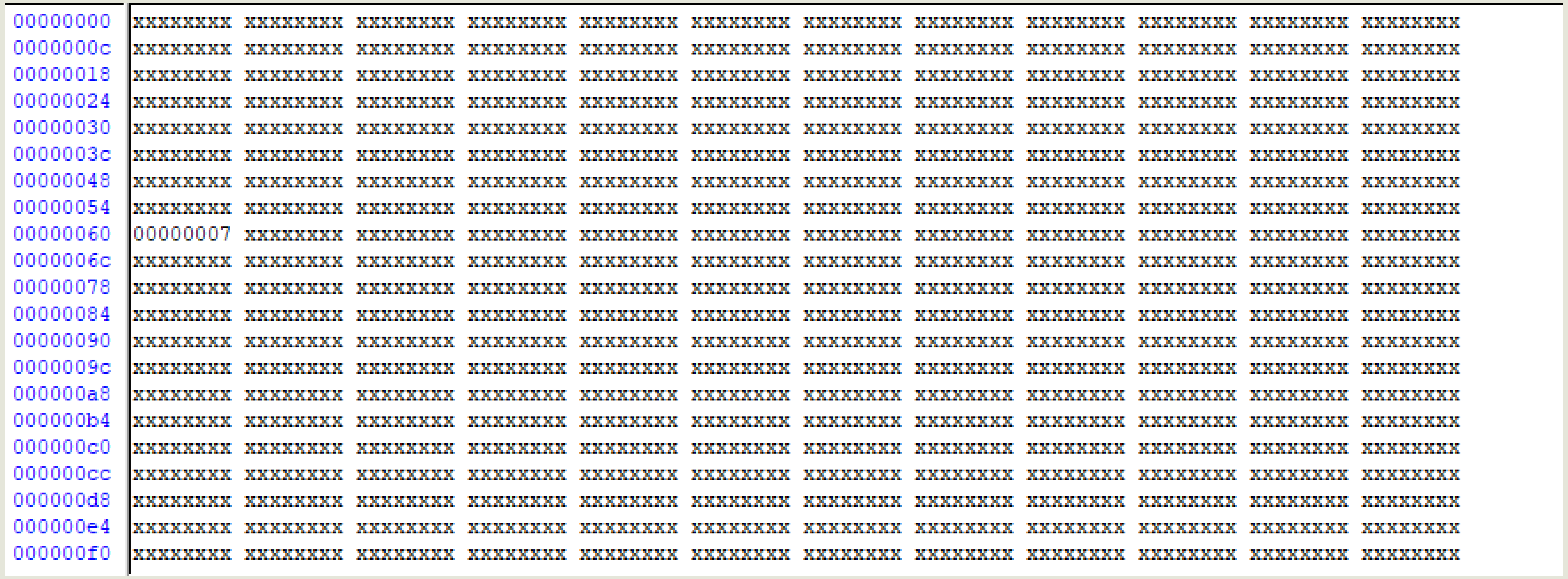
sw x7, 84(x3): Store 7 in location 96



```
clk        1'h0
reset      1'h0
done       1'h0
stall      1'h1
PC         32'h00000034    00...  0000002c  00000030  00000034
mem_read   1'h0
mem_write  1'h1
```

Simulation Results

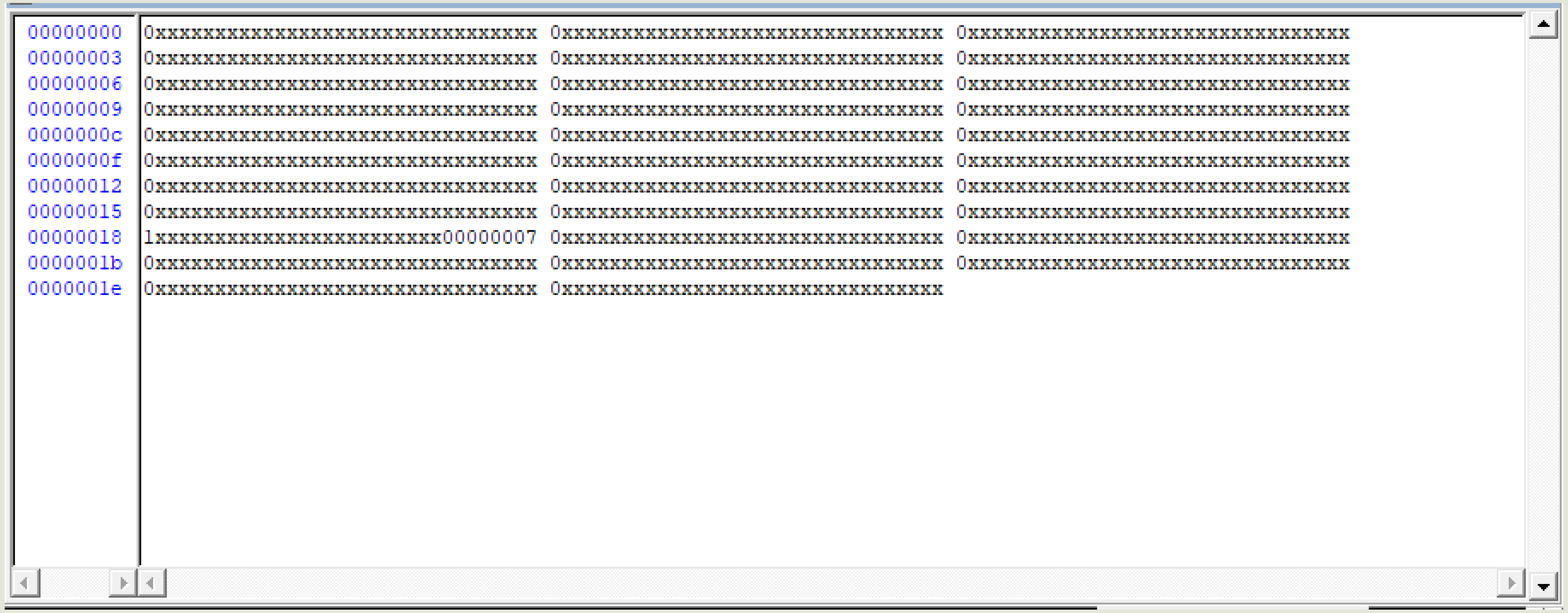
sw x7, 84(x3) : Main Memory view



```
00000000 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000000c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000018 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000024 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000030 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000003c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000048 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000054 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000060 00000007 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000006c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000078 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000084 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000090 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000009c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000a8 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000b4 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000c0 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000cc xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000d8 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000e4 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000f0 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
```

Simulation Results

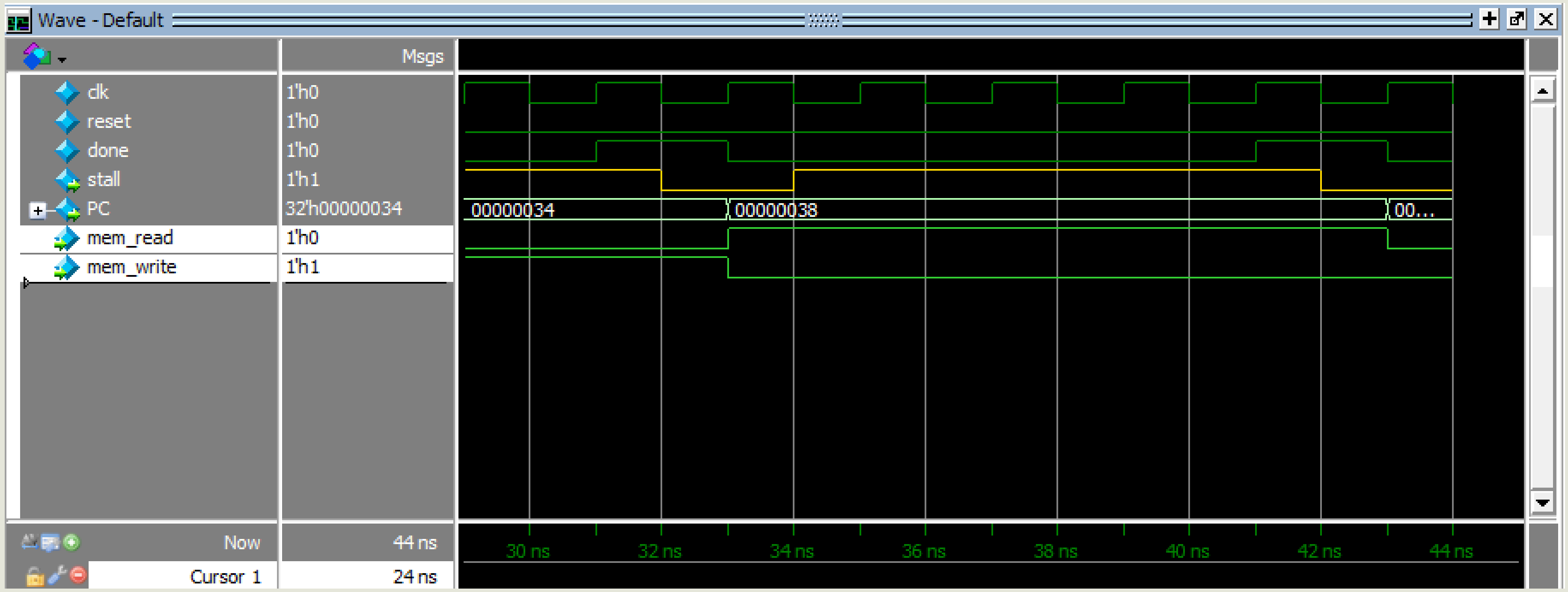
sw x7, 84(x3) : Cache Memory View



```
00000000 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000003 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000006 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000009 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000000c 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000000f 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000012 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000015 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000018 1xxxxxxxxxxxxxxxxxxxxxxxx00000007 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000001b 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000001e 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

Simulation Results

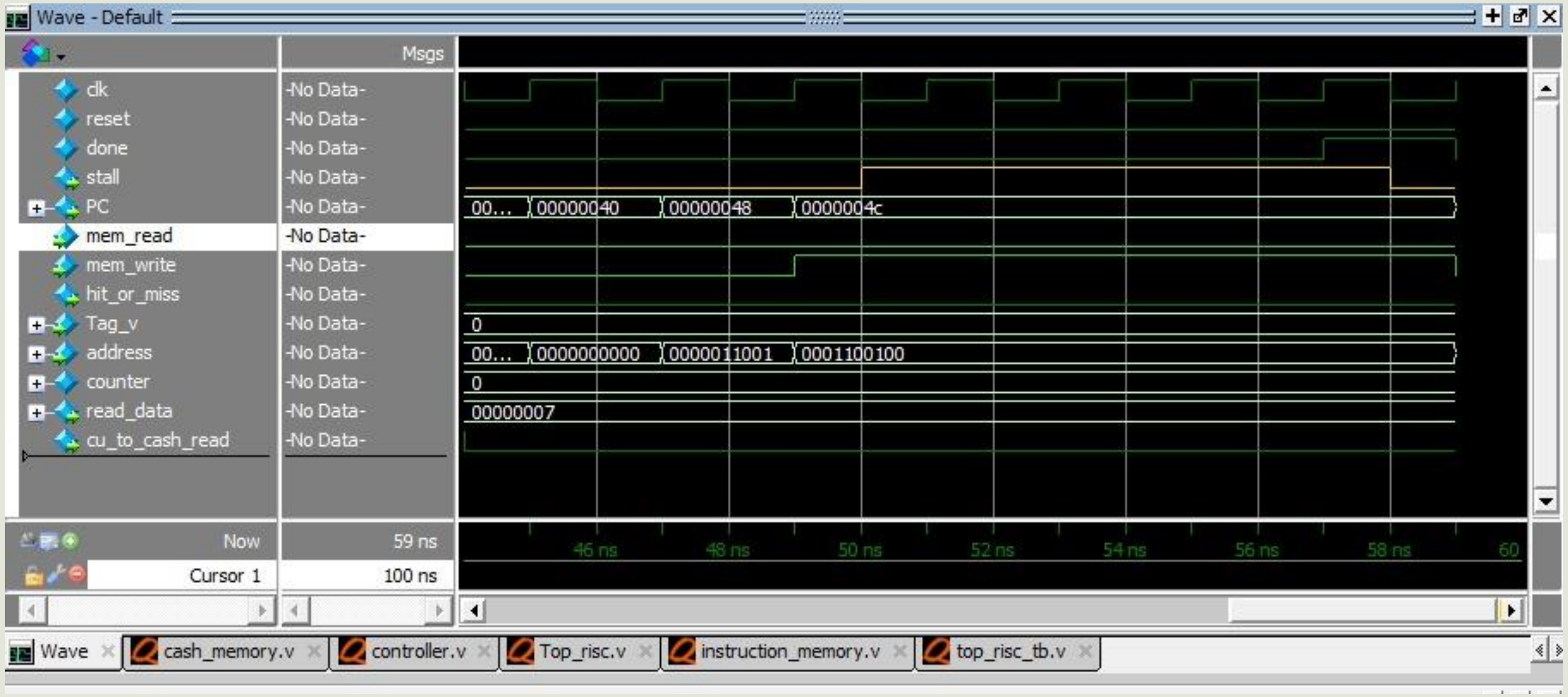
lw x2, 96(x0): load from location 96 to register x2



