

out-ex1.txt

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1

```
./run-ex1.sh
TEST: ex1
./freess -exe program-ex1 -pw 4 -wins 16 -pregs 24 -robs 99 -lqs 3 -sqs 3 -llat 2 -afu 1 -int no
```

LIST OF INITIALIZATION PARAMETERS

-----[General]

```
Program Name      = program-ex1
Silent            = no
Interactive       = no
Mode              = no
Iterations        = 3
Starting Cycle    = 0
```

-----[Architecture]

```
Logical Registers = 8
Physical Registers = 24
Pipeline Structure = FDPiXWC
Unified LSU       = yes
In-Order Issue    = no
In-Order Complete = no
Unified Dispatch/Issue = yes
Fetch Width       = 4
Decode Width      = 4
Dispatch Width    = 4
Issue Width       = 4
Write-Back Width  = 4
Commit Width      = 4
Window Size       = 16
ROB Size          = 99
Integer ALU Units  = 1
Integer ALU Latency = 0
Integer Mult. Units = 1
Integer Mult. Latency = 4
Integer Mult. Pipe = yes
Floating Point Units = 4
Floating Point Mult = 1
Load Units        = 1
Load Latency      = 2
Load Pipe         = yes
Store Units       = 1
Store Latency     = 1
Store Pipe        = yes
Branch Units      = 1
Branch Latency    = 0
Load Queue Size   = 3
Store Queue Size  = 3
Speculation       = yes
Write Back Latency = 0
```

-----[Program Defaults]

```
Log File Name      = def.log
-----
```

* Input program: 'program-ex1'

```
x1 <-- 00001000
x4 <-- 00004000
x5 <-- 00005000
x6 <-- 00006000
000) 1 3 4 2 --> LW    x3,2(x4)
001) 1 7 5 2 --> LW    x7,2(x5)
002) 7 7 7 3 --> MUL   x7,x7,x3
003) 6 1 1 -1 --> ADDI  x1,x1,-1
004) 2 7 6 2 --> SW    x7,2(x6)
005) 6 2 2 8 --> ADDI  x2,x2,8
006) 4 1 0 -7 --> BNE   x1,x0,-7
```

* TOTAL_ INSTRUCTIONS=7

* NUMBER_OF_ITERATIONS=3

```
- STAGE = 4 entries.
  FETCH STAGE = 4 entries.
  DECODE STAGE = 4 entries.
  DISPATCH STAGE = 4 entries.
  ISSUE STAGE = 4 entries.
```

2

REG.FILE: xi:	1	2	3	4	5	6	7	8
Pi:	7	-	2	1	3	-	5	-
Qi:	1	0	1	0	0	0	1	0

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3

Vi: 00001000 00000000 00000000 00004000 00005000 00006000 00000000 00000000

```
=====
STAGES:          F D P I X W C RENAMED-STR    INSTRUCTION-WINDOW          REORDER-BUFFER          A M L S B F X
TOTAL SLOTS:     4 4 4 4 9 4 4 24            16                      99                      1 1 1 0 1 4 1
BUSY SLOTS:      3 4 0 0 0 0 0 7              0                      0                      0 0 0 0 0 0 0
STALLS:          0 0 0 0 0 0 0 0              0                      0                      0 0 0 0 0 0 0
=====
PC  INSTRUCTION   F D P I X W C Pi,Pj Pk Pl    IW#  OPCD Pi  Pj  Pk I/Pl  Cj Ck Cl  ROB# PC  xi  oPi s x c  +-----+
000] LW  x3,2(x4)  0 1                P2,2(P1)    000)  LW P2 P1 - 2 2 - - 000) 000 x3 - 0 0 0  |LQ(0 )|
001] LW  x7,2(x5)  0 1                P4,2(P3)    001)  LW P4 P3 - 2 2 - - 001) 001 x7 - 0 0 0  |PC  OP Pi  EFAD Ci|
002] MUL  x7,x7,x3  0 1                P5,P4,P2    002)  MUL P5 P4 P2 - . . - 002) 002 x7 P4 0 0 0  +-----+
003] ADDI x1,x1,-1  0 1                P7,P6,-1    003)  ADDI P7 P6 - -1 2 - - 003) 003 x1 P6 0 0 0  +-----+
004] SW   x7,2(x6)  1                      ,2(P8)<-P5    004]  SW  x7,2(x6)  1 2                      |SQ(0 )|
005] ADDI x2,x2,8   1                      P10,P9,8     005]  ADDI x2,x2,8   1 2                      |PC  OP Pi  EFAD Cl|
006] BNE  x1,x0,-7  1                      ,P7,P0,-7    006]  BNE  x1,x0,-7  1 2                      +-----+
----- Press ENTER to continue (PC=0,IC=7,CK=1,CTOT=2,IPC=3.50)...
```

```
=====
PHYSICAL REGS:  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                * * * * *
qi:  0 1 0 1 1 0 1 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1
vi:  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
=====
REG.FILE: xi:      1      2      3      4      5      6      7      8
          Pi:      7      10     2      1      3      8      5      -
          Qi:      1      1      1      0      0      0      1      0
          Vi: 00001000 00000000 00000000 00004000 00005000 00006000 00000000 00000000
=====
STAGES:          F D P I X W C RENAMED-STR    INSTRUCTION-WINDOW          REORDER-BUFFER          A M L S B F X
TOTAL SLOTS:     4 4 4 4 9 4 4 24            16                      99                      1 1 1 0 1 4 1
BUSY SLOTS:      4 3 4 0 0 0 0 10            4                      4                      0 0 0 0 0 0 0
STALLS:          0 0 0 0 0 0 0 0              0                      0                      0 0 0 0 0 0 0
=====
PC  INSTRUCTION   F D P I X W C Pi,Pj Pk Pl    IW#  OPCD Pi  Pj  Pk I/Pl  Cj Ck Cl  ROB# PC  xi  oPi s x c  +-----+
000] LW  x3,2(x4)  0 1 2                P2,2(P1)    000)  LW P2 P1 - 2 2 - - 000) 000 x3 - 0 0 0  |LQ(0 )|
001] LW  x7,2(x5)  0 1 2                P4,2(P3)    001)  LW P4 P3 - 2 2 - - 001) 001 x7 - 0 0 0  |PC  OP Pi  EFAD Ci|
002] MUL  x7,x7,x3  0 1 2                P5,P4,P2    002)  MUL P5 P4 P2 - . . - 002) 002 x7 P4 0 0 0  +-----+
003] ADDI x1,x1,-1  0 1 2                P7,P6,-1    003)  ADDI P7 P6 - -1 2 - - 003) 003 x1 P6 0 0 0  +-----+
004] SW   x7,2(x6)  1 2                      ,2(P8)<-P5    004]  SW  x7,2(x6)  1 2                      |SQ(0 )|
005] ADDI x2,x2,8   1 2                      P10,P9,8     005]  ADDI x2,x2,8   1 2                      |PC  OP Pi  EFAD Cl|
006] BNE  x1,x0,-7  1 2                      ,P7,P0,-7    006]  BNE  x1,x0,-7  1 2                      +-----+
007] LW  x3,2(x4)  2
008] LW  x7,2(x5)  2
009] MUL  x7,x7,x3  2
010] ADDI x1,x1,-1  2
----- Press ENTER to continue (PC=4,IC=11,CK=2,CTOT=3,IPC=3.67)...
```

```
=====
PHYSICAL REGS:  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                * * * * *
qi:  0 1 0 1 1 0 1 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1
vi:  00 00 00 00 00 00 FF 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
=====
REG.FILE: xi:      1      2      3      4      5      6      7      8
          Pi:      7      10     11     1      3      8      13     -
          Qi:      1      1      1      0      0      0      1      0
          Vi: 00001000 00000000 00000000 00004000 00005000 00006000 00000000 00000000
=====
STAGES:          F D P I X W C RENAMED-STR    INSTRUCTION-WINDOW          REORDER-BUFFER          A M L S B F X
TOTAL SLOTS:     4 4 4 4 9 4 4 24            16                      99                      1 1 1 0 1 4 1
BUSY SLOTS:      4 4 4 0 2 0 0 13            4                      6                      0 0 0 0 0 0 0
STALLS:          0 1 1 2 0 0 0 0              0                      0                      0 0 1 0 0 0 0
=====
PC  INSTRUCTION   F D P I X W C Pi,Pj Pk Pl    IW#  OPCD Pi  Pj  Pk I/Pl  Cj Ck Cl  ROB# PC  xi  oPi s x c  +-----+
000] LW  x3,2(x4)  0 1 2 3 3                P2,2(P1)    000>  LW P2 P1 - 2 3 3 - 000) 000 x3 - 0 0 0  |LQ(1 )|
001] LW  x7,2(x5)  0 1 2                P4,2(P3)    001)  LW P4 P3 - 2 2 - - 001) 001 x7 - 0 0 0  |PC  OP Pi  EFAD Ci|
002] MUL  x7,x7,x3  0 1 2                P5,P4,P2    002)  MUL P5 P4 P2 - . . - 002) 002 x7 P4 0 0 0  |000] LW P2 4002 3|
003] ADDI x1,x1,-1  0 1 2 3 3                P7,P6,-1    003>  ADDI P7 P6 - -1 3 3 - 003) 003 x1 P6 0 0 0  +-----+
```

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```
004] SW    x7,2(x6)      1 2 3      ,2(P8)<-P5      000) SW - P5 P8 2 - 3 - 004) 004 - - 1 0 0
005] ADDI x2,x2,8        1 2 3      P10,P9,8      003) ADDI P10 P9 - 8 3 - - 005) 005 x2 P9 0 0 0
006] BNE x1,x0,-7        1 2      ,P7,P0,-7
007] LW x3,2(x4)          2 3      P11,2(P1)
008] LW x7,2(x5)          2 3      P12,2(P3)
009] MUL x7,x7,x3         2 3      P13,P12,P11
010] ADDI x1,x1,-1        2
011] SW x7,2(x6)          3
012] ADDI x2,x2,8         3
013] BNE x1,x0,-7        3
```

```
+-----+
|SQ(0 )|
|PC  OP P1 EFAD C1|
+-----+
```

----- Press ENTER to continue (PC=0,IC=14,CK=3,CTOT=4,IPC=3.50) ...

