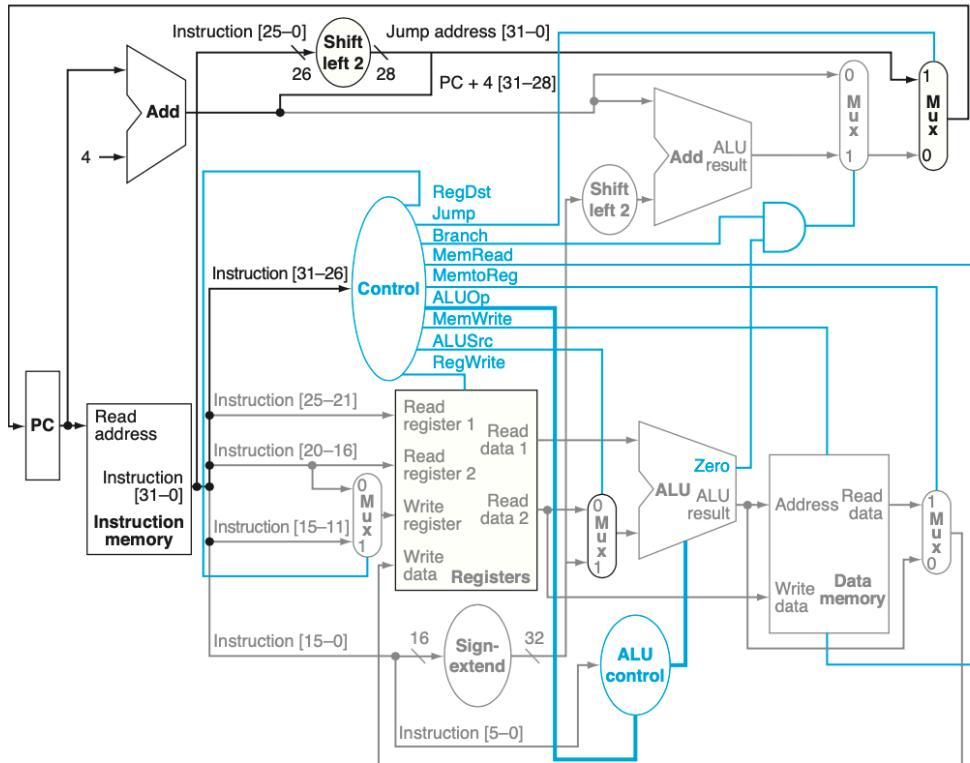


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Single Cycle Implementation diagram

	R-type addiu	sw	beq	jr
op5	0 0 1	1	0	0
op4	0 0 0	0	0	0
op3	0 1 0	1	0	0
op2	0 0 0	0	1	0
op1	0 0 1	1	0	1
op0	0 0 1	1	0	0
RegDst	1 0 0	x	x	0x
ALUSrc	0 0 1	1	0	0x
MemtoReg	0 0 1	x	x	0x
RegWrite	1 1 1	0	0	0x
MemoryWrite	0 0 0	1	0	0x
MemRead	0 0 1	0	0	0x
Branch	0 0 0	0	1	0x
ALUOp1	1 0 0	0	0	x
ALUOp0	0 0 0	0	1	x
jump	0 0 0	0	0	1

Control Signal

	lw	sw	beq	add	sub	and	or	slt
ALUOp1	0	0	0	1	1	1	1	1
ALUOp0	0	0	1	0	0	0	0	0
Func1[3]	x	x	x	0	0	0	0	1
Func1[2]	x	x	x	0	0	1	1	0
Func1[1]	x	x	x	0	1	0	0	1
Func1[0]	x	x	x	0	0	0	1	0
ALU[3]	0	0	0	0	0	0	0	0
ALU[2]	0	0	1	0	1	0	0	1
ALU[1]	1			1	1	0	0	1
ALU[0]	0	0	0	0	0	0	1	1