```
clk        1'h0
reset      1'h0
done       1'h0
stall      1'h1
PC         32'h00000034
mem_read   1'h0
mem_write  1'h1
Now        44 ns
Cursor 1   24 ns
```

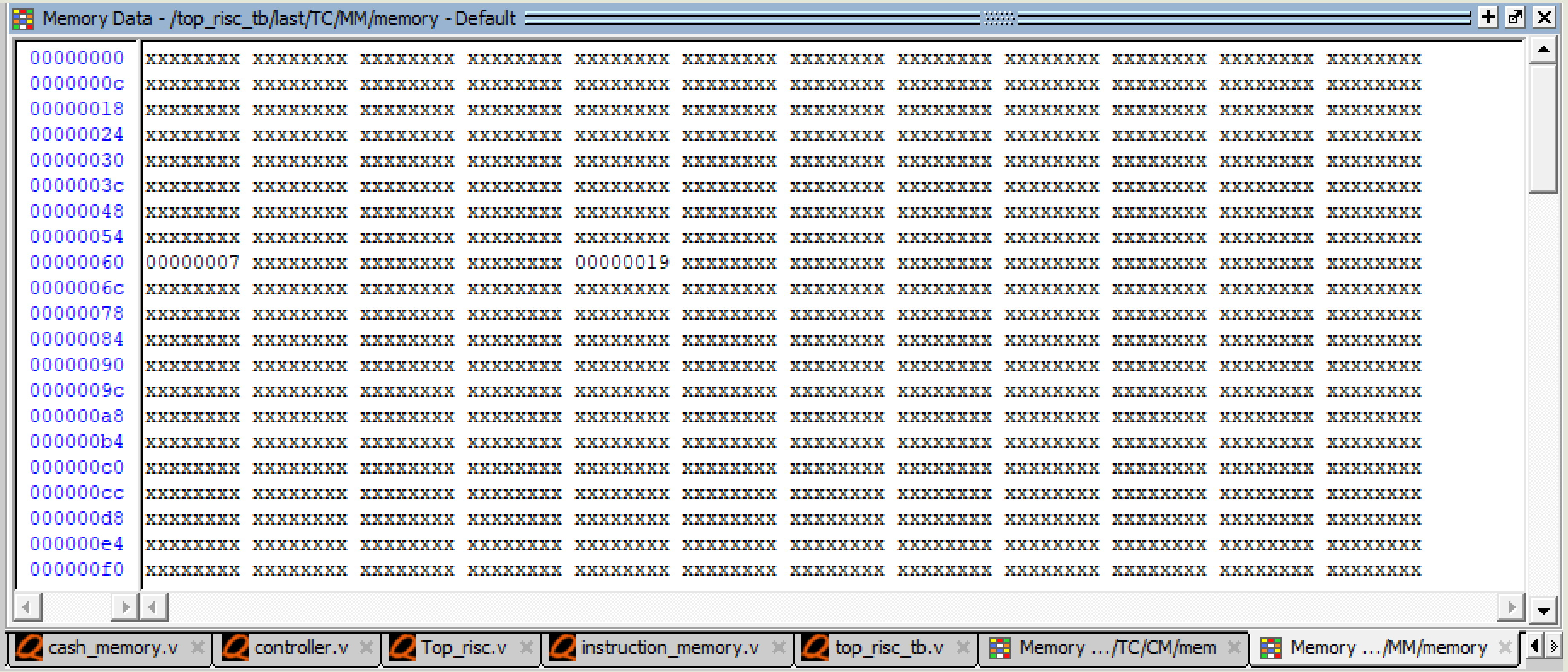
Simulation Results

sw x2, 0x20(x3)



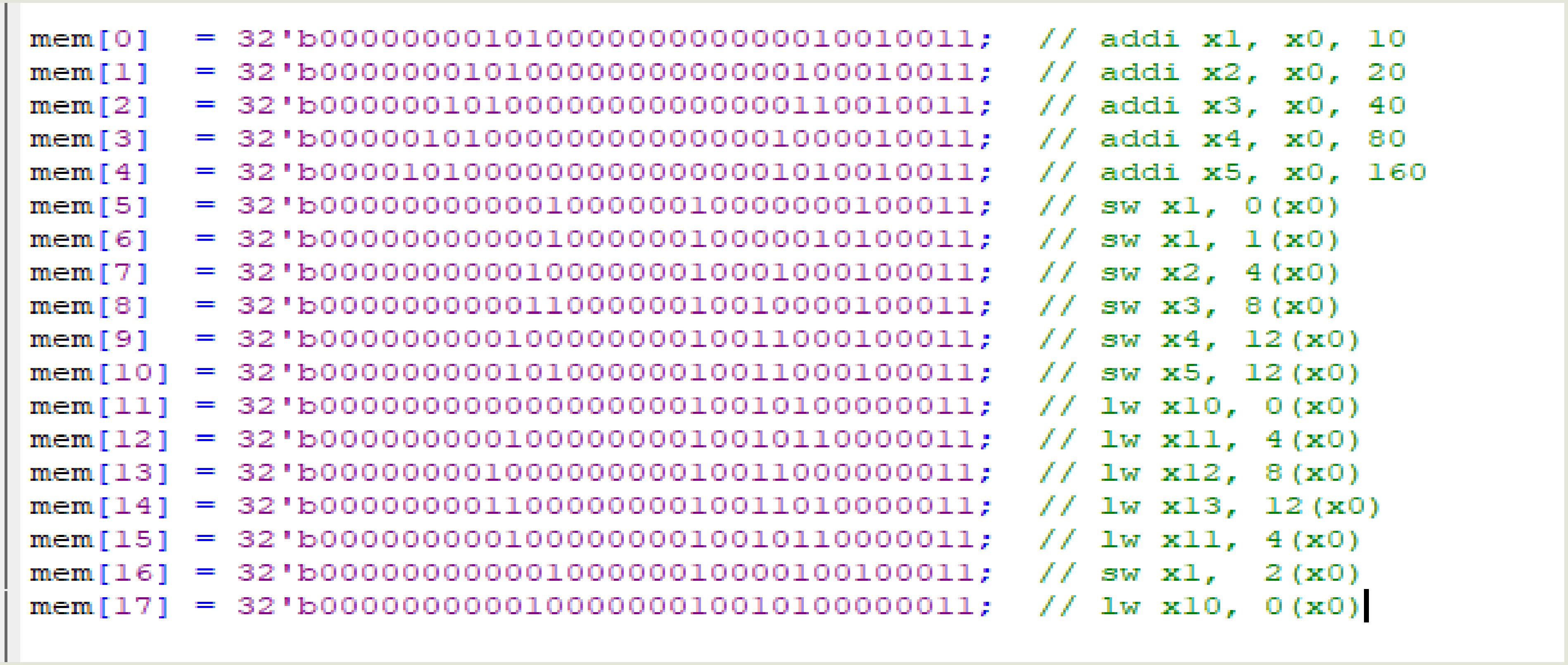
Simulation Results

sw x2, 0x20(x3) : Main Memory view 0x19 Stored in in Location 0x64



```
00000000 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000000c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000018 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000024 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000030 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000003c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000048 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000054 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000060 00000007 xxxxxxxx xxxxxxxx xxxxxxxx 00000019 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000006c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000078 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000084 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000090 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000009c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000a8 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000b4 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000c0 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000cc xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000d8 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000e4 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000f0 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
```

Other Test Program