```
@003 stall due to no L-unit available
@003 stall due to NO SLOTS when trying to move instnction LW/001 from stage P to stage I.
@003 stall due to NO SLOTS when trying to move instnction MUL/002 from stage P to stage I.
@003 stall due to NO SLOTS when trying to move instnction BNE/006 from stage D to stage P.
@003 stall due to NO SLOTS when trying to move instnction ADDI/010 from stage F to stage D.
```

=====

PHYSICAL REGS: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

```
qi: 0 1 0 1 1 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
vi: 00 00 00 00 00 00 FF 00 00 08 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

=====

REG.FILE: xi: 1 2 3 4 5 6 7 8

Pi: 14 10 11 1 3 8 13 -

Qi: 1 1 1 0 0 0 1 0

Vi: 00000FFF 00000000 00000000 00004000 00005000 00006000 00000000 00000000

=====

STAGES:	F	D	P	I	X	W	C	RENAMED-STR	INSTRUCTION-WINDOW	REORDER-BUFFER	A	M	L	S	B	F	X
TOTAL SLOTS:	4	4	4	4	9	4	4	24	16	99	1	1	1	0	1	4	1
BUSY SLOTS:	4	4	4	0	2	1	0	14	4	8	0	0	0	0	0	0	0
STALLS:	0	3	3	4	0	0	0	0	0	0	0	0	2	0	0	0	0

=====

PC	INSTRUCTION	F	D	P	I	X	W	C	Pi,Pj	Pk	P1	IW#	OPCD	Pi	Pj	Pk	I/P1	Cj	Ck	C1	ROB#	PC	xi	oPi	s	x	c
000]	LW x3,2(x4)	0	1	2	3	3			P2,2(P1)			----	LW	P2	P1	-	2	3	3	-	000)	000	x3	-	0	0	0
001]	LW x7,2(x5)	0	1	2					P4,2(P3)			001)	LW	P4	P3	-	2	2	-	-	001)	001	x7	-	0	0	0
002]	MUL x7,x7,x3	0	1	2					P5,P4,P2			002)	MUL	P5	P4	P2	-	.	.	-	002)	002	x7	P4	0	0	0
003]	ADDI x1,x1,-1	0	1	2	3	3	4		P7,P6,-1			----	ADDI	P7	P6	-	-1	3	3	-	003)	003	x1	P6	0	0	1
004]	SW x7,2(x6)	1	2	3	4	4			,2(P8)<-P5			000>	SW	-	P5	P8	2	-	4	-	004)	004	-	-	1	0	0
005]	ADDI x2,x2,8	1	2	3	4	4			P10,P9,8			003>	ADDI	P10	P9	-	8	4	4	-	005)	005	x2	P9	0	0	0
006]	BNE x1,x0,-7	1	2	4					,P7,P0,-7			000)	BNE	-	P7	P0	-7	4	4	-	006)	006	-	-	0	0	0
007]	LW x3,2(x4)	2	3	4					P11,2(P1)			003)	LW	P11	P1	-	2	4	-	-	007)	000	x3	P2	0	0	0
008]	LW x7,2(x5)	2	3						P12,2(P3)																		
009]	MUL x7,x7,x3	2	3						P13,P12,P11																		
010]	ADDI x1,x1,-1	2	4						P14,P7,-1																		
011]	SW x7,2(x6)	3	4						,2(P8)<-P13																		
012]	ADDI x2,x2,8	3																									
013]	BNE x1,x0,-7	3																									
014]	LW x3,2(x4)	4																									
015]	LW x7,2(x5)	4																									

=====

----- Press ENTER to continue (PC=2,IC=16,CK=4,CTOT=5,IPC=3.20) ...

```
@004 stall due to no L-unit available
@004 stall due to NO SLOTS when trying to move instnction LW/001 from stage P to stage I.
@004 stall due to NO SLOTS when trying to move instnction MUL/002 from stage P to stage I.
@004 stall due to NO SLOTS when trying to move instnction LW/008 from stage D to stage P.
@004 stall due to NO SLOTS when trying to move instnction MUL/009 from stage D to stage P.
@004 stall due to NO SLOTS when trying to move instnction ADDI/012 from stage F to stage D.
@004 stall due to NO SLOTS when trying to move instnction BNE/013 from stage F to stage D.
```

=====

PHYSICAL REGS: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

```
qi: 0 0 0 1 1 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1
vi: 00 00 00 00 00 00 FF 00 00 08 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

=====

REG.FILE: xi: 1 2 3 4 5 6 7 8

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```
Pi:      14      15      11      1      3      8      13      -
Qi:      1      1      1      0      0      0      1      0
Vi:  00000FFF 00000008 00000000 00004000 00005000 00006000 00000000 00000000

=====
STAGES:          F D P I X W C RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A M L S B F X
TOTAL SLOTS:     4 4 4 4 9 4 4 24          16                99          1 1 1 0 1 4 1
BUSY SLOTS:      4 4 4 0 2 1 0 15          4                10          0 0 0 0 0 0 0
STALLS:          0 5 5 6 0 0 1 0           0                0          0 0 3 0 0 0 0
=====

PC  INSTRUCTION  F D P I X W C Pi,Pj Pk P1  IW#  OPCODE Pi Pj Pk I/P1  Cj Ck Cl  ROB# PC xi oPi s x c  +-----+
000] LW  x3,2(x4)  0 1 2 3 3 5  C P1,2(P1)  ----  LW P2 P1 - 2 3 3 - 000) 000 x3 - 0 0 1  |LQ(1 )|
001] LW  x7,2(x5)  0 1 2 5 5  P4,2(P3)  001>  LW P4 P3 - 2 5 5 - 001) 001 x7 - 0 0 0  |PC  OP Pi EFAD Ci|
002] MUL  x7,x7,x3  0 1 2  P5,P4,P2  002)  MUL P5 P4 P2 - . . - 002) 002 x7 P4 0 0 0  |---- LW P2 4002 5|
003] ADDI x1,x1,-1  0 1 2 3 3 4  P7,P6,-1  ----  ADDI P7 P6 - -1 3 3 - 003) 003 x1 P6 0 0 1  |001] LW P4 5002 5|
004] SW  x7,2(x6)  1 2 3 4 4  ,2(P8)<-P5  ----  SW - P5 P8 2 - 4 - 004) 004 - - 1 0 0  +-----+
005] ADDI x2,x2,8  1 2 3 4 4 5  P10,P9,8  ----  ADDI P10 P9 - 8 4 4 - 005) 005 x2 P9 0 0 1  +-----+
006] BNE  x1,x0,-7  1 2 4 5 5  ,P7,P0,-7  000>  BNE - P7 P0 -7 5 5 - 006) 006 - - 0 0 0  |SQ(1 )|
007] LW  x3,2(x4)  2 3 4  P11,2(P1)  003)  LW P11 P1 - 2 4 - - 007) 000 x3 P2 0 0 0  |PC  OP P1 EFAD Cl|
008] LW  x7,2(x5)  2 3 5  P12,2(P3)  000)  LW P12 P3 - 2 5 - - 008) 001 x7 P5 0 0 0  |. SW P5 6002 .|
009] MUL  x7,x7,x3  2 3 5  P13,P12,P11 001)  MUL P13 P12 P11 - . . - 009) 002 x7 P12 0 0 0  +-----+
010] ADDI x1,x1,-1  2 4  P14,P7,-1  +-----+
011] SW  x7,2(x6)  3 4  ,2(P8)<-P13  +-----+
012] ADDI x2,x2,8  3 5  P15,P10,8  +-----+
013] BNE  x1,x0,-7  3 5  ,P14,P0,-7  +-----+
014] LW  x3,2(x4)  4  +-----+
015] LW  x7,2(x5)  4  +-----+
016] MUL  x7,x7,x3  5  +-----+
017] ADDI x1,x1,-1  5  +-----+

----- Press ENTER to continue (PC=4,IC=18,CK=5,CTOT=6,IPC=3.00)...
@005 stall due to NO SLOTS when trying to move instnction ADDI/003 from stage W to stage C.
@005 stall due to NO SLOTS when trying to move instnction MUL/002 from stage P to stage I.
@005 stall due to no L-unit available
@005 stall due to NO SLOTS when trying to move instnction LW/007 from stage P to stage I.
@005 stall due to NO SLOTS when trying to move instnction ADDI/010 from stage D to stage P.
@005 stall due to NO SLOTS when trying to move instnction SW/011 from stage D to stage P.
@005 stall due to NO SLOTS when trying to move instnction LW/014 from stage F to stage D.
@005 stall due to NO SLOTS when trying to move instnction LW/015 from stage F to stage D.

=====
PHYSICAL REGS:  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                * * * * * * * * * * * * * *
qi:  0 0 0 1 1 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1
vi:  00 00 00 00 00 00 FF 00 00 08 00 00 00 00 00 00 00 00 00 00 00 00 00 00

=====
REG.FILE: xi:      1      2      3      4      5      6      7      8
Pi:      14      15      16      1      3      8      13      -
Qi:      1      1      1      0      0      0      1      0
Vi:  00000FFF 00000008 00000000 00004000 00005000 00006000 00000000 00000000

=====
STAGES:          F D P I X W C RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A M L S B F X
TOTAL SLOTS:     4 4 4 4 9 4 4 24          16                99          1 1 1 0 1 4 1
BUSY SLOTS:      4 4 4 0 2 1 0 16          4                10          0 0 0 0 0 0 0
STALLS:          0 8 8 9 0 0 1 0           0                0          0 0 4 0 0 0 0
=====

PC  INSTRUCTION  F D P I X W C Pi,Pj Pk P1  IW#  OPCODE Pi Pj Pk I/P1  Cj Ck Cl  ROB# PC xi oPi s x c  +-----+
000] LW  x3,2(x4)  0 1 2 3 3 5 6 P2,2(P1)  ----  LW P2 P1 - 2 3 3 - ---- 000 x3 - 0 0 1  |LQ(2 )|
001] LW  x7,2(x5)  0 1 2 5 5  P4,2(P3)  ----  LW P4 P3 - 2 5 5 - 001) 001 x7 - 0 0 0  |PC  OP Pi EFAD Ci|
002] MUL  x7,x7,x3  0 1 2  P5,P4,P2  002)  MUL P5 P4 P2 - . . - 002) 002 x7 P4 0 0 0  |---- LW P2 4002 5|
003] ADDI x1,x1,-1  0 1 2 3 3 4  P7,P6,-1  ----  ADDI P7 P6 - -1 3 3 - 003) 003 x1 P6 0 0 1  |001] LW P4 5002 5|
004] SW  x7,2(x6)  1 2 3 4 4 5  ,2(P8)<-P5  ----  SW - P5 P8 2 - 4 - 004) 004 - - 1 0 0  |007] LW P11 4002 6|
005] ADDI x2,x2,8  1 2 3 4 4 5  P10,P9,8  ----  ADDI P10 P9 - 8 4 4 - 005) 005 x2 P9 0 0 1  +-----+
006] BNE  x1,x0,-7  1 2 4 5 5 6  ,P7,P0,-7  ----  BNE - P7 P0 -7 5 5 - 006) 006 - - 0 0 1  +-----+
007] LW  x3,2(x4)  2 3 4 6 6  P11,2(P1)  003>  LW P11 P1 - 2 6 6 - 007) 000 x3 P2 0 0 0  +-----+
008] LW  x7,2(x5)  2 3 5  P12,2(P3)  000)  LW P12 P3 - 2 5 - - 008) 001 x7 P5 0 0 0  |SQ(1 )|
009] MUL  x7,x7,x3  2 3 5  P13,P12,P11 001)  MUL P13 P12 P11 - . . - 009) 002 x7 P12 0 0 0  |PC  OP P1 EFAD Cl|
010] ADDI x1,x1,-1  2 4 6  P14,P7,-1  003)  ADDI P14 P7 - -1 6 - - 010) 003 x1 P7 0 0 0  |. SW P5 6002 .|
011] SW  x7,2(x6)  3 4  ,2(P8)<-P13  +-----+
012] ADDI x2,x2,8  3 5  P15,P10,8  +-----+
```