ALU Control Signal

## Results:

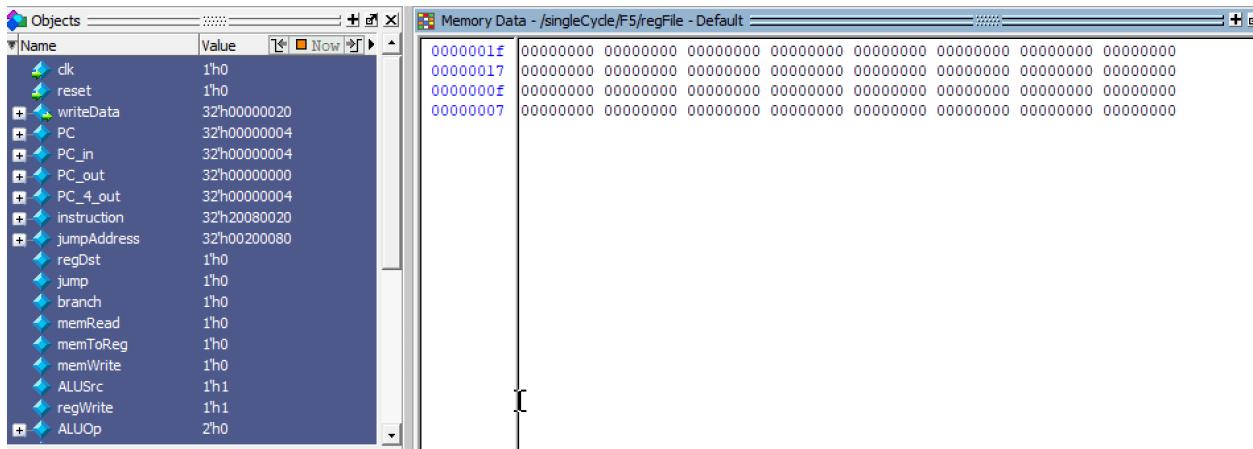
Instructions running during the program,

```

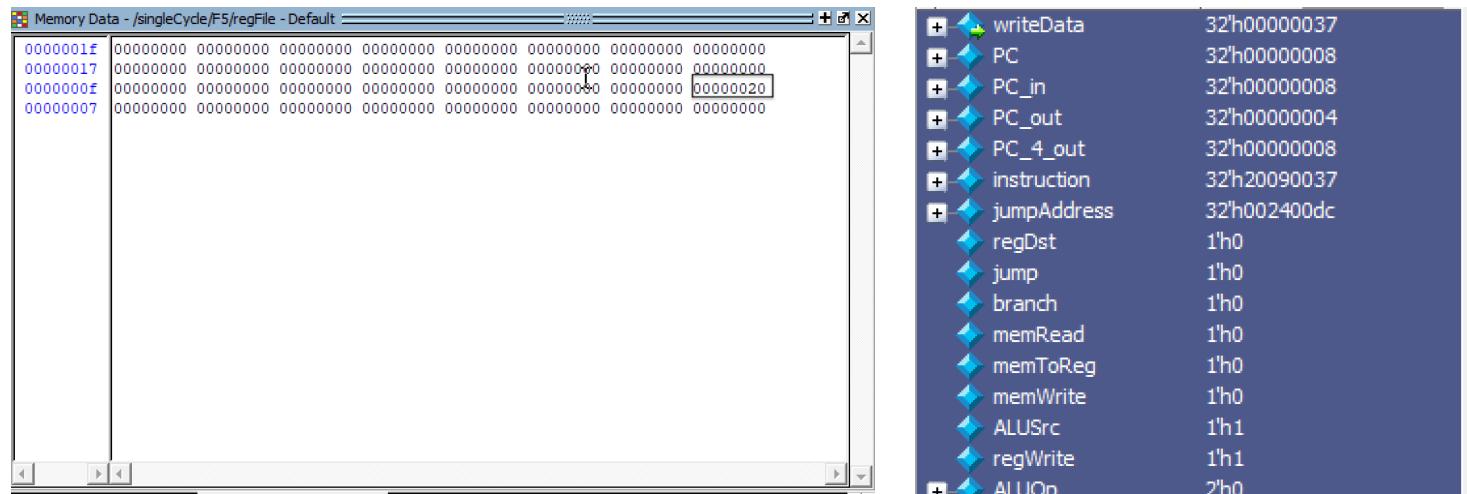
addi $t0, $zero, 32
addi $t1, $zero, 55
add $s0, $t0, $t1
sub $s1, $t0, $t1
and $s2, $t0, $t1
or $s3, $t0, $t1
LOOP: slt $s4, $t0, $t1
      beq $s4, $zero, EXIT
      add $t2, $t0, $t1
      add $t2, $t2, $t1
      add $t3, $t2, $t0
      lw $s5, 4($zero)
      add $s6, $t2, $s5
      add $s7, $s5, $t3
EXIT: sw $s5, 8($zero)
      j LOOP
    
```