```
mem[0]   = 32'b00000000101000000000000010010011;   // addi x1,  x0,  10
mem[1]   = 32'b00000001010000000000000100010011;   // addi x2,  x0,  20
mem[2]   = 32'b00000010100000000000000110010011;   // addi x3,  x0,  40
mem[3]   = 32'b00000101000000000000001000010011;   // addi x4,  x0,  80
mem[4]   = 32'b00001010000000000000001010010011;   // addi x5,  x0,  160
mem[5]   = 32'b00000000000100000010000000100011;   // sw x1,  0(x0)
mem[6]   = 32'b00000000000100000010000010100011;   // sw x1,  1(x0)
mem[7]   = 32'b00000000001000000010001000100011;   // sw x2,  4(x0)
mem[8]   = 32'b00000000001100000010010000100011;   // sw x3,  8(x0)
mem[9]   = 32'b00000000010000000010011000100011;   // sw x4,  12(x0)
mem[10]  = 32'b00000000010100000010011000100011;   // sw x5,  12(x0)
mem[11]  = 32'b00000000000000000010010100000011;   // lw x10,  0(x0)
mem[12]  = 32'b00000000010000000010010110000011;   // lw x11,  4(x0)
mem[13]  = 32'b00000000100000000010011000000011;   // lw x12,  8(x0)
mem[14]  = 32'b00000000110000000010011010000011;   // lw x13,  12(x0)
mem[15]  = 32'b00000000010000000010010110000011;   // lw x11,  4(x0)
mem[16]  = 32'b00000000000100000010000100100011;   // sw x1,   2(x0)
mem[17]  = 32'b00000000001000000010010100000011;   // lw x10,  0(x0)
```

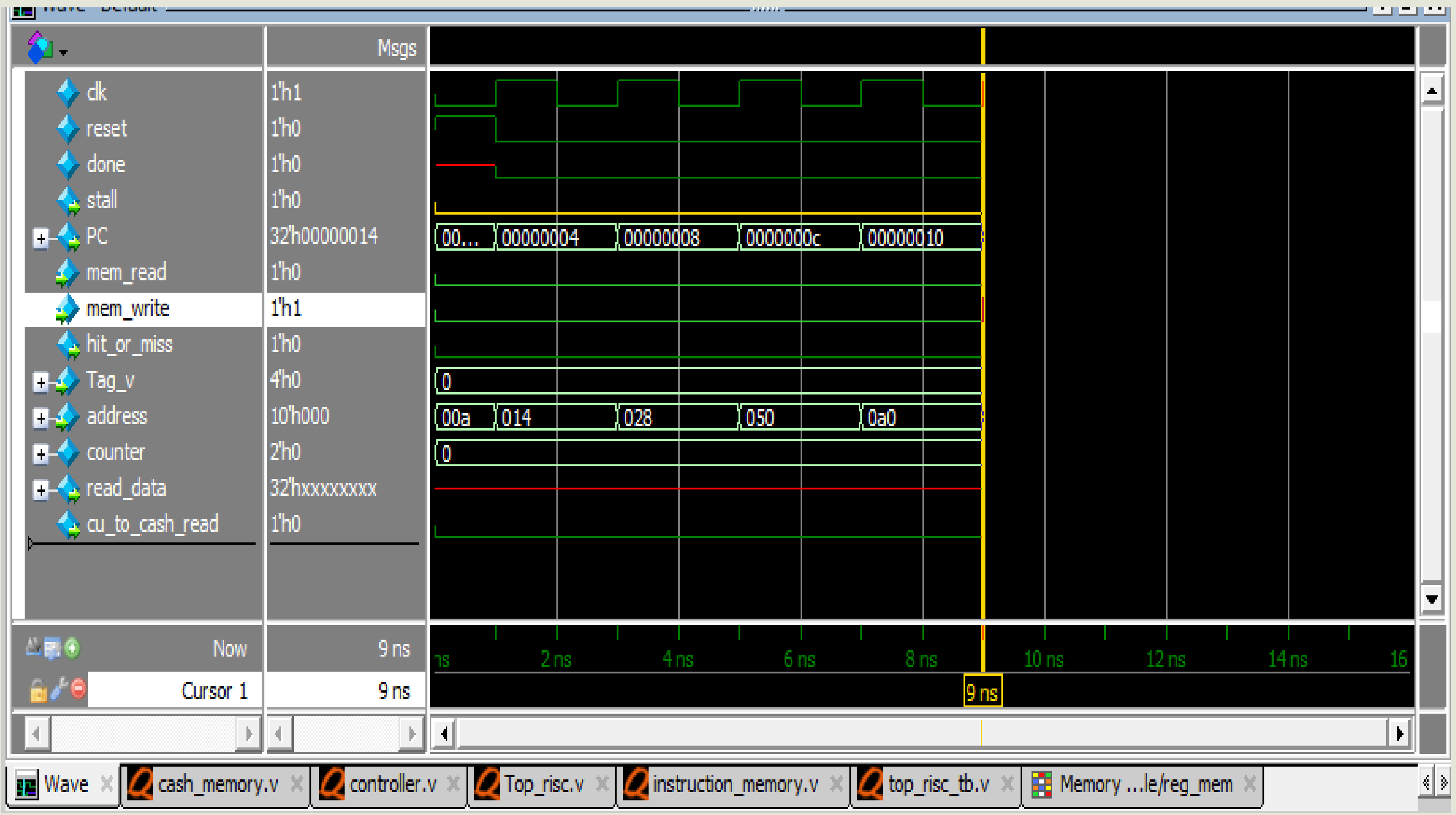
addi x1, x0, 10

addi x2, x0, 20

addi x3, x0, 40

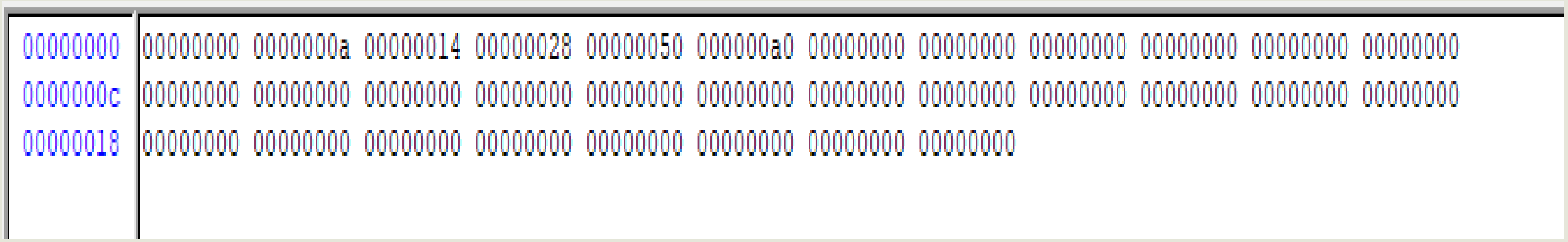
addi x4, x0, 80

addi x5, x0, 160



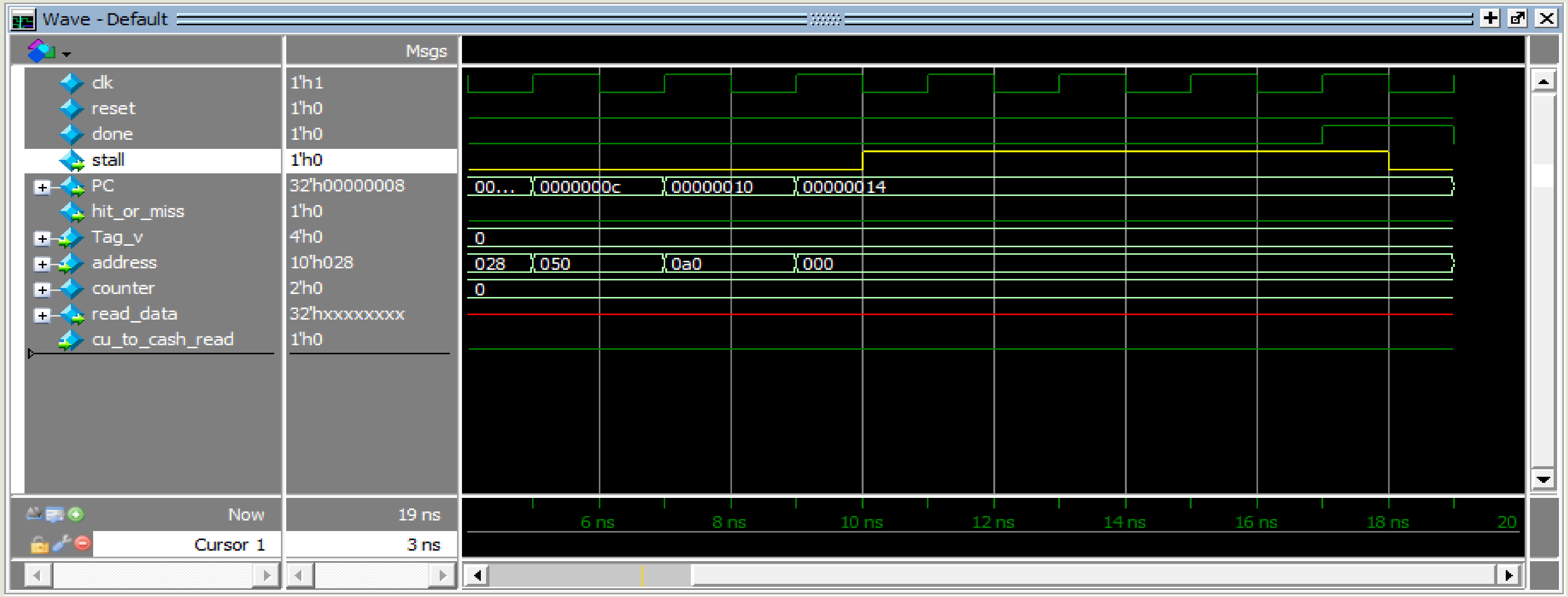
Simulation Results

Store 10,20,40,80,160 in register file


```
00000000 00000000 0000000a 00000014 00000028 00000050 000000a0 00000000 00000000 00000000 00000000 00000000 00000000
0000000c 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000018 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
```

Simulation Results

sw x1, 0(x0)


Wave - Default

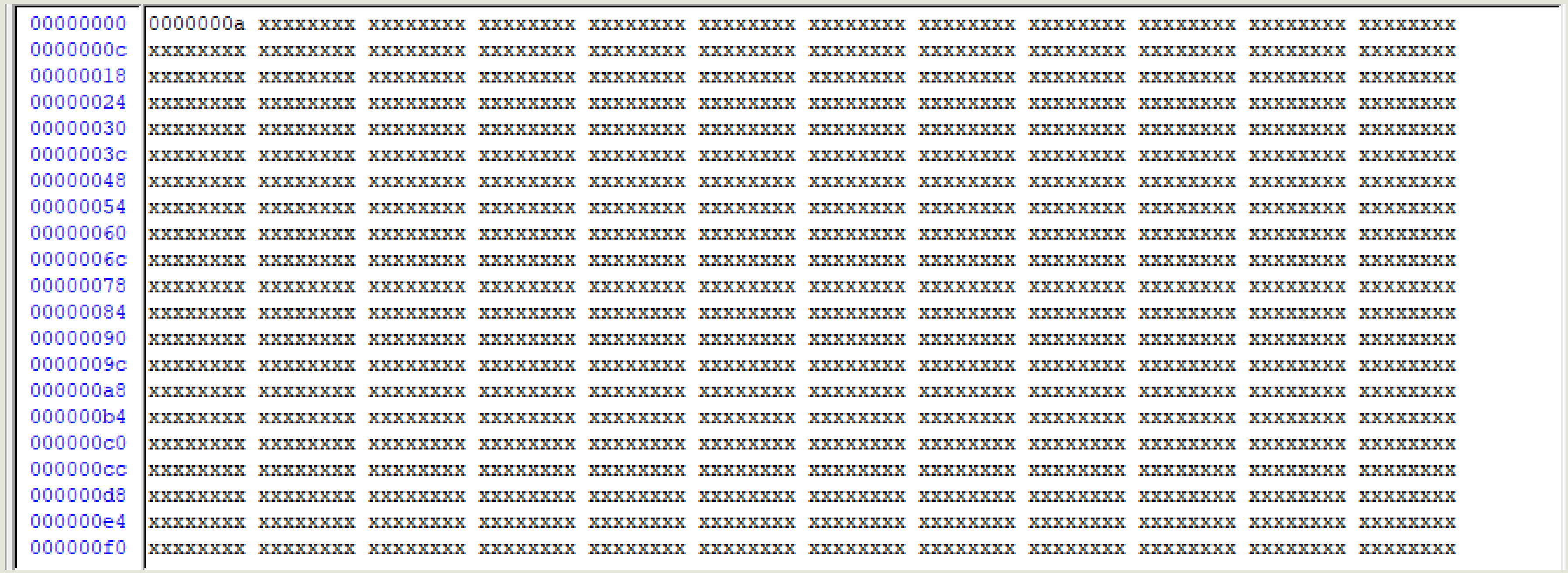
	Msgs
clk	1'h1
reset	1'h0
done	1'h0
stall	1'h0
PC	32'h00000008
hit_or_miss	1'h0
Tag_v	4'h0
address	10'h028
counter	2'h0
read_data	32'hxxxxxxxx
cu_to_cash_read	1'h0

PC: 00... | 0000000c | 00000010 | 00000014
Tag_v: 0
address: 028 | 050 | 0a0 | 000
counter: 0

Now 19 ns
Cursor 1 3 ns

Simulation Results

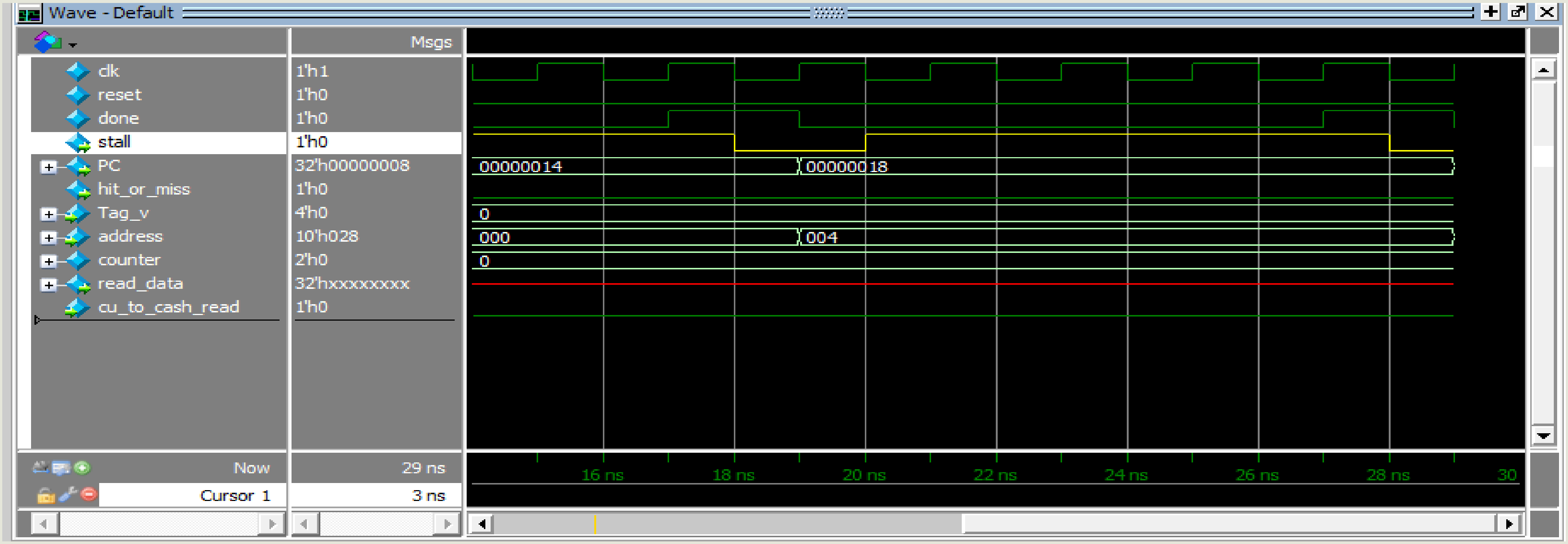
Store 10 in location 0x00000000