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```
qi:  0 0 0 0 1 0 0 0 0 0 0 1 1 0 1 1 1 1 1 1 1 1
vi:  00 00 00 00 00 00 FF 00 00 08 00 00 00 FE 10 00 00 00 00 00 00 00 00 00

=====
REG.FILE: xi:      1      2      3      4      5      6      7      8
          Pi:     19     20     16      1      3      8     18      -
          Qi:      1      1      1      0      0      0      1      0
          Vi: 00000FFE 00000008 00000000 00004000 00005000 00006000 00000000 00000000

=====
STAGES:          F D P I X W C RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A M L S B F X
TOTAL SLOTS:      4 4 4 4 9 4 4 24          16                    99                    1 1 1 0 1 4 1
BUSY SLOTS:       0 4 4 0 4 1 0 20          4                     15                    0 0 0 0 0 0 0
STALLS:          0 9 10 11 0 0 2 0          0                     0                    0 0 4 0 0 0 0

=====
PC  INSTRUCTION  F D P I X W C Pi,Pj Pk P1  IW#  OPCD Pi Pj Pk I/P1  Cj Ck Cl  ROB# PC xi oPi s x c  +-----+
000] LW  x3,2(x4)  0 1 2 3 3 5 6 P2,2(P1)  ----  LW P2 P1 - 2 3 3 -  ---- 000 x3 - 0 0 1  |LQ(1 )|
001] LW  x7,2(x5)  0 1 2 5 5 7 8 P4,2(P3)  ----  LW P4 P3 - 2 5 5 -  ---- 001 x7 - 0 0 1  |PC  OP Pi EFAD Ci|
002] MUL  x7,x7,x3  0 1 2 7 7      P5,P4,P2  ----  MUL P5 P4 P2 - 7 7 - 002) 002 x7 P4 0 0 0  |---- LW P2 4002 5|
003] ADDI x1,x1,-1  0 1 2 3 3 4      P7,P6,-1  ----  ADDI P7 P6 - -1 3 3 - 003) 003 x1 P6 0 0 1  |---- LW P4 5002 7|
004] SW  x7,2(x6)  1 2 3 4 4      ,2(P8)<-P5  ----  SW - P5 P8 2 - 4 - 004) 004 - - 1 0 0  |---- LW P11 4002 8|
005] ADDI x2,x2,8   1 2 3 4 4 5      P10,P9,8  ----  ADDI P10 P9 - 8 4 4 - 005) 005 x2 P9 0 0 1  |008] LW P12 5002 7|
006] BNE  x1,x0,-7  1 2 4 5 5 6      ,P7,P0,-7  ----  BNE - P7 P0 -7 5 5 - 006) 006 - - 0 0 1  +-----+
007] LW  x3,2(x4)  2 3 4 6 6 8      P11,2(P1)  ----  LW P11 P1 - 2 6 6 - 007) 000 x3 P2 0 0 1  |
008] LW  x7,2(x5)  2 3 5 7 7      P12,2(P3)  ----  LW P12 P3 - 2 7 7 - 008) 001 x7 P5 0 0 0  +-----+
009] MUL  x7,x7,x3  2 3 5      P13,P12,P11 001) MUL P13 P12 P11 - . - 009) 002 x7 P12 0 0 0  |SQ(2 )|
010] ADDI x1,x1,-1  2 4 6 7 7 8      P14,P7,-1  ----  ADDI P14 P7 - -1 7 7 - 010) 003 x1 P7 0 0 1  |PC  OP P1 EFAD C1|
011] SW  x7,2(x6)  3 4 7 8 8      ,2(P8)<-P13 000> SW - P13 P8 2 - 8 - 011) 004 - - 1 0 0  |. SW P5 6002 .|
012] ADDI x2,x2,8   3 5 7 8 8      P15,P10,8 002> ADDI P15 P10 - 8 8 8 - 012) 005 x2 P10 0 0 0  |. SW P13 6002 .|
013] BNE  x1,x0,-7  3 5 7 8 8      ,P14,P0,-7 003> BNE - P14 P0 -7 8 8 - 013) 006 - - 0 0 0  +-----+
014] LW  x3,2(x4)  4 6 8      P16,2(P1) 000) LW P16 P1 - 2 8 8 - 014) 000 x3 P11 0 0 0  |
015] LW  x7,2(x5)  4 7 8      P17,2(P3) 002) LW P17 P3 - 2 8 - - 015) 001 x7 P13 0 0 0  |
016] MUL  x7,x7,x3  5 7 8      P18,P17,P16 003) MUL P18 P17 P16 - . . - 016) 002 x7 P17 0 0 0  |
017] ADDI x1,x1,-1  5 7      P19,P14,-1
018] SW  x7,2(x6)  6 8      ,2(P8)<-P18
019] ADDI x2,x2,8   7 8      P20,P15,8
020] BNE  x1,x0,-7  7 8      ,P19,P0,-7

----- Press ENTER to continue (PC=8,IC=21,CK=8,CTOT=9,IPC=2.33)...
#008 stall due to NO SLOTS when trying to move instnction MUL/009 from stage P to stage I.
#008 stall due to NO SLOTS when trying to move instnction ADDI/017 from stage D to stage P.
```

```
=====
PHYSICAL REGS:  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                * * * * *
qi:  0 0 0 0 1 0 0 0 0 0 0 0 0 1 0 0 1 1 1 1 1 1 1 1
vi:  00 00 00 00 00 00 FF 00 00 08 00 00 00 FE 10 00 00 00 00 00 00 00 00 00 00

=====
REG.FILE: xi:      1      2      3      4      5      6      7      8
          Pi:     19     20     16      1      3      8     18      -
          Qi:      1      1      1      0      0      0      1      0
          Vi: 00000FFE 00000010 00000000 00004000 00005000 00006000 00000000 00000000

=====
STAGES:          F D P I X W C RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A M L S B F X
TOTAL SLOTS:      4 4 4 4 9 4 4 24          16                    99                    1 1 1 0 1 4 1
BUSY SLOTS:       0 2 4 0 3 1 0 20          4                     17                    0 0 0 0 0 0 0
STALLS:          0 9 12 13 0 0 3 0          0                     0                    0 0 5 0 0 0 0