- The results depicted in the below images are carried out with a clock of 100ns and also, the data to the write register is written back in the next clock cycle.
- regFile in the above images contains the data stored in the registers and memory file is for data memory

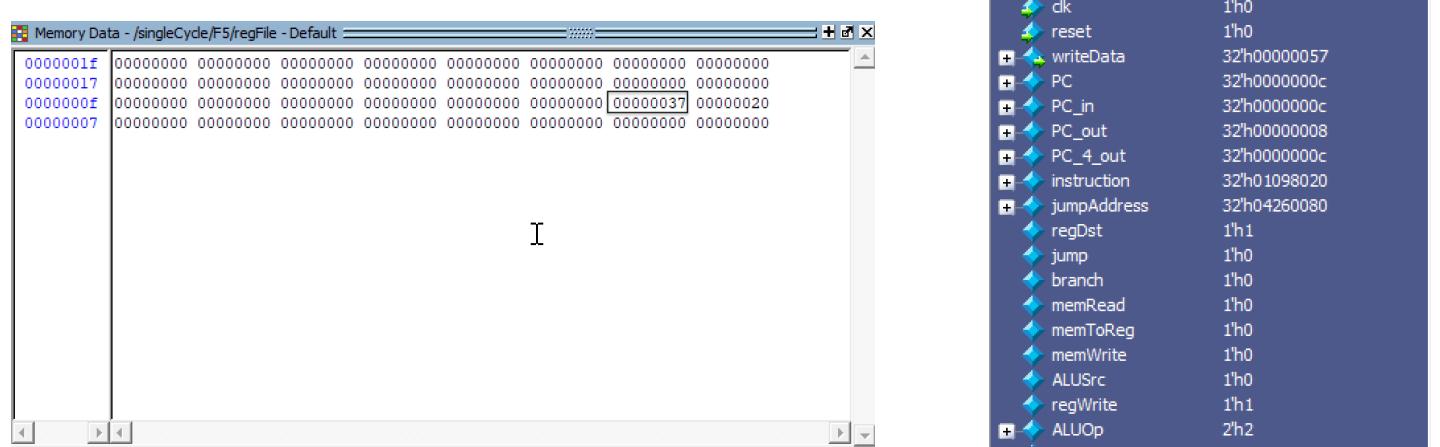
Time = 90 ns



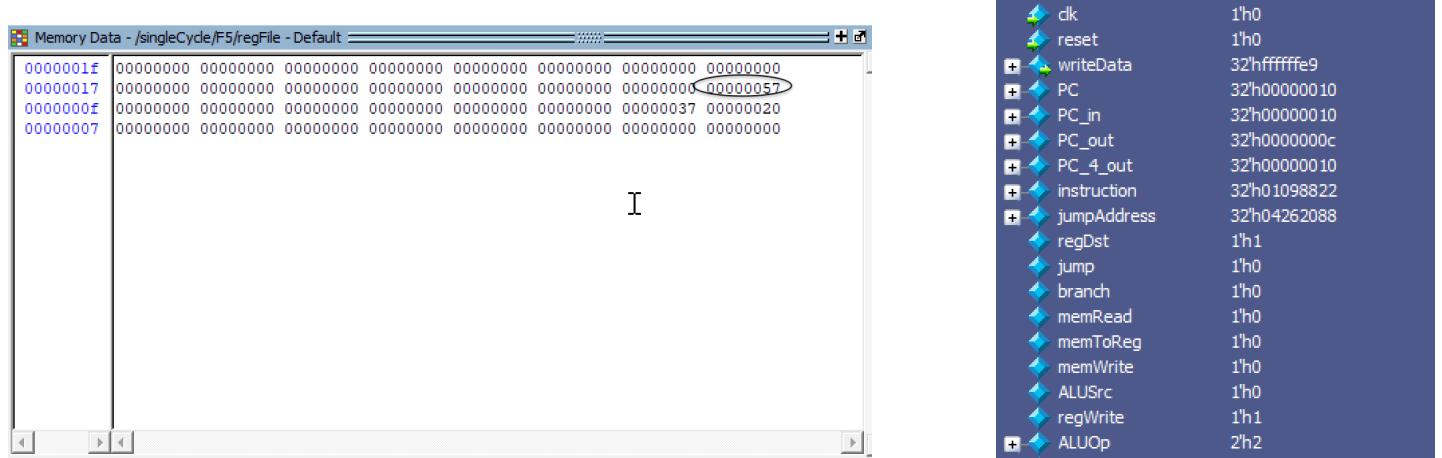
Time = 190 ns



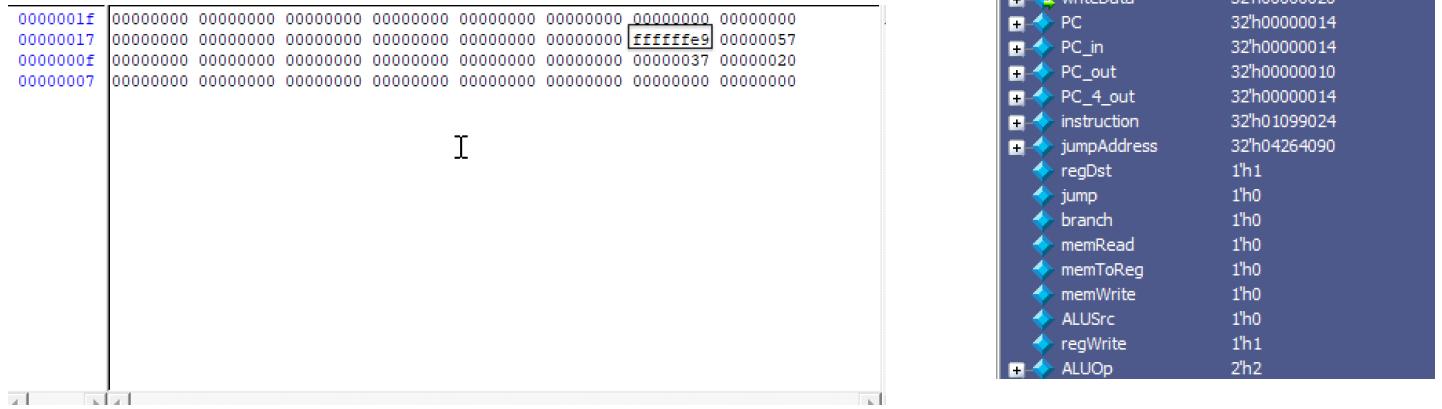
Time = 290 ns



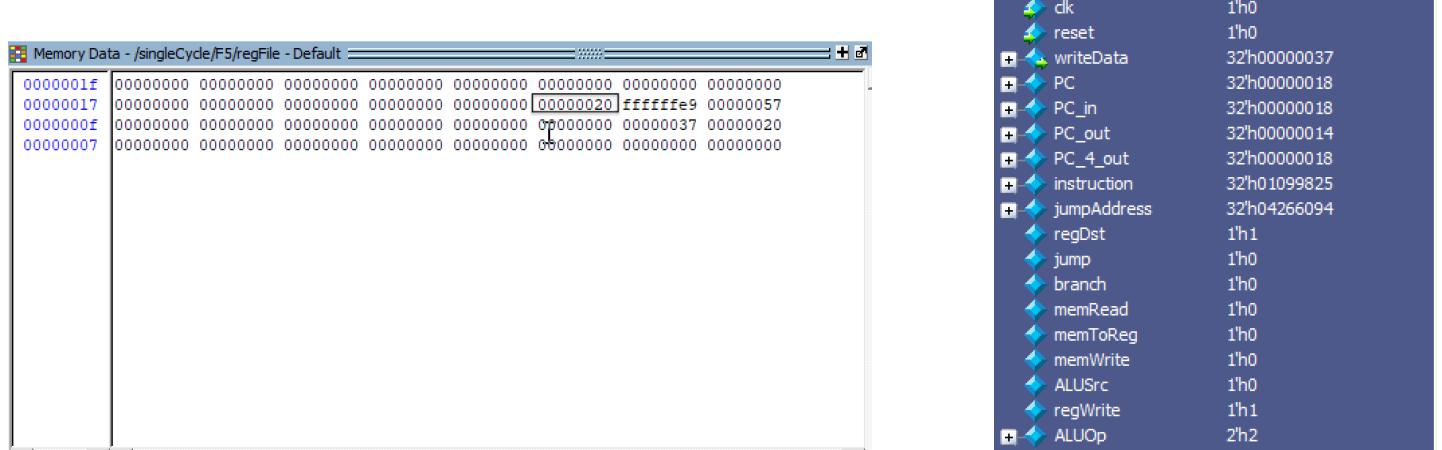
Time = 390 ns



Time = 490 ns



Time = 590 ns



Time = 690 ns

Memory Data - /singleCycle/F5/regFile - Default	
0000001f	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000017	00000000 00000000 00000000 00000037 00000020 ffffffe9 00000057
0000000f	00000000 00000000 00000000 00000000 00000000 00000000 00000037 00000020
00000007	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

clk	1'h0
reset	1'h0
writeData	32'h00000001
+ PC	32'h0000001c
+ PC_in	32'h0000001c