```
00000000 0000000a xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000000c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000018 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000024 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000030 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000003c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000048 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000054 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000060 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000006c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000078 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000084 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000090 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000009c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000a8 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000b4 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000c0 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000cc xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000d8 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000e4 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000f0 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
```

Simulation Results

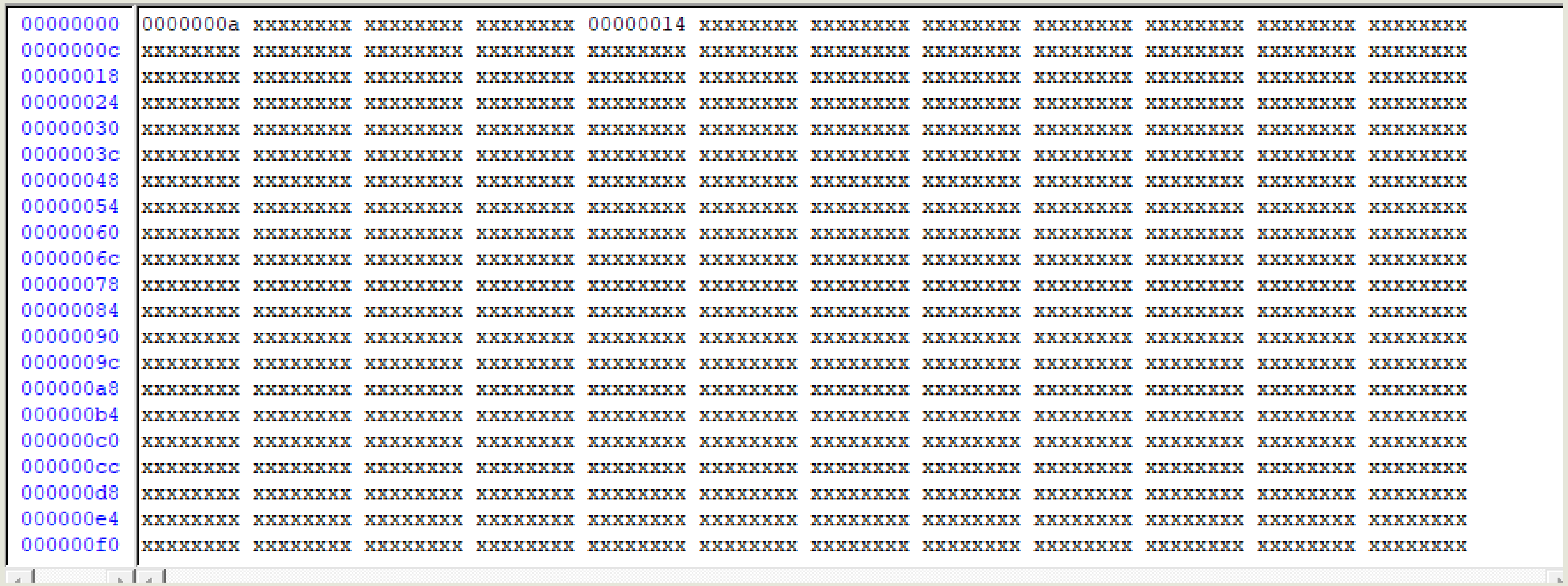
sw x2, 4(x0)



```
clk            1'h1
reset          1'h0
done           1'h0
stall          1'h0
PC             32'h00000008    00000014        00000018
hit_or_miss    1'h0
Tag_v          4'h0            0
address        10'h028         000             004
counter        2'h0            0
read_data      32'hxxxxxxxx
cu_to_cash_read 1'h0

Now            29 ns
Cursor 1       3 ns
```

Simulation Results

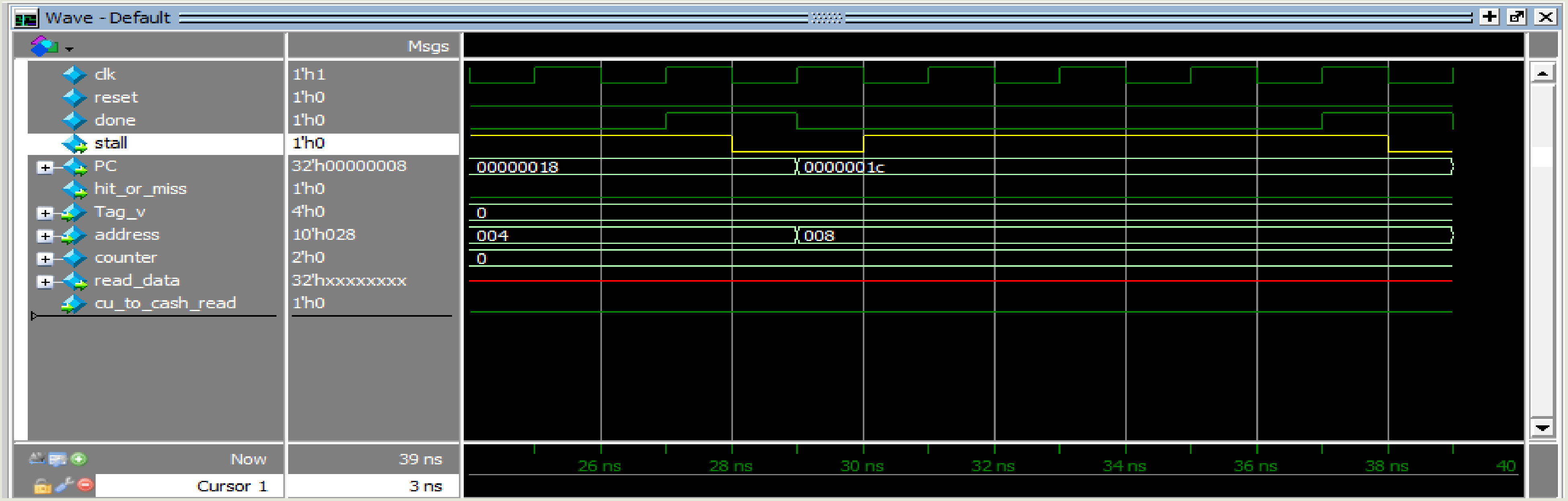
Store 20 in location 0x00000004



```
00000000 0000000a xxxxxxxx xxxxxxxx xxxxxxxx 00000014 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000000c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000018 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000024 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000030 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000003c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000048 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000054 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000060 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000006c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000078 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000084 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000090 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000009c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000a8 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000b4 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000c0 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000cc xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000d8 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000e4 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000f0 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
```

Simulation Results

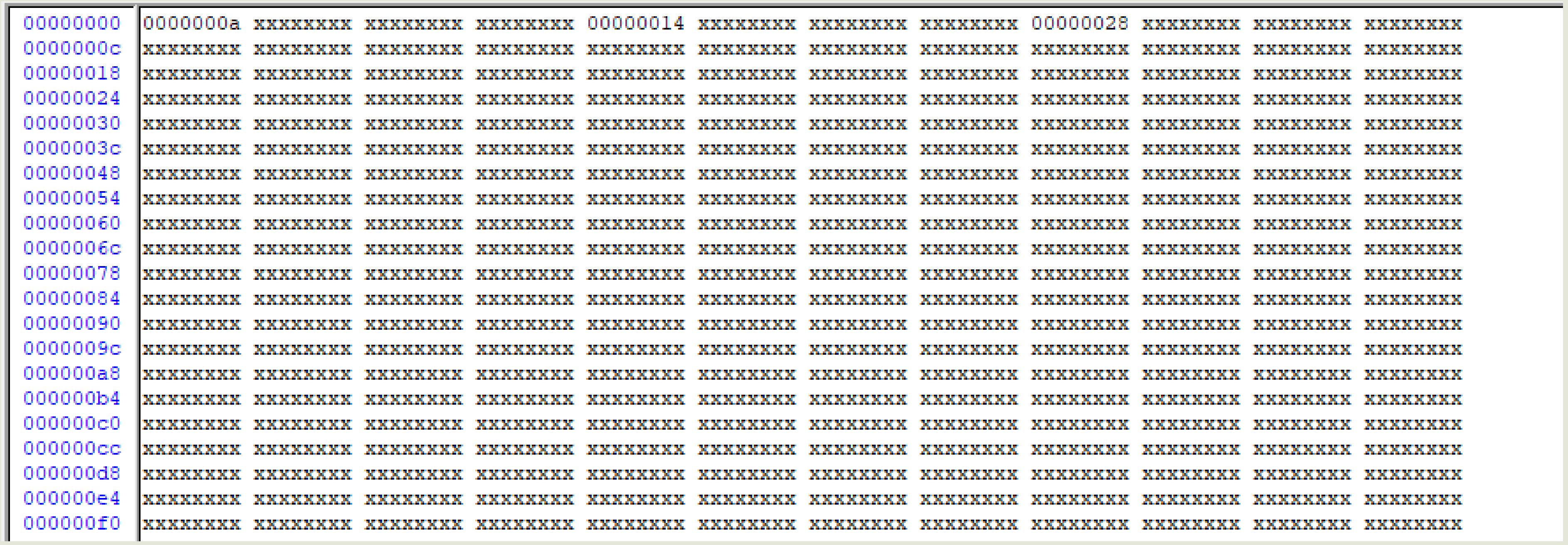
sw x3, 8(x0)



```
clk            1'h1
reset          1'h0
done           1'h0
stall          1'h0
PC             32'h00000008
hit_or_miss    1'h0
Tag_v          4'h0
address        10'h028
counter        2'h0
read_data      32'hxxxxxxxx
cu_to_cash_read 1'h0

Now            39 ns
Cursor 1       3 ns
```

Simulation Results

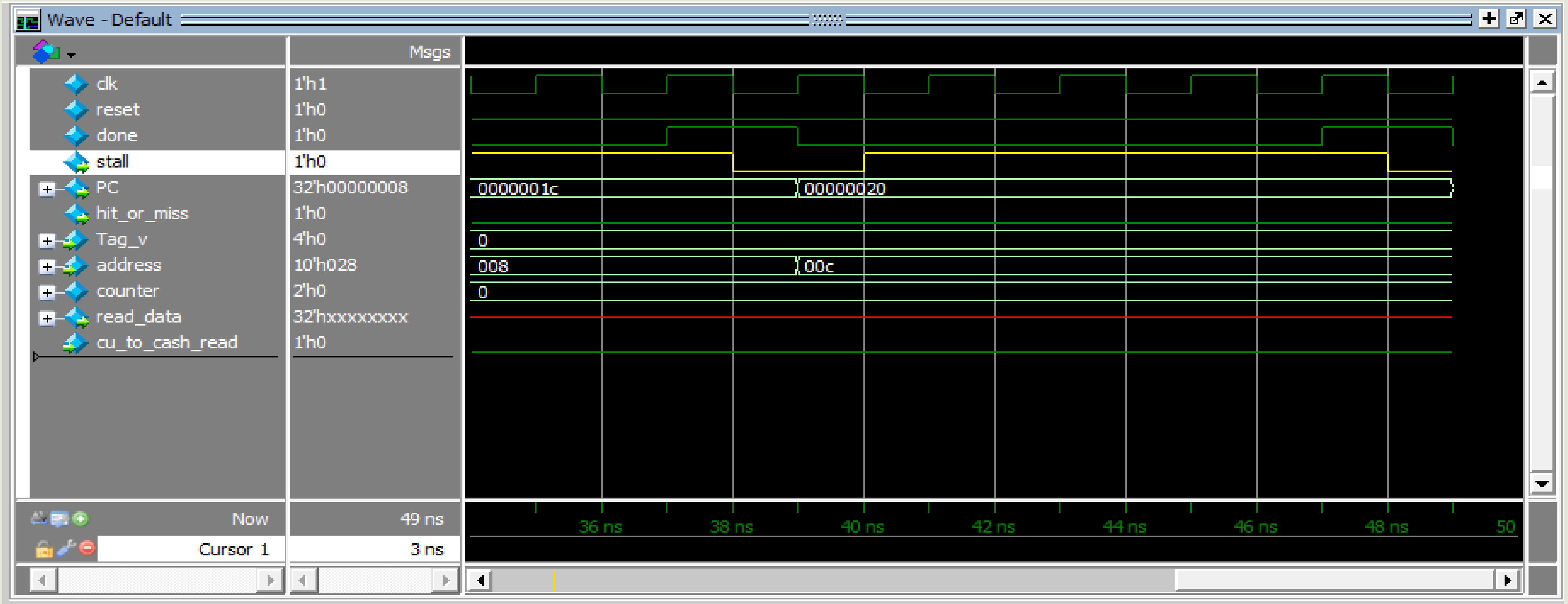
Store 40 in location 0x00000008