=====
PC  INSTRUCTION  F D P I X W C Pi,Pj Pk P1  IW#  OPCD Pi Pj Pk I/P1  Cj Ck Cl  ROB# PC xi oPi s x c  +-----+
000] LW  x3,2(x4)  0 1 2 3 3 5 6 P2,2(P1)  ----  LW P2 P1 - 2 3 3 -  ---- 000 x3 - 0 0 1  |LQ(1 )|
001] LW  x7,2(x5)  0 1 2 5 5 7 8 P4,2(P3)  ----  LW P4 P3 - 2 5 5 -  ---- 001 x7 - 0 0 1  |PC  OP Pi EFAD Ci|
002] MUL  x7,x7,x3  0 1 2 7 7      P5,P4,P2  ----  MUL P5 P4 P2 - 7 7 - 002) 002 x7 P4 0 0 0  |---- LW P2 4002 5|
003] ADDI x1,x1,-1  0 1 2 3 3 4      P7,P6,-1  ----  ADDI P7 P6 - -1 3 3 - 003) 003 x1 P6 0 0 1  |---- LW P4 5002 7|
004] SW  x7,2(x6)  1 2 3 4 4      ,2(P8)<-P5  ----  SW - P5 P8 2 - 4 - 004) 004 - - 1 0 0  |---- LW P11 4002 8|
005] ADDI x2,x2,8   1 2 3 4 4 5      P10,P9,8  ----  ADDI P10 P9 - 8 4 4 - 005) 005 x2 P9 0 0 1  |---- LW P12 5002 9|
006] BNE  x1,x0,-7  1 2 4 5 5 6      ,P7,P0,-7  ----  BNE - P7 P0 -7 5 5 - 006) 006 - - 0 0 1  |014] LW P16 4002 9|
007] LW  x3,2(x4)  2 3 4 6 6 8      P11,2(P1)  ----  LW P11 P1 - 2 6 6 - 007) 000 x3 P2 0 0 1  +-----+
008] LW  x7,2(x5)  2 3 5 7 7 9      P12,2(P3)  ----  LW P12 P3 - 2 7 7 - 008) 001 x7 P5 0 0 1  |
009] MUL  x7,x7,x3  2 3 5 9 9      P13,P12,P11 001> MUL P13 P12 P11 - 9 9 - 009) 002 x7 P12 0 0 0  +-----+
010] ADDI x1,x1,-1  2 4 6 7 7 8      P14,P7,-1  ----  ADDI P14 P7 - -1 7 7 - 010) 003 x1 P7 0 0 1  |SQ(2 )|
```

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```
011] SW   x7,2(x6)      3  4  7  8  8      ,2(P8)<-P13  ---- SW -   P13 P8  2    -  8 -  8 -  011) 004 -   -  1  0  0 | PC  OP P1 EFAD C1 |
012] ADDI x2,x2,8       3  5  7  8  8  9      P15,P10,8  ---- ADDI P15 P10 -   8  8  8 -  012) 005 x2 P10 0 0 1 | . SW P5 6002 . |
013] BNE  x1,x0,-7      3  5  7  8  8  9      ,P14,P0,-7  ---- BNE -   P14 P0 -7   8  8 -  013) 006 -   -  0  0  1 | . SW P13 6002 . |
014] LW   x3,2(x4)      4  6  8  9  9      P16,2(P1)    000> LW P16 P1 -   2  9  9 -  014) 000 x3 P11 0 0 0 +-----+
015] LW   x7,2(x5)      4  7  8      P17,2(P3)    002) LW P17 P3 -   2  8 -  015) 001 x7 P13 0 0 0
016] MUL  x7,x7,x3      5  7  8      P18,P17,P16  003) MUL P18 P17 P16 -   .  . -  016) 002 x7 P17 0 0 0
017] ADDI x1,x1,-1      5  7  9      P19,P14,-1  000) ADDI P19 P14 -  -1  9 -  017) 003 x1 P14 0 0 0
018] SW   x7,2(x6)      6  8  9      ,2(P8)<-P18  001) SW -   P18 P8  2    -  9 -  018) 004 -   -  1  0  0
019] ADDI x2,x2,8       7  8      P20,P15,8
020] BNE  x1,x0,-7      7  8      ,P19,P0,-7
```

----- Press ENTER to continue (PC=8,IC=21,CK=9,CTOT=10,IPC=2.10)...

@009 stall due to NO SLOTS when trying to move instnction ADDI/010 from stage W to stage C.
@009 stall due to no L-unit available
@009 stall due to NO SLOTS when trying to move instnction LW/015 from stage P to stage I.
@009 stall due to NO SLOTS when trying to move instnction MUL/016 from stage P to stage I.
@009 stall due to NO SLOTS when trying to move instnction ADDI/019 from stage D to stage P.
@009 stall due to NO SLOTS when trying to move instnction BNE/020 from stage D to stage P.

```
=====
PHYSICAL REGS:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *
qi:   0  0  0  0  0  1  0  0  0  0  0  0  0  1  0  0  1  1  1  1  1  1  1  1
vi:   00 00 00 00 00 00 FF 00 00 08 00 00 00 FE 10 00 00 00 FD 00 00 00 00 00
=====
REG.FILE: xi:      1      2      3      4      5      6      7      8
          P1:      19      20      16      1      3      8      18      -
          Qi:      1      1      1      0      0      0      1      0
          Vi: 00000FFE 00000010 00000000 00004000 00005000 00006000 00000000 00000000
=====
```

```
=====
STAGES:          F  D  P  I  X  W  C  RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A  M  L  S  B  F  X
TOTAL SLOTS:     4  4  4  4  9  4  4  24          16          99          1  1  1  0  1  4  1
BUSY SLOTS:      0  0  4  0  5  1  0  20          4          19          0  0  0  0  0  0  0
STALLS:          0  9 12 15  0  0  4  0          0          0          0  0  5  1  0  0  0
=====
```

```
PC  INSTRUCTION      F  D  P  I  X  W  C  Pi,Pj Pk P1  IW#  OPCODE Pi  Pj  Pk  I/P1  Cj  Ck  Cl  ROB#  PC  xi  oPi  s  x  c  +-----+
000] LW   x3,2(x4)    0  1  2  3  3  5  6  P2,2(P1)  ---- LW P2 P1 -   2  3  3 -  ---- 000 x3 -   0  0  1 | LQ(2 ) |
001] LW   x7,2(x5)    0  1  2  5  5  7  8  P4,2(P3)  ---- LW P4 P3 -   2  5  5 -  ---- 001 x7 -   0  0  1 | PC  OP Pi EFAD Ci |
002] MUL  x7,x7,x3    0  1  2  7  7      P5,P4,P2  ---- MUL P5 P4 P2 -   7  7 -  002) 002 x7 P4 0 0 0 | ---- LW P2 4002 5 |
003] ADDI x1,x1,-1    0  1  2  3  3  4      P7,P6,-1  ---- ADDI P7 P6 -  -1  3  3 -  003) 003 x1 P6 0 0 1 | ---- LW P4 5002 7 |
004] SW   x7,2(x6)    1  2  3  4  4      ,2(P8)<-P5  ---- SW -   P5 P8  2    -  4 -  004) 004 -   -  1  0  0 | ---- LW P11 4002 8 |
005] ADDI x2,x2,8     1  2  3  4  4  5      P10,P9,8  ---- ADDI P10 P9 -   8  4  4 -  005) 005 x2 P9 0 0 1 | ---- LW P12 5002 9 |
006] BNE  x1,x0,-7    1  2  4  5  5  6      ,P7,P0,-7  ---- BNE -   P7 P0 -7   5  5 -  006) 006 -   -  0  0  1 | 014] LW P16 4002 9 |
007] LW   x3,2(x4)    2  3  4  6  6  8      P11,2(P1)  ---- LW P11 P1 -   2  6  6 -  007) 000 x3 P2 0 0 1 | 015] LW P17 5002 10 |
008] LW   x7,2(x5)    2  3  5  7  7  9      P12,2(P3)  ---- LW P12 P3 -   2  7  7 -  008) 001 x7 P5 0 0 1 +-----+
009] MUL  x7,x7,x3    2  3  5  9  9      P13,P12,P11  ---- MUL P13 P12 P11 -   9  9 -  009) 002 x7 P12 0 0 0
010] ADDI x1,x1,-1    2  4  6  7  7  8      P14,P7,-1  ---- ADDI P14 P7 -  -1  7  7 -  010) 003 x1 P7 0 0 1 +-----+
011] SW   x7,2(x6)    3  4  7  8  8      ,2(P8)<-P13  ---- SW -   P13 P8  2    -  8 -  011) 004 -   -  1  0  0 | SQ(2 ) |
012] ADDI x2,x2,8     3  5  7  8  8  9      P15,P10,8  ---- ADDI P15 P10 -   8  8  8 -  012) 005 x2 P10 0 0 1 | PC  OP P1 EFAD C1 |
013] BNE  x1,x0,-7    3  5  7  8  8  9      ,P14,P0,-7  ---- BNE -   P14 P0 -7   8  8 -  013) 006 -   -  0  0  1 | . SW P5 6002 . |
014] LW   x3,2(x4)    4  6  8  9  9      P16,2(P1)  ---- LW P16 P1 -   2  9  9 -  014) 000 x3 P11 0 0 0 | . SW P13 6002 . |
015] LW   x7,2(x5)    4  7  8 10 10      P17,2(P3)    002> LW P17 P3 -   2 10 10 -  015) 001 x7 P13 0 0 0 +-----+
016] MUL  x7,x7,x3    5  7  8      P18,P17,P16  003) MUL P18 P17 P16 -   .  . -  016) 002 x7 P17 0 0 0
017] ADDI x1,x1,-1    5  7  9 10 10      P19,P14,-1  000> ADDI P19 P14 -  -1 10 10 -  017) 003 x1 P14 0 0 0
018] SW   x7,2(x6)    6  8  9      ,2(P8)<-P18  001) SW -   P18 P8  2    -  9 -  018) 004 -   -  1  0  0
019] ADDI x2,x2,8     7  8 10      P20,P15,8    000) ADDI P20 P15 -   8 10 -  019) 005 x2 P15 0 0 0
020] BNE  x1,x0,-7    7  8 10      ,P19,P0,-7    002) BNE -   P19 P0 -7   . 10 -  020) 006 -   -  0  0  0
```

----- Press ENTER to continue (PC=8,IC=21,CK=10,CTOT=11,IPC=1.91)...