+ PC_out	32'h00000018
+ PC_4_out	32'h0000001c
+ instruction	32'h0109a02a
+ jumpAddress	32'h042680a8
+ regDst	1'h1
+ jump	1'h0
+ branch	1'h0
+ memRead	1'h0
+ memToReg	1'h0
+ memWrite	1'h0
+ ALUSrc	1'h0
+ regWrite	1'h1
+ ALUOp	2'h2

Time = 790 ns

Memory Data - /singleCycle/F5/regFile - Default	
0000001f	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000017	00000000 00000000 00000000 00000037 00000020 ffffffe9 00000057
0000000f	00000000 00000000 00000000 00000000 00000000 00000000 00000037 00000020
00000007	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

clk	1'h0
reset	1'h0
writeData	32'h00000001
+ PC	32'h00000020
+ PC_in	32'h00000020
+ PC_out	32'h0000001c
+ PC_4_out	32'h00000020
+ instruction	32'h12800006
+ jumpAddress	32'h0a000018
+ regDst	1'h0
+ jump	1'h0
+ branch	1'h1
+ memRead	1'h0
+ memToReg	1'h0
+ memWrite	1'h0
+ ALUSrc	1'h0
+ regWrite	1'h0
+ ALUOp	2'h1

Time = 890 ns, no branching

Objects	
Name	Value Now
clk	1'h1