```
00000000  0000000a xxxxxxxx xxxxxxxx xxxxxxxx 00000014 xxxxxxxx xxxxxxxx xxxxxxxx 00000028 xxxxxxxx xxxxxxxx xxxxxxxx
0000000c  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000018  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000024  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000030  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000003c  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000048  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000054  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000060  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000006c  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000078  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000084  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000090  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000009c  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000a8  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000b4  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000c0  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000cc  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000d8  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000e4  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000f0  xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
```

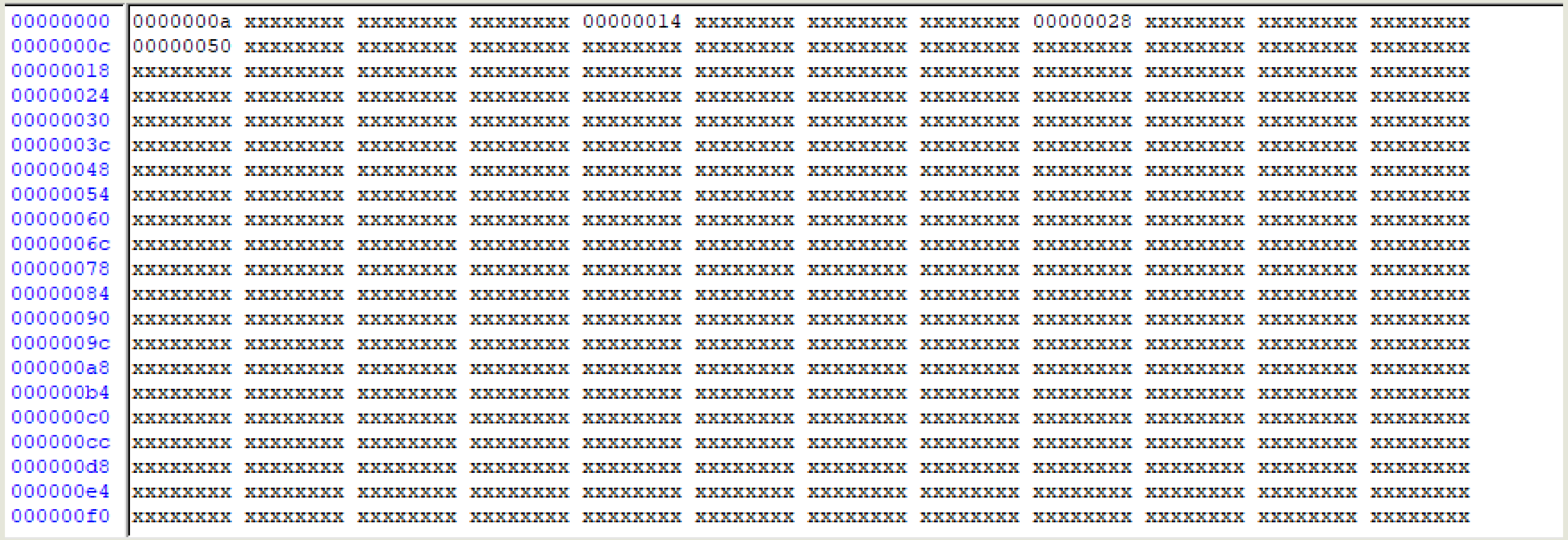
Simulation Results

sw x4, 12(x0)



Simulation Results

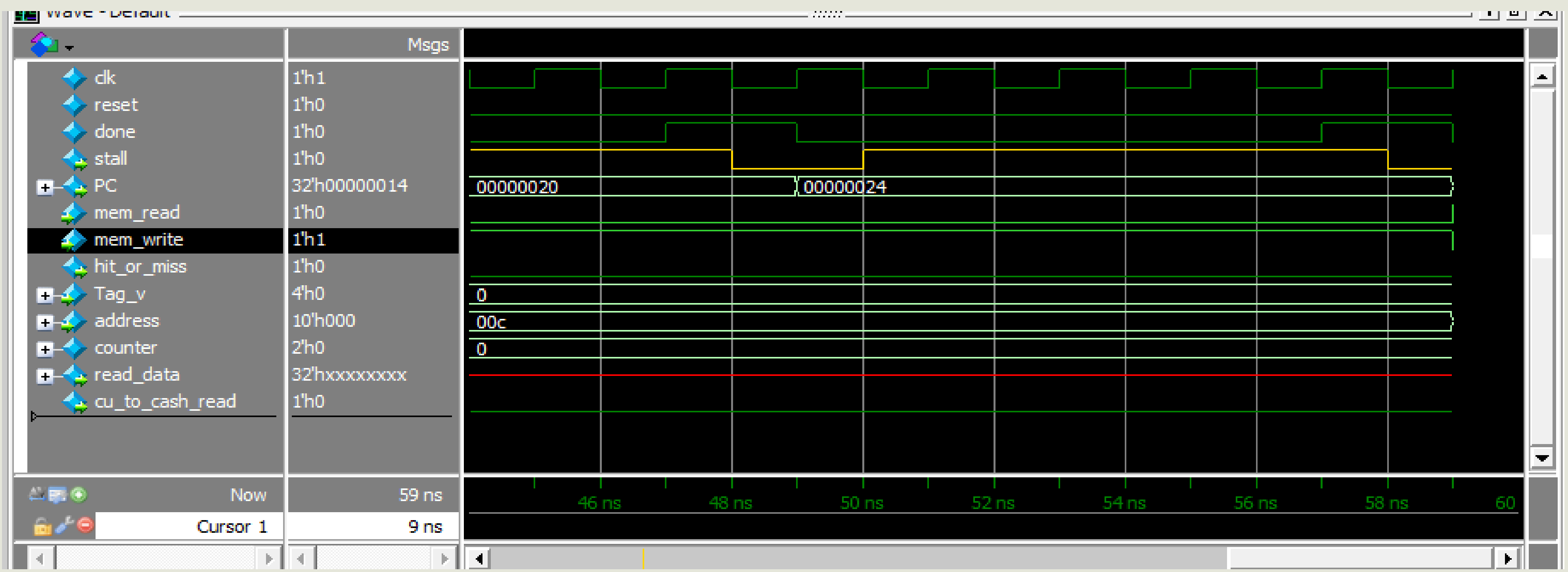
Store 0x80 in location 0x0000000c



```
00000000 0000000a xxxxxxxx xxxxxxxx xxxxxxxx 00000014 xxxxxxxx xxxxxxxx xxxxxxxx 00000028 xxxxxxxx xxxxxxxx xxxxxxxx
0000000c 00000050 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000018 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000024 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000030 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000003c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000048 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000054 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000060 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000006c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000078 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000084 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000090 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000009c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000a8 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000b4 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000c0 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000cc xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000d8 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000e4 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
000000f0 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
```

Simulation Results

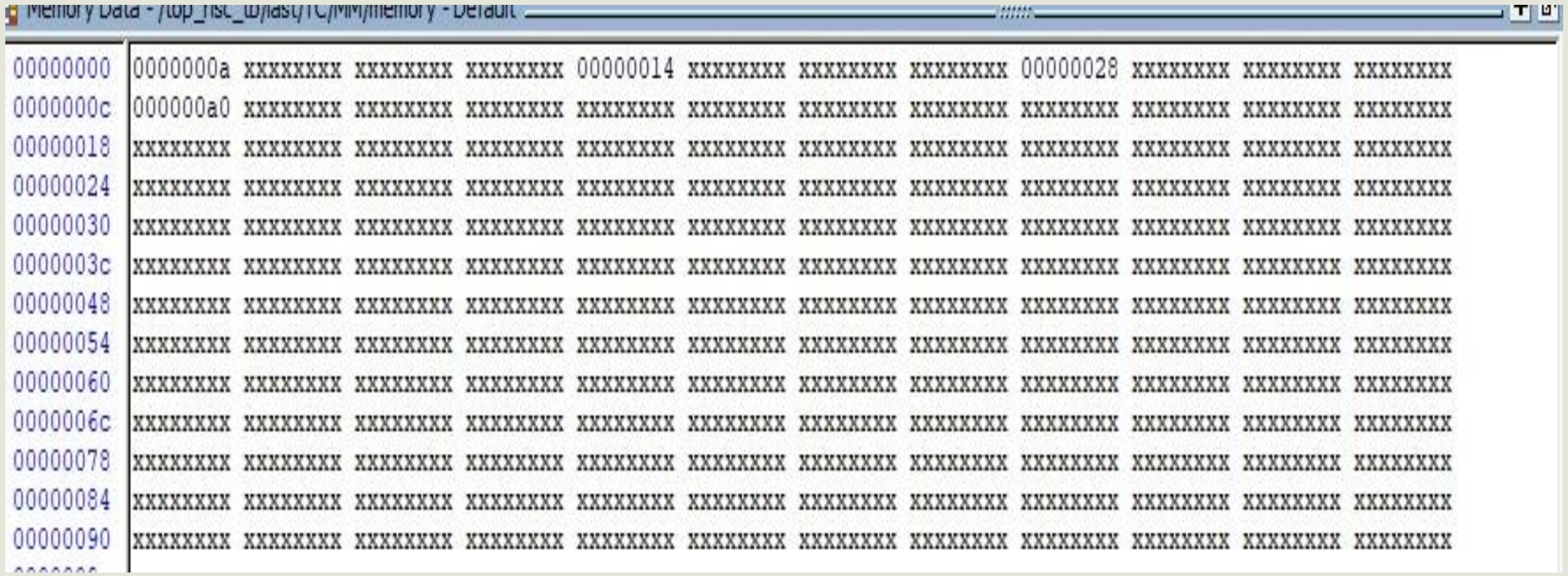
sw x5, 12(x0)



```
                 Msgs
dk               1'h1
reset            1'h0
done             1'h0
stall            1'h0
PC               32'h00000014     00000020        00000024
mem_read         1'h0
mem_write        1'h1
hit_or_miss      1'h0
Tag_v            4'h0             0
address          10'h000          00c
counter          2'h0             0
read_data        32'hxxxxxxxx
cu_to_cash_read  1'h0