@010 stall due to NO SLOTS when trying to move instnction BNE/013 from stage W to stage C.
@010 stall due to NO SLOTS when trying to move instnction MUL/016 from stage P to stage I.
@010 stall due to no S-unit available
@010 stall due to NO SLOTS when trying to move instnction SW/018 from stage P to stage I.

```
=====
PHYSICAL REGS:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *
qi:   0  0  0  0  1  0  0  0  0  0  0  0  1  0  0  0  1  1  0  1  1  1  1  1
=====
```


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```
vi: 00 00 00 00 00 00 FF 00 00 08 00 00 00 FE 10 00 00 00 FD 18 00 00 00 00

=====
REG.FILE: x1:      1      2      3      4      5      6      7      8
          P1:     19     20     16      1      3      8     18      -
          Q1:      0      1      0      0      0      0      1      0
          Vi: 00000FFD 00000010 00000000 00004000 00005000 00006000 00000000 00000000

=====
STAGES:          F D P I X W C RENAMED-STR    INSTRUCTION-WINDOW    REORDER-BUFFER          A M L S B F X
TOTAL SLOTS:      4 4 4 4 9 4 4 24          16                      99                      1 1 1 0 1 4 1
BUSY SLOTS:       0 0 1 0 5 1 0 20          1                      19                      0 0 0 0 0 0 0
STALLS:          0 9 12 16 0 0 5 0          0                      0                      0 0 5 1 0 0 0

=====
PC  INSTRUCTION    F D P I X W C Pi,Pj Pk P1  IW#  OPCODE Pi Pj Pk I/P1  Cj Ck Cl  ROB# PC xi oPi s x c  +-----+
000] LW  x3,2(x4)   0 1 2 3 3 5 6 P2,2(P1)  ----  LW P2 P1 - 2 3 3 -  ---- 000 x3 - 0 0 1  |LQ(1 )|
001] LW  x7,2(x5)   0 1 2 5 5 7 8 P4,2(P3)  ----  LW P4 P3 - 2 5 5 -  ---- 001 x7 - 0 0 1  |PC  OP Pi EFAD C1|
002] MUL  x7,x7,x3  0 1 2 7 7  P5,P4,P2  ----  MUL P5 P4 P2 - 7 7 -  002) 002 x7 P4 0 0 0  |---- LW P2 4002 5|
003] ADDI x1,x1,-1  0 1 2 3 3 4  P7,P6,-1  ----  ADDI P7 P6 - -1 3 3 -  003) 003 x1 P6 0 0 1  |---- LW P4 5002 7|
004] SW  x7,2(x6)   1 2 3 4 4  ,2(P8)<-P5  ----  SW - P5 P8 2 - 4 -  004) 004 - - 1 0 0  |---- LW P11 4002 8|
005] ADDI x2,x2,8    1 2 3 4 4 5  P10,P9,8  ----  ADDI P10 P9 - 8 4 4 -  005) 005 x2 P9 0 0 1  |---- LW P12 5002 9|
006] BNE  x1,x0,-7  1 2 4 5 5 6  ,P7,P0,-7  ----  BNE - P7 P0 -7 5 5 -  006) 006 - - 0 0 1  |---- LW P16 4002 11|
007] LW  x3,2(x4)   2 3 4 6 6 8  P11,2(P1)  ----  LW P11 P1 - 2 6 6 -  007) 000 x3 P2 0 0 1  |015] LW P17 5002 10|
008] LW  x7,2(x5)   2 3 5 7 7 9  P12,2(P3)  ----  LW P12 P3 - 2 7 7 -  008) 001 x7 P5 0 0 1  +-----+
009] MUL  x7,x7,x3  2 3 5 9 9  P13,P12,P11  ----  MUL P13 P12 P11 - 9 9 -  009) 002 x7 P12 0 0 0  +-----+
010] ADDI x1,x1,-1  2 4 6 7 7 8  P14,P7,-1  ----  ADDI P14 P7 - -1 7 7 -  010) 003 x1 P7 0 0 1  +-----+
011] SW  x7,2(x6)   3 4 7 8 8  ,2(P8)<-P13  ----  SW - P13 P8 2 - 8 -  011) 004 - - 1 0 0  |SQ(3 )|
012] ADDI x2,x2,8    3 5 7 8 8 9  P15,P10,8  ----  ADDI P15 P10 - 8 8 8 -  012) 005 x2 P10 0 0 1  |PC  OP P1 EFAD C1|
013] BNE  x1,x0,-7  3 5 7 8 8 9  P14,P0,-7  ----  BNE - P14 P0 -7 8 8 -  013) 006 - - 0 0 1  |. SW P5 6002 .|
014] LW  x3,2(x4)   4 6 8 9 9 11 P16,2(P1)  ----  LW P16 P1 - 2 9 9 -  014) 000 x3 P11 0 0 1  |. SW P13 6002 .|
015] LW  x7,2(x5)   4 7 8 10 10 P17,2(P3)  ----  LW P17 P3 - 2 10 10 -  015) 001 x7 P13 0 0 0  |. SW P18 6002 .|
016] MUL  x7,x7,x3  5 7 8  P18,P17,P16 003) MUL P18 P17 P16 - . -  016) 002 x7 P17 0 0 0  +-----+
017] ADDI x1,x1,-1  5 7 9 10 10 11 P19,P14,-1  ----  ADDI P19 P14 - -1 10 10 -  017) 003 x1 P14 0 0 1  +-----+
018] SW  x7,2(x6)   6 8 9 11 11 ,2(P8)<-P18 001> SW - P18 P8 2 - 11 -  018) 004 - - 1 0 0  +-----+
019] ADDI x2,x2,8    7 8 10 11 11 P20,P15,8 000> ADDI P20 P15 - 8 11 11 -  019) 005 x2 P15 0 0 0  +-----+
020] BNE  x1,x0,-7  7 8 10 11 11 ,P19,P0,-7 002> BNE - P19 P0 -7 11 11 -  020) 006 - - 0 0 0  +-----+

Press ENTER to continue (PC=8,IC=21,CK=11,CTOT=12,IPC=1.75)...

#011 stall due to NO SLOTS when trying to move instnction BNE/013 from stage W to stage C.
#011 stall due to NO SLOTS when trying to move instnction MUL/016 from stage P to stage I.
```

```
=====
PHYSICAL REGS: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
               * * * * *
               qi: 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 1 0 0 1 1 1 1
               vi: 00 00 00 00 00 00 FF 00 00 08 00 00 00 FE 10 00 00 00 FD 18 00 00 00 00

=====
REG.FILE: x1:      1      2      3      4      5      6      7      8
          P1:     19     20     16      1      3      8     18      -
          Q1:      0      0      0      0      0      0      1      0
          Vi: 00000FFD 00000018 00000000 00004000 00005000 00006000 00000000 00000000

=====
STAGES:          F D P I X W C RENAMED-STR    INSTRUCTION-WINDOW    REORDER-BUFFER          A M L S B F X
TOTAL SLOTS:      4 4 4 4 9 4 4 24          16                      99                      1 1 1 0 1 4 1
BUSY SLOTS:       0 0 0 0 2 1 0 20          0                      19                      0 0 0 0 0 0 0
STALLS:          0 9 12 16 0 0 6 0          0                      0                      0 0 5 1 0 0 0