reset	1'h0
+ PC	32'h00000024
+ PC_in	32'h00000024
+ PC_out	32'h00000020
+ PC_4_out	32'h00000024
+ instruction	32'h01095020
+ jumpAddress	32'h04254080
+ regDst	1'h1
+ jump	1'h0
+ branch	1'h0
+ memRead	1'h0
+ memToReg	1'h0
+ memWrite	1'h0

Time = 990 ns

Memory Data - /singleCycle/F5/regFile - Default							
	0000000f	00000000	00000000	00000000	00000000	00000000	00000000
0000001f	00000000	00000000	00000000	00000000	00000000	00000000	00000000
00000017	00000000	00000000	00000000	00000001	00000037	00000020	ffffffe9 00000057
0000000f	00000000	00000000	00000000	00000000	00000057	00000037	00000020
00000007	00000000	00000000	00000000	00000000	00000000	00000000	00000000

clk	1'h0
reset	1'h0
writeData	32'h0000008e
PC	32'h00000028
PC_in	32'h00000028
PC_out	32'h00000024
PC_4_out	32'h00000028
instruction	32'h01495020
jumpAddress	32'h05254080
regDst	1'h1
jump	1'h0
branch	1'h0
memRead	1'h0
memToReg	1'h0
memWrite	1'h0
ALUSrc	1'h0
regWrite	1'h1
ALUOp	2'h2