Now              59 ns
Cursor 1         9 ns
```

Simulation Results

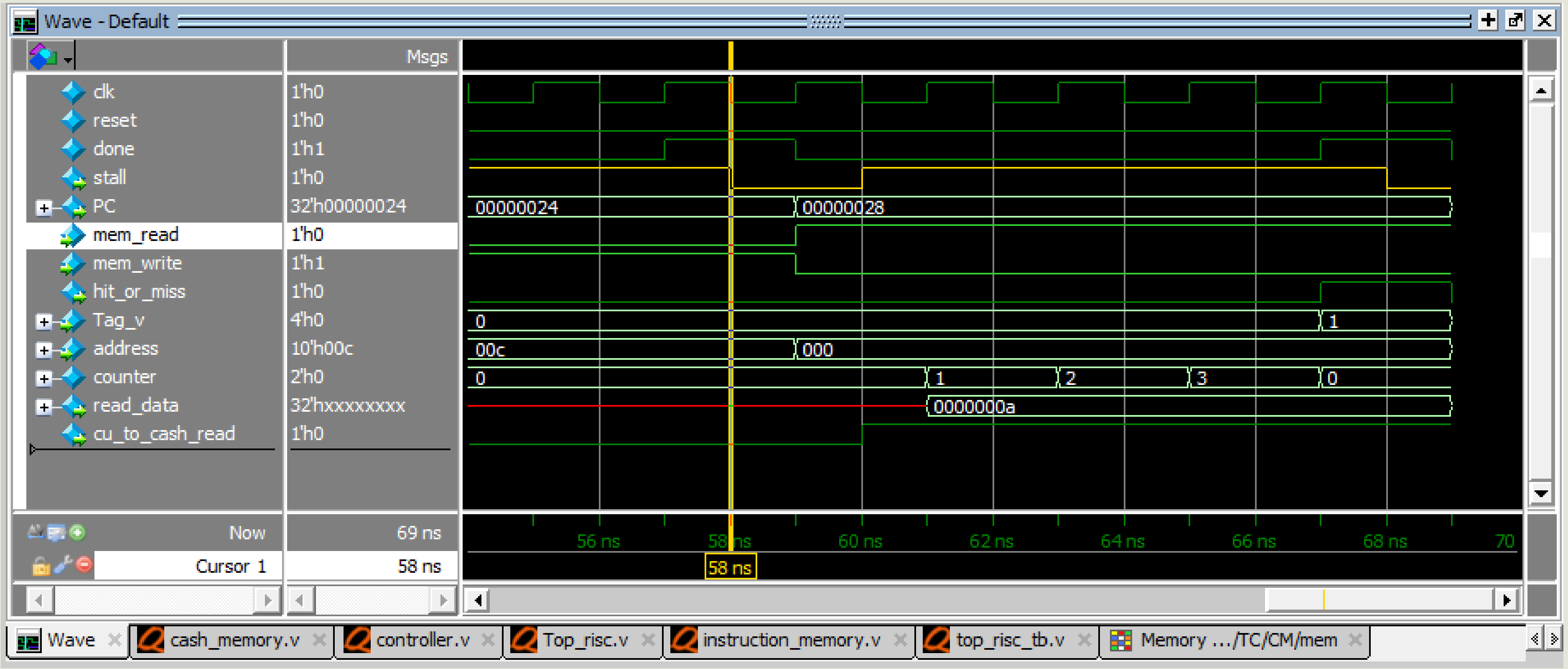
Store 0x160 in location 0x0000000c



```
Memory Data - /top_risc_tb/last/TC/MM/memory - Default
00000000 0000000a xxxxxxxx xxxxxxxx xxxxxxxx 00000014 xxxxxxxx xxxxxxxx xxxxxxxx 00000028 xxxxxxxx xxxxxxxx xxxxxxxx
0000000c 000000a0 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000018 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000024 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000030 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000003c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000048 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000054 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000060 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
0000006c xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000078 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000084 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
00000090 xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx xxxxxxxx
```

Simulation Results

lw x10, 0(x0)



Wave - Default

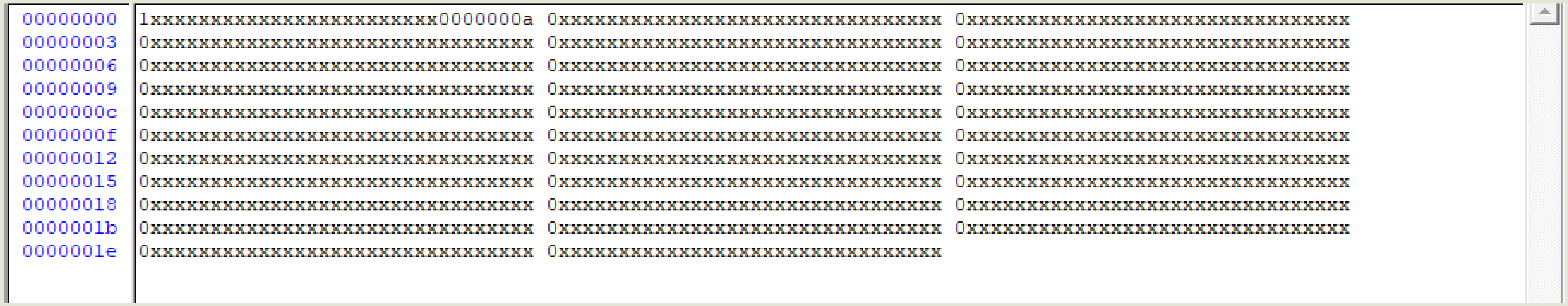
Signal	Msgs
clk	1'h0
reset	1'h0
done	1'h1
stall	1'h0
PC	32'h00000024
mem_read	1'h0
mem_write	1'h1
hit_or_miss	1'h0
Tag_v	4'h0
address	10'h00c
counter	2'h0
read_data	32'hxxxxxxxx
cu_to_cash_read	1'h0

```
PC:        00000024 | 00000028
Tag_v:     0 | 1
address:   00c | 000
counter:   0 | 1 | 2 | 3 | 0
read_data: 0000000a
```

Now 69 ns
Cursor 1 58 ns

Simulation Results

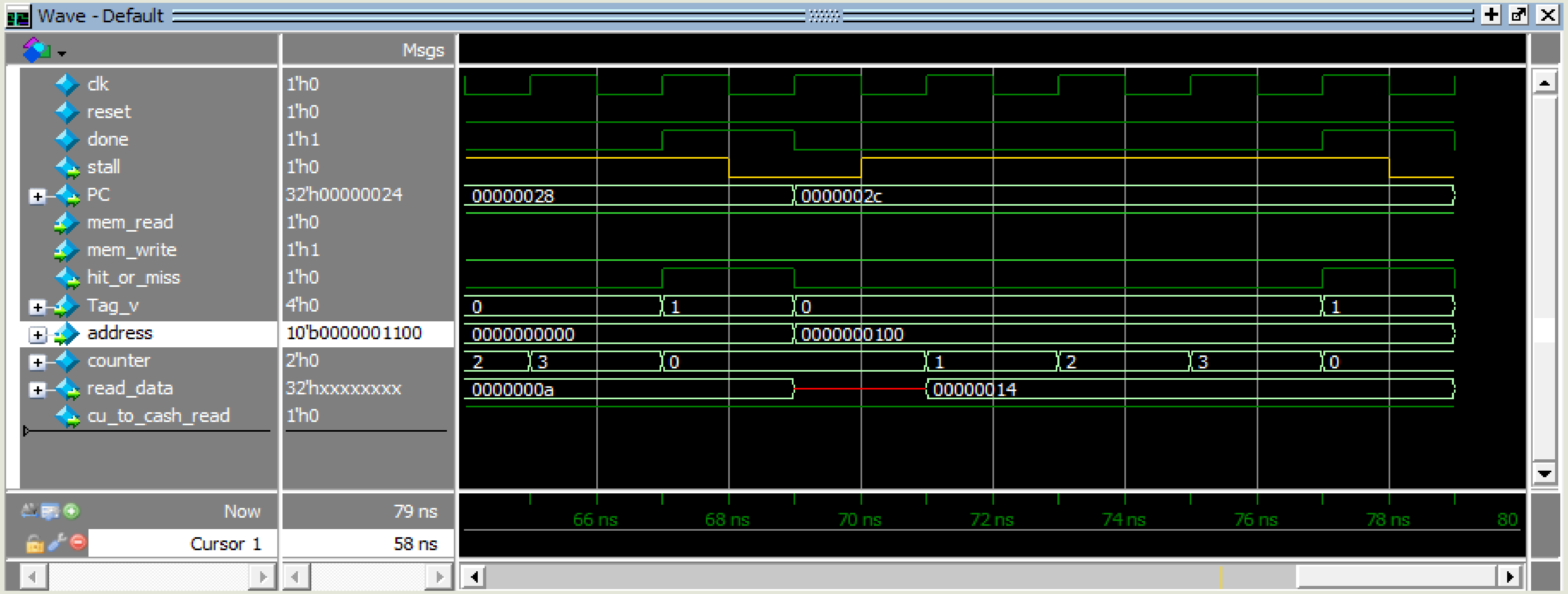
Store block 1 in cache memory then read the value 10



```
00000000 1xxxxxxxxxxxxxxxxxxxxxxxxx0000000a 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000003 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000006 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000009 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000000c 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000000f 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000012 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000015 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000018 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000001b 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000001e 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

Simulation Results

lw x11, 4(x0)

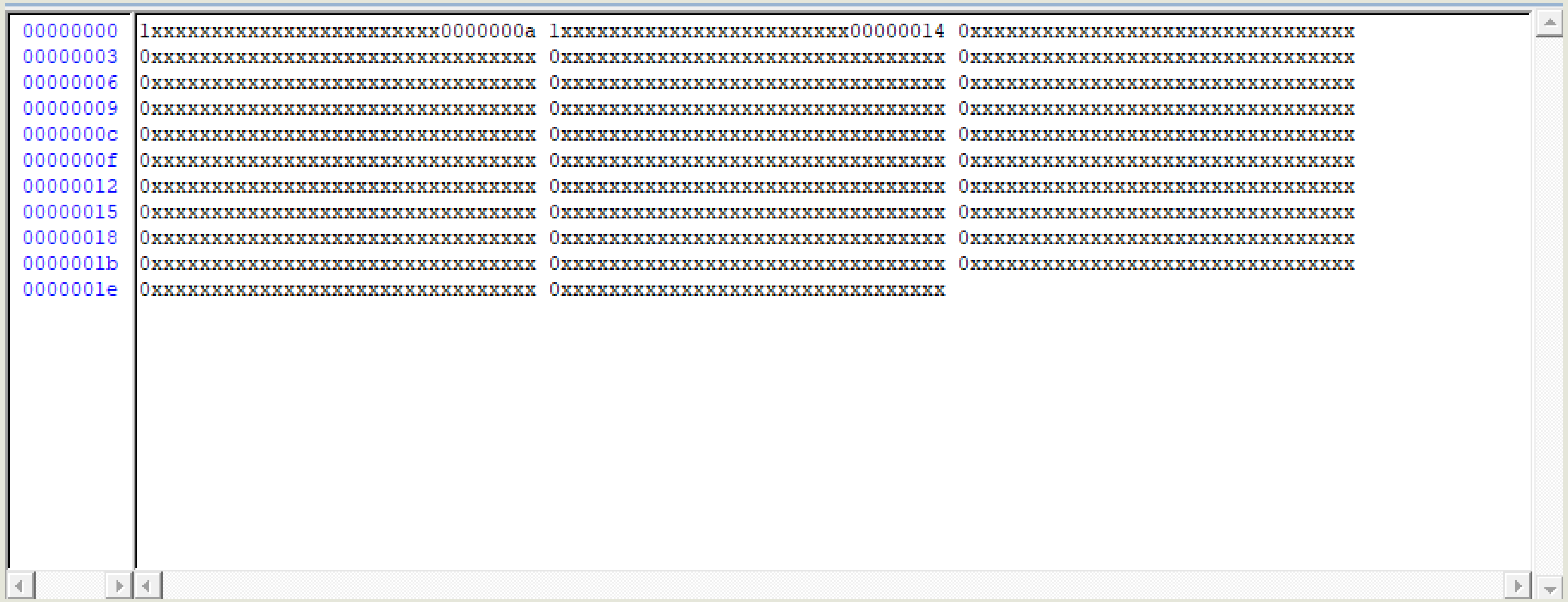


Wave - Default

	Msgs
clk	1'h0
reset	1'h0
done	1'h1
stall	1'h0
PC	32'h00000024
mem_read	1'h0
mem_write	1'h1
hit_or_miss	1'h0
Tag_v	4'h0
address	10'b0000001100
counter	2'h0
read_data	32'hxxxxxxxx
cu_to_cash_read	1'h0
Now	79 ns
Cursor 1	58 ns