=====
PC  INSTRUCTION    F D P I X W C Pi,Pj Pk P1  IW#  OPCODE Pi Pj Pk I/P1  Cj Ck Cl  ROB# PC xi oPi s x c  +-----+
000] LW  x3,2(x4)   0 1 2 3 3 5 6 P2,2(P1)  ----  LW P2 P1 - 2 3 3 -  ---- 000 x3 - 0 0 1  |LQ(0 )|
001] LW  x7,2(x5)   0 1 2 5 5 7 8 P4,2(P3)  ----  LW P4 P3 - 2 5 5 -  ---- 001 x7 - 0 0 1  |PC  OP Pi EFAD C1|
002] MUL  x7,x7,x3  0 1 2 7 7 12 P5,P4,P2  ----  MUL P5 P4 P2 - 7 7 -  002) 002 x7 P4 0 0 1  |---- LW P2 4002 5|
003] ADDI x1,x1,-1  0 1 2 3 3 4  P7,P6,-1  ----  ADDI P7 P6 - -1 3 3 -  003) 003 x1 P6 0 0 1  |---- LW P4 5002 7|
004] SW  x7,2(x6)   1 2 3 4 4 12 ,2(P8)<-P5  ----  SW - P5 P8 2 - 4 -  004) 004 - - 1 0 1  |---- LW P11 4002 8|
005] ADDI x2,x2,8    1 2 3 4 4 5  P10,P9,8  ----  ADDI P10 P9 - 8 4 4 -  005) 005 x2 P9 0 0 1  |---- LW P12 5002 9|
006] BNE  x1,x0,-7  1 2 4 5 5 6  ,P7,P0,-7  ----  BNE - P7 P0 -7 5 5 -  006) 006 - - 0 0 1  |---- LW P16 4002 11|
007] LW  x3,2(x4)   2 3 4 6 6 8  P11,2(P1)  ----  LW P11 P1 - 2 6 6 -  007) 000 x3 P2 0 0 1  |---- LW P17 5002 12|
008] LW  x7,2(x5)   2 3 5 7 7 9  P12,2(P3)  ----  LW P12 P3 - 2 7 7 -  008) 001 x7 P5 0 0 1  +-----+
009] MUL  x7,x7,x3  2 3 5 9 9  P13,P12,P11  ----  MUL P13 P12 P11 - 9 9 -  009) 002 x7 P12 0 0 0  +-----+
010] ADDI x1,x1,-1  2 4 6 7 7 8  P14,P7,-1  ----  ADDI P14 P7 - -1 7 7 -  010) 003 x1 P7 0 0 1  +-----+
011] SW  x7,2(x6)   3 4 7 8 8  ,2(P8)<-P13  ----  SW - P13 P8 2 - 8 -  011) 004 - - 1 0 0  |SQ(2 )|
```

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```
012] ADDI x2,x2,8      3 5 7 8 8 9      P15,P10,8      ---- ADDI P15 P10 - 8 8 8 - 012) 005 x2 P10 0 0 1 |PC  OP P1  EFAD C1|
013] BNE x1,x0,-7      3 5 7 8 8 9      ,P14,P0,-7      ---- BNE - P14 P0 -7 8 8 - 013) 006 - - 0 0 1 |---- SW P5 6002 12|
014] LW x3,2(x4)        4 6 8 9 9 11     P16,2(P1)        ---- LW P16 P1 - 2 9 9 - 014) 000 x3 P11 0 0 1 |. SW P13 6002 .|
015] LW x7,2(x5)        4 7 8 10 10 12    P17,2(P3)        ---- LW P17 P3 - 2 10 10 - 015) 001 x7 P13 0 0 1 |. SW P18 6002 .|
016] MUL x7,x7,x3       5 7 8 12 12     P18,P17,P16     003> MUL P18 P17 P16 - 12 12 - 016) 002 x7 P17 0 0 0 |-----|
017] ADDI x1,x1,-1      5 7 9 10 10 11    P19,P14,-1      ---- ADDI P19 P14 - -1 10 10 - 017) 003 x1 P14 0 0 1 |
018] SW x7,2(x6)        6 8 9 11 11     ,2(P8)<-P18      ---- SW - P18 P8 2 - 11 - 018) 004 - - 1 0 0 |
019] ADDI x2,x2,8       7 8 10 11 11 12    P20,P15,8       ---- ADDI P20 P15 - 8 11 11 - 019) 005 x2 P15 0 0 1 |
020] BNE x1,x0,-7      7 8 10 11 11 12    ,P19,P0,-7      ---- BNE - P19 P0 -7 11 11 - 020) 006 - - 0 0 1 |
```

Press ENTER to continue (PC=8,IC=21,CK=12,CTOT=13,IPC=1.62)...

@012 stall due to NO SLOTS when trying to move instnuction ADDI/017 from stage W to stage C.

```
=====
PHYSICAL REGS:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *
qi:  0  0  0  1  0  1  0  0  1  0  0  0  1  0  0  0  0  1  0  0  1  0  0  1  1  1  1
vi:  00 00 00 00 00 00 FF 00 00 08 00 00 00 FE 10 00 00 00 FD 18 00 00 00 00 00 00
=====
REG.FILE: xi:      1      2      3      4      5      6      7      8
          Pi:     19     20     16      1      3      8     18      -
          Qi:      0      0      0      0      0      0      1      0
          Vi: 00001000 00000000 00000000 00004000 00005000 00006000 00000000 00000000
=====
STAGES:          F  D  P  I  X  W  C  RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A  M  L  S  B  F  X
TOTAL SLOTS:     4  4  4  4  9  4  4  24          16          99          1  1  1  0  1  4  1
BUSY SLOTS:      0  0  0  0  2  0  0  17          0          15          0  0  0  0  0  0  0
STALLS:          0  9 12 16  0  0  6  0          0          0          0  0  5  1  0  0  0
```

```
=====
PC  INSTRUCTION      F  D  P  I  X  W  C  Pi,Pj Pk P1  IW#  OPCODE Pi  Pj  Pk I/P1  Cj  Ck  Cl  ROB# PC  xi  oPi s x c  +-----+
000] LW x3,2(x4)      0  1  2  3  3  5  6  P2,2(P1)  ---- LW P2 P1 - 2 3 3 - ---- 000 x3 - 0 0 1 |LQ(0 )|
001] LW x7,2(x5)      0  1  2  5  5  7  8  P4,2(P3)  ---- LW P4 P3 - 2 5 5 - ---- 001 x7 - 0 0 1 |PC  OP Pi  EFAD Ci|
002] MUL x7,x7,x3     0  1  2  7  7 12 13 P5,P4,P2  ---- MUL P5 P4 P2 - 7 7 - ---- 002 x7 P4 0 0 1 |---- LW P2 4002 5|
003] ADDI x1,x1,-1    0  1  2  3  3  4 13 P7,P6,-1  ---- ADDI P7 P6 - -1 3 3 - ---- 003 x1 P6 0 0 1 |---- LW P4 5002 7|
004] SW x7,2(x6)      1  2  3  4  4 12 13 ,2(P8)<-P5  ---- SW - P5 P8 2 - 4 - ---- 004 - - 1 0 1 |---- LW P11 4002 8|
005] ADDI x2,x2,8     1  2  3  4  4 13 P10,P9,8  ---- ADDI P10 P9 - 8 4 4 - ---- 005 x2 P9 0 0 1 |---- LW P12 5002 9|
006] BNE x1,x0,-7     1  2  4  5  5  6  ,P7,P0,-7  ---- BNE - P7 P0 -7 5 5 - 006) 006 - - 0 0 1 |---- LW P16 4002 11|
007] LW x3,2(x4)      2  3  4  6  6  8  P11,2(P1)  ---- LW P11 P1 - 2 6 6 - 007) 000 x3 P2 0 0 1 |---- LW P17 5002 12|
008] LW x7,2(x5)      2  3  5  7  7  9  P12,2(P3)  ---- LW P12 P3 - 2 7 7 - 008) 001 x7 P5 0 0 1 |-----|
009] MUL x7,x7,x3     2  3  5  9  9  P13,P12,P11  ---- MUL P13 P12 P11 - 9 9 - 009) 002 x7 P12 0 0 0 |
010] ADDI x1,x1,-1    2  4  6  7  7  8  P14,P7,-1  ---- ADDI P14 P7 - -1 7 7 - 010) 003 x1 P7 0 0 1 |-----+
011] SW x7,2(x6)      3  4  7  8  8  ,2(P8)<-P13  ---- SW - P13 P8 2 - 8 - 011) 004 - - 1 0 0 |SQ(2 )|
012] ADDI x2,x2,8     3  5  7  8  8  9  P15,P10,8  ---- ADDI P15 P10 - 8 8 8 - 012) 005 x2 P10 0 0 1 |PC  OP P1  EFAD C1|
013] BNE x1,x0,-7     3  5  7  8  8  9  ,P14,P0,-7  ---- BNE - P14 P0 -7 8 8 - 013) 006 - - 0 0 1 |---- SW P5 6002 12|
014] LW x3,2(x4)      4  6  8  9  9 11  P16,2(P1)  ---- LW P16 P1 - 2 9 9 - 014) 000 x3 P11 0 0 1 |. SW P13 6002 .|
015] LW x7,2(x5)      4  7  8 10 10 12  P17,2(P3)  ---- LW P17 P3 - 2 10 10 - 015) 001 x7 P13 0 0 1 |. SW P18 6002 .|
016] MUL x7,x7,x3     5  7  8 12 12  P18,P17,P16  ---- MUL P18 P17 P16 - 12 12 - 016) 002 x7 P17 0 0 0 |-----|
017] ADDI x1,x1,-1    5  7  9 10 10 11  P19,P14,-1  ---- ADDI P19 P14 - -1 10 10 - 017) 003 x1 P14 0 0 1 |
018] SW x7,2(x6)      6  8  9 11 11  ,2(P8)<-P18  ---- SW - P18 P8 2 - 11 - 018) 004 - - 1 0 0 |
019] ADDI x2,x2,8     7  8 10 11 11 12  P20,P15,8  ---- ADDI P20 P15 - 8 11 11 - 019) 005 x2 P15 0 0 1 |
020] BNE x1,x0,-7     7  8 10 11 11 12  ,P19,P0,-7  ---- BNE - P19 P0 -7 11 11 - 020) 006 - - 0 0 1 |
```

Press ENTER to continue (PC=8,IC=21,CK=13,CTOT=14,IPC=1.50)...

```
=====
PHYSICAL REGS:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *
qi:  0  1  0  1  1  1  0  0  1  0  0  0  0  0  0  0  1  0  0  1  1  1  1  1
vi:  00 00 00 00 00 00 FF 00 00 08 00 00 00 FE 10 00 00 00 FD 18 00 00 00 00 00 00
=====
REG.FILE: xi:      1      2      3      4      5      6      7      8
          Pi:     19     20     16      1      3      8     18      -
          Qi:      0      0      0      0      0      0      1      0
          Vi: 00001000 00000000 00000000 00004000 00005000 00006000 00000000 00000000
=====
STAGES:          F  D  P  I  X  W  C  RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A  M  L  S  B  F  X
TOTAL SLOTS:     4  4  4  4  9  4  4  24          16          99          1  1  1  0  1  4  1
BUSY SLOTS:      0  0  0  0  1  1  0  15          0          12          0  0  0  0  0  0  0
STALLS:          0  9 12 16  0  0  6  0          0          0          0  0  5  1  0  0  0
```