Time = 1090 ns

Memory Data - /singleCycle/F5/regFile - Default							
	0000000f	00000000	00000000	00000000	00000000	00000000	00000000
0000001f	00000000	00000000	00000000	00000000	00000000	00000000	00000000
00000017	00000000	00000000	00000000	00000001	00000037	00000020	ffffffe9 00000057
0000000f	00000000	00000000	00000000	00000000	0000008e	00000037	00000020
00000007	00000000	00000000	00000000	00000000	00000000	00000000	00000000

clk	1'h0
reset	1'h0
writeData	32'h000000ae
PC	32'h0000002c
PC_in	32'h0000002c
PC_out	32'h00000028
PC_4_out	32'h0000002c
instruction	32'h01485820
jumpAddress	32'h05216080
regDst	1'h1
jump	1'h0
branch	1'h0
memRead	1'h0
memToReg	1'h0
memWrite	1'h0
ALUSrc	1'h0
regWrite	1'h1
ALUOp	2'h2

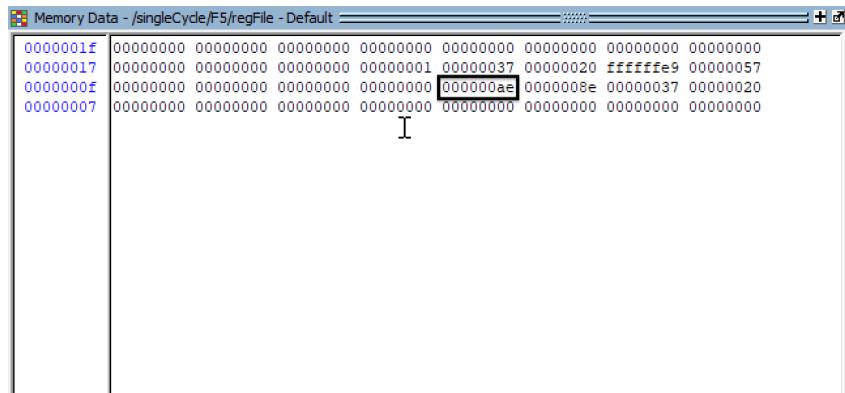
Time = 1190 ns, lw instruction

Memory Data - /singleCycle/F5/regFile - Default							
	0000000f	00000000	00000000	00000000	00000000	00000000	00000000
0000001f	00000000	00000000	00000000	00000000	00000000	00000000	00000000
00000017	00000000	00000000	00000000	00000001	00000037	00000020	ffffffe9 00000057
0000000f	00000000	00000000	00000000	000000ae	0000008e	00000037	00000020
00000007	00000000	00000000	00000000	00000000	00000000	00000000	00000000

clk	1'h0
reset	1'h0
writeData	32'h00000000
PC	32'h00000030
PC_in	32'h00000030
PC_out	32'h0000002c
PC_4_out	32'h00000030
instruction	32'h8c150004
jumpAddress	32'h00540010
regDst	1'h0
jump	1'h0
branch	1'h0
memRead	1'h1
memToReg	1'h1
memWrite	1'h0
ALUSrc	1'h1
regWrite	1'h1
ALUOp	2'h0