Simulation Results

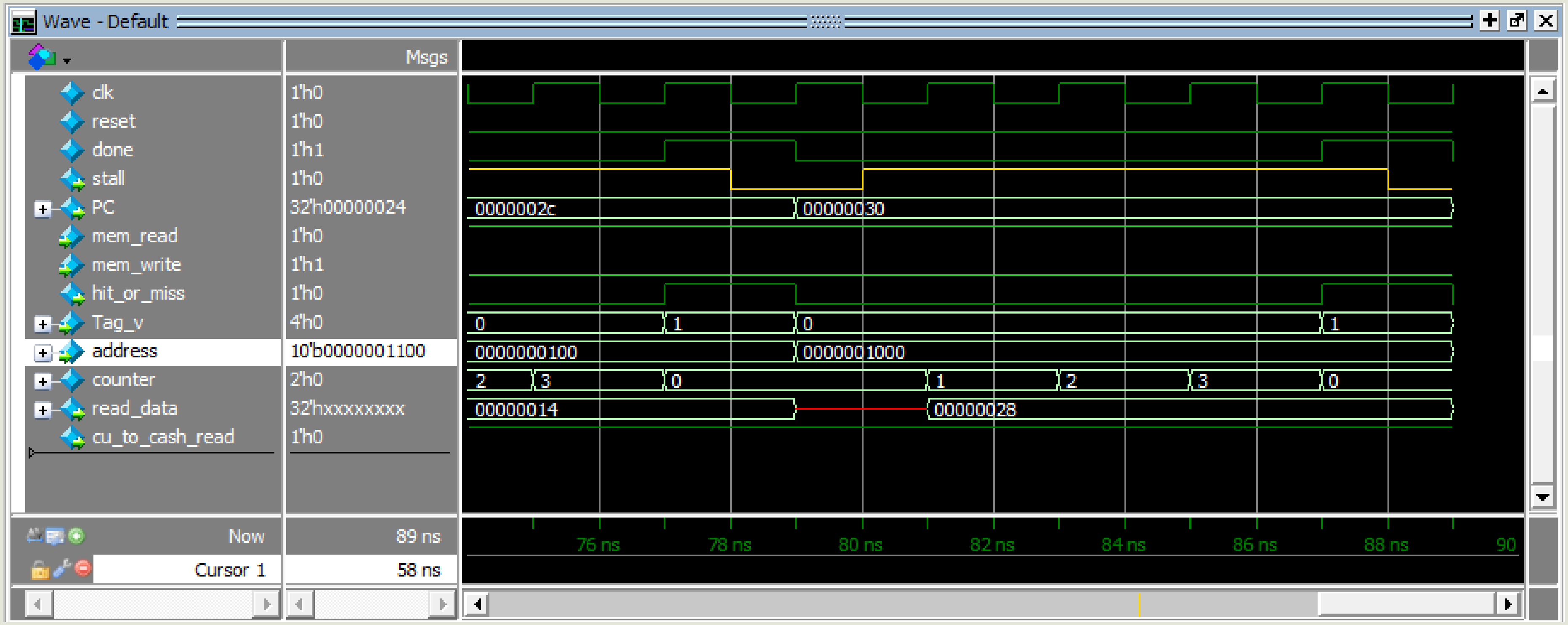
Store block 2 in cache memory then read the value 20



```
00000000 1xxxxxxxxxxxxxxxxxxxxxxxxx0000000a 1xxxxxxxxxxxxxxxxxxxxxxxxx00000014 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000003 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000006 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000009 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000000c 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000000f 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000012 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000015 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000018 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000001b 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000001e 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

Simulation Results

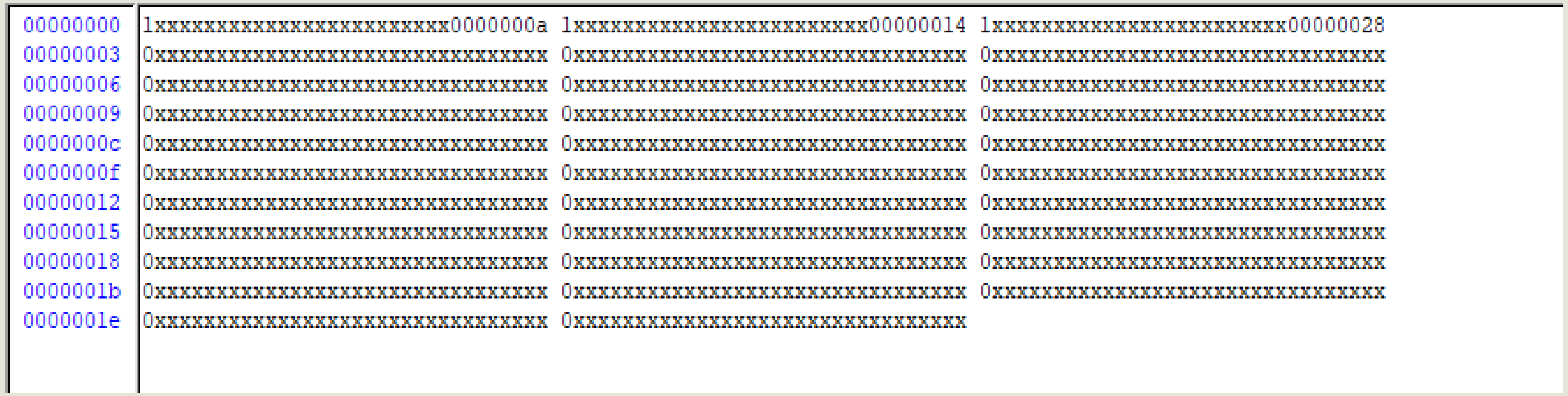
lw x12, 8(x0)



```
clk             1'h0
reset           1'h0
done            1'h1
stall           1'h0
PC              32'h00000024     0000002c        00000030
mem_read        1'h0
mem_write       1'h1
hit_or_miss     1'h0
Tag_v           4'h0             0    1    0    1
address         10'b0000001100   0000000100      0000001000
counter         2'h0             2  3  0  1  2  3  0
read_data       32'hxxxxxxxx     00000014        00000028
cu_to_cash_read 1'h0

Now       89 ns
Cursor 1  58 ns
76 ns  78 ns  80 ns  82 ns  84 ns  86 ns  88 ns  90
```

Simulation Results

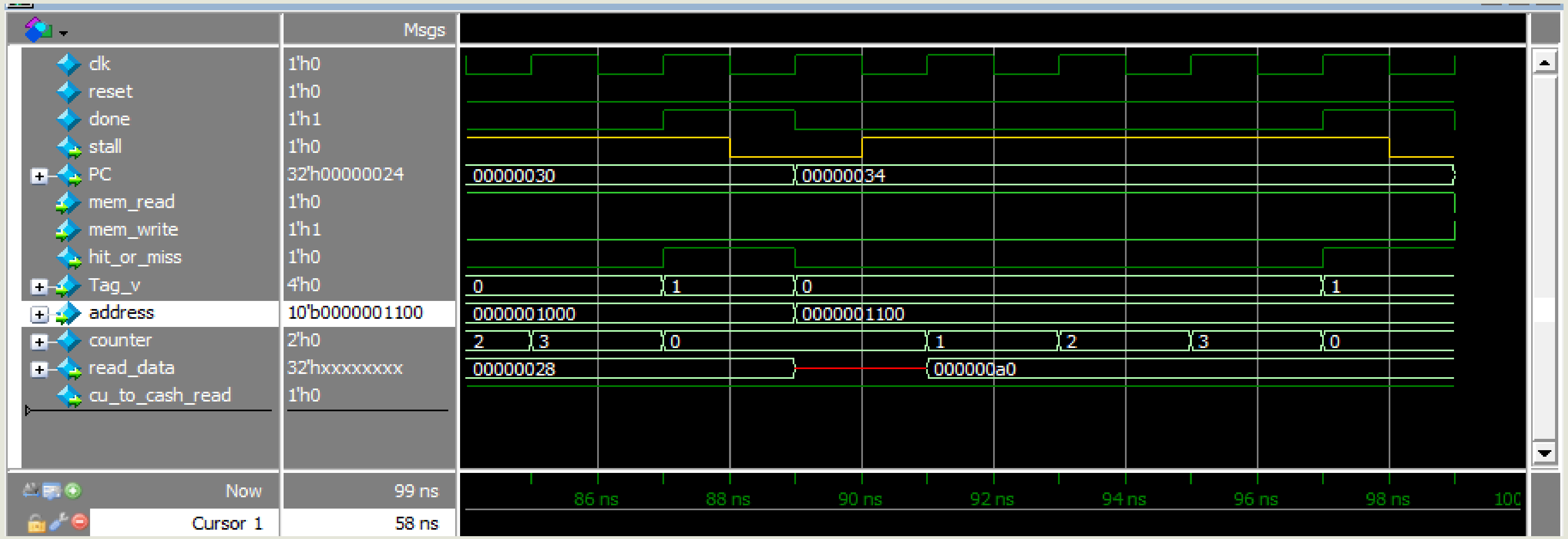
Store block 3 in cache memory then read the value 40



```
00000000  1xxxxxxxxxxxxxxxxxxxxxxxx0000000a 1xxxxxxxxxxxxxxxxxxxxxxxx00000014 1xxxxxxxxxxxxxxxxxxxxxxxx00000028
00000003  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000006  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000009  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000000c  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000000f  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000012  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000015  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000018  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000001b  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000001e  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

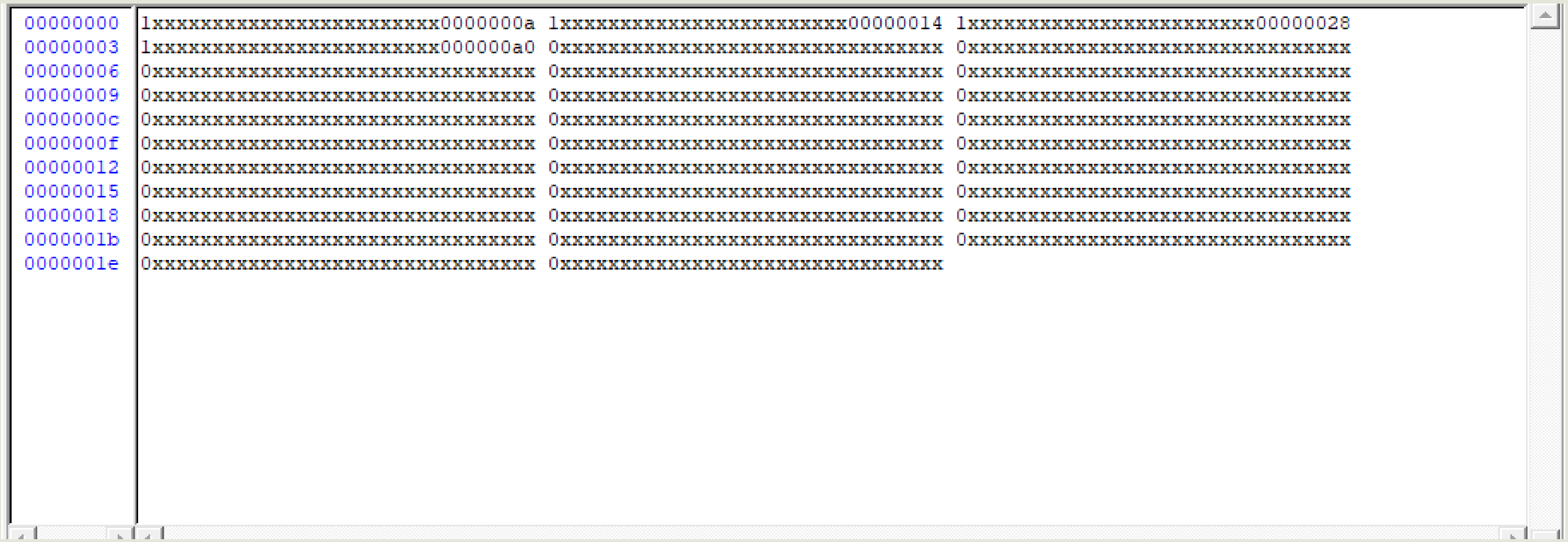
Simulation Results

lw x13, 12(x0)