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```
PC INSTRUCTION F D P I X W C Pi,Pj Pk P1 IW# OPCD Pi Pj Pk I/P1 Cj Ck Cl ROB# PC xi oPi s x c +-----+
000] LW x3,2(x4) 0 1 2 3 3 5 6 P2,2(P1) ---- LW P2 P1 - 2 3 3 - ---- 000 x3 - 0 0 1 |LQ(0 )|
001] LW x7,2(x5) 0 1 2 5 5 7 8 P4,2(P3) ---- LW P4 P3 - 2 5 5 - ---- 001 x7 - 0 0 1 |PC OP Pi EFAD Ci|
002] MUL x7,x7,x3 0 1 2 7 7 12 13 P5,P4,P2 ---- MUL P5 P4 P2 - 7 7 7 - ---- 002 x7 P4 0 0 1 |---- LW P2 4002 5|
003] ADDI x1,x1,-1 0 1 2 3 3 4 13 P7,P6,-1 ---- ADDI P7 P6 - -1 3 3 - ---- 003 x1 P6 0 0 1 |---- LW P4 5002 7|
004] SW x7,2(x6) 1 2 3 4 4 12 13 ,2(P8)<-P5 ---- SW - P5 P8 2 - 4 - ---- 004 - - 1 0 1 |---- LW P11 4002 8|
005] ADDI x2,x2,8 1 2 3 4 4 5 13 P10,P9,8 ---- ADDI P10 P9 - 8 4 4 - ---- 005 x2 P9 0 0 1 |---- LW P12 5002 9|
006] BNE x1,x0,-7 1 2 4 5 5 6 14 ,P7,P0,-7 ---- BNE - P7 P0 -7 5 5 - ---- 006 - - 0 0 1 |---- LW P16 4002 11|
007] LW x3,2(x4) 2 3 4 6 6 8 14 P11,2(P1) ---- LW P11 P1 - 2 6 6 - ---- 000 x3 P2 0 0 1 |---- LW P17 5002 12|
008] LW x7,2(x5) 2 3 5 7 7 9 14 P12,2(P3) ---- LW P12 P3 - 2 7 7 - ---- 001 x7 P5 0 0 1 +-----+
009] MUL x7,x7,x3 2 3 5 9 9 14 P13,P12,P11 ---- MUL P13 P12 P11 - 9 9 - 009) 002 x7 P12 0 0 1
010] ADDI x1,x1,-1 2 4 6 7 7 8 P14,P7,-1 ---- ADDI P14 P7 - -1 7 7 - 010) 003 x1 P7 0 0 1 +-----+
011] SW x7,2(x6) 3 4 7 8 8 14 ,2(P8)<-P13 ---- SW - P13 P8 2 - 8 - 011) 004 - - 1 0 1 |SQ(1 )|
012] ADDI x2,x2,8 3 5 7 8 8 9 P15,P10,8 ---- ADDI P15 P10 - 8 8 8 - 012) 005 x2 P10 0 0 1 |PC OP P1 EFAD C1|
013] BNE x1,x0,-7 3 5 7 8 8 9 ,P14,P0,-7 ---- BNE - P14 P0 -7 8 8 - 013) 006 - - 0 0 1 |---- SW P5 6002 12|
014] LW x3,2(x4) 4 6 8 9 9 11 P16,2(P1) ---- LW P16 P1 - 2 9 9 - 014) 000 x3 P11 0 0 1 |---- SW P13 6002 14|
015] LW x7,2(x5) 4 7 8 10 10 12 P17,2(P3) ---- LW P17 P3 - 2 10 10 - 015) 001 x7 P13 0 0 1 |. SW P18 6002 .|
016] MUL x7,x7,x3 5 7 8 12 12 P18,P17,P16 ---- MUL P18 P17 P16 - 12 12 - 016) 002 x7 P17 0 0 0 +-----+
017] ADDI x1,x1,-1 5 7 9 10 10 11 P19,P14,-1 ---- ADDI P19 P14 - -1 10 10 - 017) 003 x1 P14 0 0 1
018] SW x7,2(x6) 6 8 9 11 11 ,2(P8)<-P18 ---- SW - P18 P8 2 - 11 - 018) 004 - - 1 0 0
019] ADDI x2,x2,8 7 8 10 11 11 12 P20,P15,8 ---- ADDI P20 P15 - 8 11 11 - 019) 005 x2 P15 0 0 1
020] BNE x1,x0,-7 7 8 10 11 11 12 ,P19,P0,-7 ---- BNE - P19 P0 -7 11 11 - 020) 006 - - 0 0 1
----- Press ENTER to continue (PC=8,IC=21,CK=14,CTOT=15,IPC=1.40)...
```

```
=====
PHYSICAL REGS: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                * * * * *
qi: 0 1 0 1 1 1 1 0 1 1 0 1 0 0 0 0 0 1 0 0 1 1 1 1
vi: 00 00 00 00 00 00 FF 00 00 08 00 00 00 FE 10 00 00 00 FD 18 00 00 00 00 00
=====
REG.FILE: xi: 1 2 3 4 5 6 7 8
          Pi: 19 20 16 1 3 8 18 -
          Qi: 0 0 0 0 0 0 1 0
          Vi: 00000FFF 00000008 00000000 00004000 00005000 00006000 00000000 00000000
=====
STAGES: F D P I X W C RENAMED-STR INSTRUCTION-WINDOW REORDER-BUFFER A M L S B F X
TOTAL SLOTS: 4 4 4 4 9 4 4 24 16 99 1 1 1 0 1 4 1
BUSY SLOTS: 0 0 0 0 1 0 0 12 0 8 0 0 0 0 0 0 0
STALLS: 0 9 12 16 0 0 6 0 0 0 0 0 0 0 0 0 0 0 0 5 1 0 0 0
```

```
PC INSTRUCTION F D P I X W C Pi,Pj Pk P1 IW# OPCD Pi Pj Pk I/P1 Cj Ck Cl ROB# PC xi oPi s x c +-----+
000] LW x3,2(x4) 0 1 2 3 3 5 6 P2,2(P1) ---- LW P2 P1 - 2 3 3 - ---- 000 x3 - 0 0 1 |LQ(0 )|
001] LW x7,2(x5) 0 1 2 5 5 7 8 P4,2(P3) ---- LW P4 P3 - 2 5 5 - ---- 001 x7 - 0 0 1 |PC OP Pi EFAD Ci|
002] MUL x7,x7,x3 0 1 2 7 7 12 13 P5,P4,P2 ---- MUL P5 P4 P2 - 7 7 7 - ---- 002 x7 P4 0 0 1 |---- LW P2 4002 5|
003] ADDI x1,x1,-1 0 1 2 3 3 4 13 P7,P6,-1 ---- ADDI P7 P6 - -1 3 3 - ---- 003 x1 P6 0 0 1 |---- LW P4 5002 7|
004] SW x7,2(x6) 1 2 3 4 4 12 13 ,2(P8)<-P5 ---- SW - P5 P8 2 - 4 - ---- 004 - - 1 0 1 |---- LW P11 4002 8|
005] ADDI x2,x2,8 1 2 3 4 4 5 13 P10,P9,8 ---- ADDI P10 P9 - 8 4 4 - ---- 005 x2 P9 0 0 1 |---- LW P12 5002 9|
006] BNE x1,x0,-7 1 2 4 5 5 6 14 ,P7,P0,-7 ---- BNE - P7 P0 -7 5 5 - ---- 006 - - 0 0 1 |---- LW P16 4002 11|
007] LW x3,2(x4) 2 3 4 6 6 8 14 P11,2(P1) ---- LW P11 P1 - 2 6 6 - ---- 000 x3 P2 0 0 1 |---- LW P17 5002 12|
008] LW x7,2(x5) 2 3 5 7 7 9 14 P12,2(P3) ---- LW P12 P3 - 2 7 7 - ---- 001 x7 P5 0 0 1 +-----+
009] MUL x7,x7,x3 2 3 5 9 9 14 15 P13,P12,P11 ---- MUL P13 P12 P11 - 9 9 - ---- 002 x7 P12 0 0 1
010] ADDI x1,x1,-1 2 4 6 7 7 8 15 P14,P7,-1 ---- ADDI P14 P7 - -1 7 7 - ---- 003 x1 P7 0 0 1 +-----+
011] SW x7,2(x6) 3 4 7 8 8 14 15 ,2(P8)<-P13 ---- SW - P13 P8 2 - 8 - ---- 004 - - 1 0 1 |SQ(1 )|
012] ADDI x2,x2,8 3 5 7 8 8 9 15 P15,P10,8 ---- ADDI P15 P10 - 8 8 8 - ---- 005 x2 P10 0 0 1 |PC OP P1 EFAD C1|
013] BNE x1,x0,-7 3 5 7 8 8 9 ,P14,P0,-7 ---- BNE - P14 P0 -7 8 8 - 013) 006 - - 0 0 1 |---- SW P5 6002 12|
014] LW x3,2(x4) 4 6 8 9 9 11 P16,2(P1) ---- LW P16 P1 - 2 9 9 - 014) 000 x3 P11 0 0 1 |---- SW P13 6002 14|
015] LW x7,2(x5) 4 7 8 10 10 12 P17,2(P3) ---- LW P17 P3 - 2 10 10 - 015) 001 x7 P13 0 0 1 |. SW P18 6002 .|
016] MUL x7,x7,x3 5 7 8 12 12 P18,P17,P16 ---- MUL P18 P17 P16 - 12 12 - 016) 002 x7 P17 0 0 0 +-----+
017] ADDI x1,x1,-1 5 7 9 10 10 11 P19,P14,-1 ---- ADDI P19 P14 - -1 10 10 - 017) 003 x1 P14 0 0 1
018] SW x7,2(x6) 6 8 9 11 11 ,2(P8)<-P18 ---- SW - P18 P8 2 - 11 - 018) 004 - - 1 0 0
019] ADDI x2,x2,8 7 8 10 11 11 12 P20,P15,8 ---- ADDI P20 P15 - 8 11 11 - 019) 005 x2 P15 0 0 1
020] BNE x1,x0,-7 7 8 10 11 11 12 ,P19,P0,-7 ---- BNE - P19 P0 -7 11 11 - 020) 006 - - 0 0 1
----- Press ENTER to continue (PC=8,IC=21,CK=15,CTOT=16,IPC=1.31)...
```