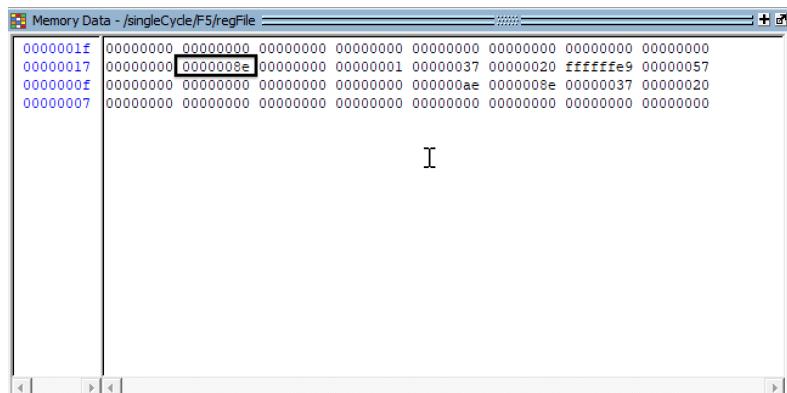
sim:/single

Time = 1290 ns



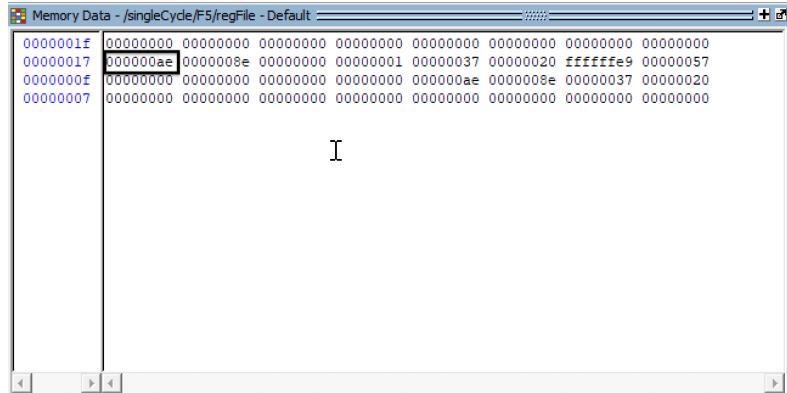
dk	1'h0
reset	1'h0
+ writeData	32'h0000008e
+ PC	32'h00000034
+ PC_in	32'h00000034
+ PC_out	32'h00000030
+ PC_4_out	32'h00000034
+ instruction	32'h0155b020
+ jumpAddress	32'h0556c080
+ regDst	1'h1
+ jump	1'h0
+ branch	1'h0
+ memRead	1'h0
+ memToReg	1'h0
+ memWrite	1'h0
+ ALUSrc	1'h0
+ regWrite	1'h1
+ ALUOp	2'h2

Time = 1390 ns



dk	1'h0
reset	1'h0
+ writeData	32'h000000ae
+ PC	32'h00000038
+ PC_in	32'h00000038
+ PC_out	32'h00000034
+ PC_4_out	32'h00000038
+ instruction	32'h02abb820
+ jumpAddress	32'h0aaeee080
+ regDst	1'h1
+ jump	1'h0
+ branch	1'h0
+ memRead	1'h0
+ memToReg	1'h0
+ memWrite	1'h0
+ ALUSrc	1'h0
+ regWrite	1'h1
+ ALUOp	2'h2

Time = 1490 ns



dk	1'h0
reset	1'h0
+ writeData	32'h00000008
+ PC	32'h0000003c
+ PC_in	32'h0000003c
+ PC_out	32'h00000038
+ PC_4_out	32'h0000003c
+ instruction	32'h20150008
+ jumpAddress	32'h00540020
+ regDst	1'h0
+ jump	1'h0
+ branch	1'h0
+ memRead	1'h0
+ memToReg	1'h0
+ memWrite	1'h0
+ ALUSrc	1'h1
+ regWrite	1'h1
+ ALUOp	2'h0

Time = 1590 ns, sw instruction, memory file is shown instead of register file

The screenshot shows two windows from the ModelSim simulation environment. On the left is the 'Objects' window, which lists various simulation objects with their current values. On the right is the 'Memory Data' window, which displays memory contents at a specific address.

**Objects Window:**

Name	Value
clk	1'h0
reset	1'h0
+ writeData	32'h00000008
+ PC	32'h00000040
+ PC_in	32'h00000040
+ PC_out	32'h0000003c
+ PC_4_out	32'h00000040
+ instruction	32'hac15008
+ jumpAddress	32'h00540020
regDst	1'h0
jump	1'h0
branch	1'h0
memRead	1'h0
memToReg	1'h0
memWrite	1'h1
ALUSrc	1'h1
regWrite	1'h0
+ ALUOp	2'h0

**Memory Data Window:**

Address	Value
0000007f	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000077	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0000006f	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000067	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0000005e	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000057	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0000004e	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000047	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0000003f	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000037	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0000002f	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000027	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0000001f	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000017	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0000000f	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00000007	00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000

Time = 1690 ns, jump instruction

The screenshot shows the 'Objects' window from the ModelSim simulation environment. It lists various simulation objects with their current values. A tooltip 'sim:/singleC' is visible near the bottom right of the window.

Name	Value
clk	1'h0
reset	1'h0
+ writeData	32'h00000000
+ PC	32'h00000018
+ PC_in	32'h00000018
+ PC_out	32'h00000040
+ PC_4_out	32'h00000044
+ instruction	32'h08000006
+ jumpAddress	32'h00000018
regDst	1'h0
jump	1'h1
branch	1'h0
memRead	1'h0
memToReg	1'h0
memWrite	1'h0
ALUSrc	1'h0
regWrite	1'h0
+ ALUOp	2'h0