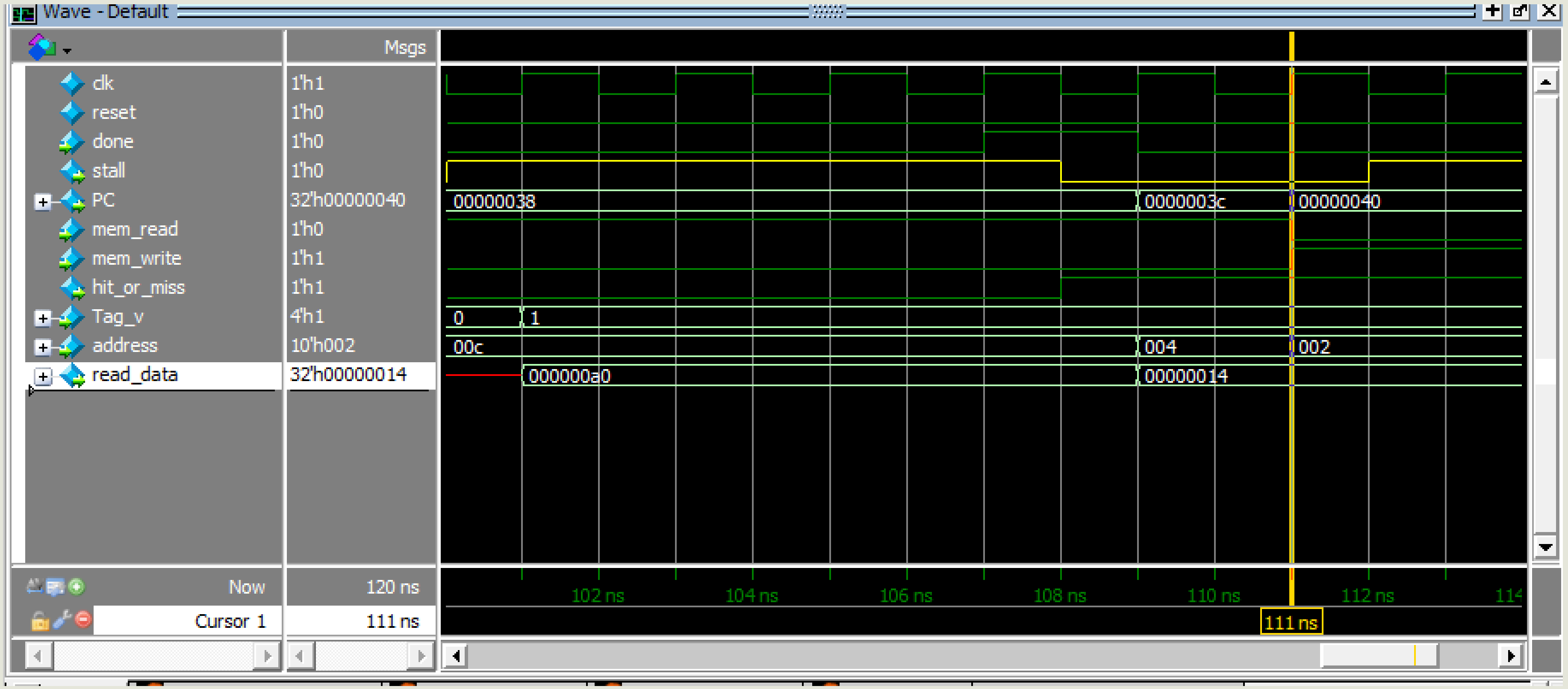
Simulation Results

Store block 4 in cache memory then read the value 160



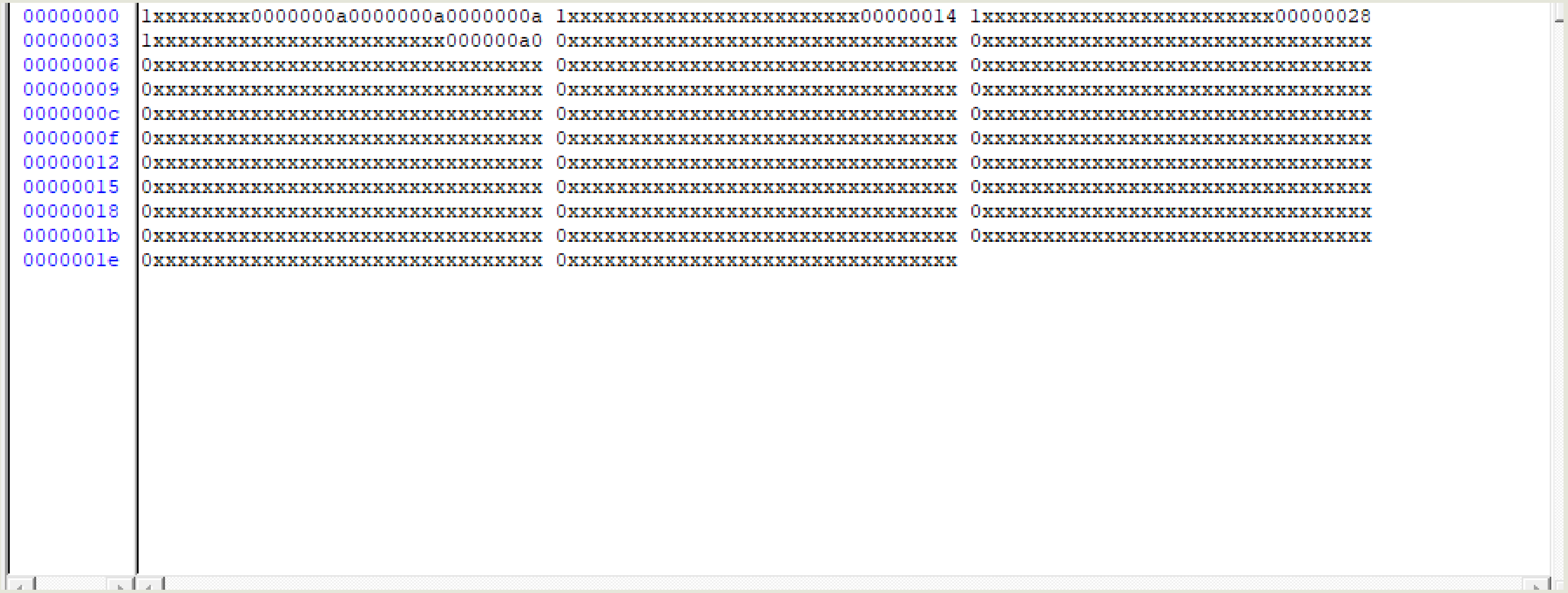
```
00000000  1xxxxxxxxxxxxxxxxxxxxxxxx0000000a 1xxxxxxxxxxxxxxxxxxxxxxxx00000014 1xxxxxxxxxxxxxxxxxxxxxxxx00000028
00000003  1xxxxxxxxxxxxxxxxxxxxxxxx000000a0 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000006  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000009  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000000c  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000000f  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000012  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000015  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000018  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000001b  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000001e  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

lw x11, 4(x0)   here we read a value we reload to cache before so Hit



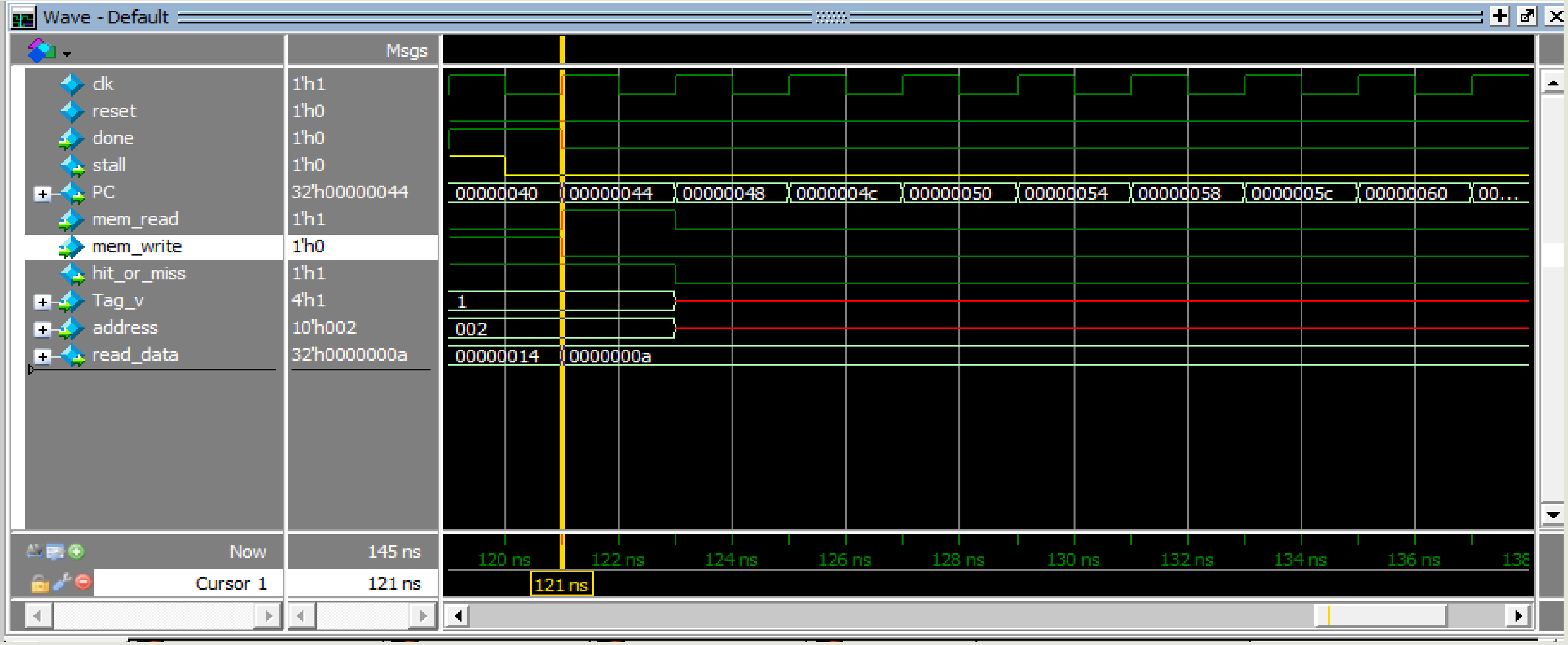
```
Wave - Default

             Msgs
clk          1'h1
reset        1'h0
done         1'h0
stall        1'h0
PC           32'h00000040    00000038 | 0000003c | 00000040
mem_read     1'h0
mem_write    1'h1
hit_or_miss  1'h1
Tag_v        4'h1            0 | 1
address      10'h002         00c | 004 | 002
read_data    32'h00000014    000000a0 | 00000014

Now          120 ns
Cursor 1     111 ns          102 ns  104 ns  106 ns  108 ns  110 ns  112 ns  114
                                                              111 ns
```

sw x1, 2(x0)



```
00000000  1xxxxxxxx0000000a0000000a0000000a 1xxxxxxxxxxxxxxxxxxxxxxxx00000014 1xxxxxxxxxxxxxxxxxxxxxxxx00000028
00000003  1xxxxxxxxxxxxxxxxxxxxxxxx000000a0 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000006  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000009  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000000c  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000000f  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000012  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000015  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
00000018  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000001b  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
0000001e  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
```

lw x10, 0(x0)here we read a value we reload to cache before so Hit



```
              Msgs
clk           1'h1
reset         1'h0
done          1'h0
stall         1'h0
PC            32'h00000044    00000040 | 00000044 | 00000048 | 0000004c | 00000050 | 00000054 | 00000058 | 0000005c | 00000060 | 00...
mem_read      1'h1
mem_write     1'h0
hit_or_miss   1'h1
Tag_v         4'h1            1
address       10'h002         002
read_data     32'h0000000a    00000014 | 0000000a

Now           145 ns          120 ns  122 ns  124 ns  126 ns  128 ns  130 ns  132 ns  134 ns  136 ns  138
Cursor 1      121 ns          121 ns
```

Time’s Up!!!

Any Questions ?

Thank You

Special Thanks to our instructors & Supervisor

.Eng Ahamed El-Gammal

.Eng Fayza Hamada