```
=====
PHYSICAL REGS: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                * * * * *
qi: 0 1 0 1 1 1 1 0 1 1 1 1 1 0 0 0 0 1 0 0 1 1 1 1
vi: 00 00 00 00 00 00 FF 00 00 08 00 00 00 FE 10 00 00 00 FD 18 00 00 00 00 00
```


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```
016] MUL  x7,x7,x3      5  7  8 12 12 17      P18,P17,P16      ---- MUL P18 P17 P16 - 12 12 - 016) 002 x7 P17 0 0 1 +-----+
017] ADDI x1,x1,-1      5  7  9 10 10 11      P19,P14,-1      ---- ADDI P19 P14 - -1 10 10 - 017) 003 x1 P14 0 0 1
018] SW   x7,2(x6)      6  8  9 11 11 17      ,2(P8)<-P18      ---- SW - P18 P8 2 - 11 - 018) 004 - - 1 0 1
019] ADDI x2,x2,8      7  8 10 11 11 12      P20,P15,8      ---- ADDI P20 P15 - 8 11 11 - 019) 005 x2 P15 0 0 1
020] BNE  x1,x0,-7      7  8 10 11 11 12      ,P19,P0,-7      ---- BNE - P19 P0 -7 11 11 - 020) 006 - - 0 0 1
```

Press ENTER to continue (PC=8,IC=21,CK=17,CTOT=18,IPC=1.17)...

#017 stall due to NO SLOTS when trying to move instnction SW/011 from stage W to stage C.

```
=====
PHYSICAL REGS:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                  *      *                      *      * * *
qi:  0  1  0  1  1  1  1  0  1  1  1  1  1  1  1  0  1  0  0  0  1  1  1  1
vi:  00 00 00 00 00 00 FF 00 00 08 00 00 00 FE 10 00 00 00 FD 18 00 00 00 00
=====
```

```
=====
REG.FILE: xi:      1      2      3      4      5      6      7      8
          Pi:     19     20     16      1      3      8     18      -
          Qi:      0      0      0      0      0      0      0      0
          Vi:  00000FFE 00000010 00000000 00004000 00005000 00006000 00000000 00000000
=====
```

```
=====
STAGES:          F  D  P  I  X  W  C RENAMED-STR      INSTRUCTION-WINDOW      REORDER-BUFFER      A  M  L  S  B  F  X
TOTAL SLOTS:     4  4  4  4  9  4  4  24      16      99      1  1  1  0  1  4  1
BUSY SLOTS:      0  0  0  0  0  0  0  7      0      1      0  0  0  0  0  0  0
STALLS:         0  9 12 16  0  0  7  0      0      0      0  0  5  1  0  0  0
=====
```

```
=====
PC  INSTRUCTION      F  D  P  I  X  W  C Pi,Pj Pk P1  IW#  OPCODE Pi  Pj  Pk I/P1  Cj Ck Cl  ROB# PC  xi  oPi s x c  +-----+
000] LW  x3,2(x4)     0  1  2  3  3  5  6 P2,2(P1)  ---- LW P2 P1 - 2  3  3 - ---- 000 x3 - 0 0 1 |LQ(0 )
001] LW  x7,2(x5)     0  1  2  5  5  7  8 P4,2(P3)  ---- LW P4 P3 - 2  5  5 - ---- 001 x7 - 0 0 1 |PC  OP Pi  EFAD Ci
002] MUL  x7,x7,x3     0  1  2  7  7 12 13 P5,P4,P2  ---- MUL P5 P4 P2 - 7  7 - ---- 002 x7 P4 0 0 1 |---- LW P2 4002 5
003] ADDI x1,x1,-1     0  1  2  3  3  4 13 P7,P6,-1  ---- ADDI P7 P6 - -1  3  3 - ---- 003 x1 P6 0 0 1 |---- LW P4 5002 7
004] SW   x7,2(x6)     1  2  3  4  4 12 13 ,2(P8)<-P5  ---- SW - P5 P8 2 - 4 - ---- 004 - - 1 0 1 |---- LW P11 4002 8
005] ADDI x2,x2,8      1  2  3  4  4  5 13 P10,P9,8  ---- ADDI P10 P9 - 8  4  4 - ---- 005 x2 P9 0 0 1 |---- LW P12 5002 9
006] BNE  x1,x0,-7     1  2  4  5  5  6 14 ,P7,P0,-7  ---- BNE - P7 P0 -7  5  5 - ---- 006 - - 0 0 1 |---- LW P16 4002 11
007] LW  x3,2(x4)     2  3  4  6  6  8 14 P11,2(P1)  ---- LW P11 P1 - 2  6  6 - ---- 000 x3 P2 0 0 1 |---- LW P17 5002 12
008] LW  x7,2(x5)     2  3  5  7  7  9 14 P12,2(P3)  ---- LW P12 P3 - 2  7  7 - ---- 001 x7 P5 0 0 1 +-----+
009] MUL  x7,x7,x3     2  3  5  9  9 14 15 P13,P12,P11  ---- MUL P13 P12 P11 - 9  9 - ---- 002 x7 P12 0 0 1
010] ADDI x1,x1,-1     2  4  6  7  7  8 15 P14,P7,-1  ---- ADDI P14 P7 - -1  7  7 - ---- 003 x1 P7 0 0 1 +-----+
011] SW   x7,2(x6)     3  4  7  8  8 14 15 ,2(P8)<-P13  ---- SW - P13 P8 2 - 8 - ---- 004 - - 1 0 1 |SQ(0 )
012] ADDI x2,x2,8      3  5  7  8  8  9 15 P15,P10,8  ---- ADDI P15 P10 - 8  8  8 - ---- 005 x2 P10 0 0 1 |PC  OP P1  EFAD Cl
013] BNE  x1,x0,-7     3  5  7  8  8  9 16 ,P14,P0,-7  ---- BNE - P14 P0 -7  8  8 - ---- 006 - - 0 0 1 |---- SW P5 6002 12
014] LW  x3,2(x4)     4  6  8  9  9 11 16 P16,2(P1)  ---- LW P16 P1 - 2  9  9 - ---- 000 x3 P11 0 0 1 |---- SW P13 6002 14
015] LW  x7,2(x5)     4  7  8 10 10 12 16 P17,2(P3)  ---- LW P17 P3 - 2 10 10 - ---- 001 x7 P13 0 0 1 |---- SW P18 6002 17
016] MUL  x7,x7,x3     5  7  8 12 12 17 18 P18,P17,P16  ---- MUL P18 P17 P16 - 12 12 - ---- 002 x7 P17 0 0 1 +-----+
017] ADDI x1,x1,-1     5  7  9 10 10 11 18 P19,P14,-1  ---- ADDI P19 P14 - -1 10 10 - ---- 003 x1 P14 0 0 1
018] SW   x7,2(x6)     6  8  9 11 11 17 18 ,2(P8)<-P18  ---- SW - P18 P8 2 - 11 - ---- 004 - - 1 0 1
019] ADDI x2,x2,8      7  8 10 11 11 12 18 P20,P15,8  ---- ADDI P20 P15 - 8 11 11 - ---- 005 x2 P15 0 0 1
020] BNE  x1,x0,-7     7  8 10 11 11 12      ,P19,P0,-7  ---- BNE - P19 P0 -7 11 11 - 020) 006 - - 0 0 1
=====
```

Press ENTER to continue (PC=8,IC=21,CK=18,CTOT=19,IPC=1.11)...

```
=====
PHYSICAL REGS:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                  *      *                      *      * * *
qi:  0  1  0  1  1  1  1  0  1  1  1  1  1  1  1  0  1  0  0  0  1  1  1  1
vi:  00 00 00 00 00 00 FF 00 00 08 00 00 00 FE 10 00 00 00 FD 18 00 00 00 00
=====
```

```
=====
REG.FILE: xi:      1      2      3      4      5      6      7      8
          Pi:     19     20     16      1      3      8     18      -
          Qi:      0      0      0      0      0      0      0      0
          Vi:  00000FFE 00000010 00000000 00004000 00005000 00006000 00000000 00000000
=====
```

```
=====
STAGES:          F  D  P  I  X  W  C RENAMED-STR      INSTRUCTION-WINDOW      REORDER-BUFFER      A  M  L  S  B  F  X
TOTAL SLOTS:     4  4  4  4  9  4  4  24      16      99      1  1  1  0  1  4  1
BUSY SLOTS:      0  0  0  0  0  0  0  7      0      0      0  0  0  0  0  0  0
STALLS:         0  9 12 16  0  0  7  0      0      0      0  0  5  1  0  0  0
=====
```

```
=====
PC  INSTRUCTION      F  D  P  I  X  W  C Pi,Pj Pk P1  IW#  OPCODE Pi  Pj  Pk I/P1  Cj Ck Cl  ROB# PC  xi  oPi s x c  +-----+
000] LW  x3,2(x4)     0  1  2  3  3  5  6 P2,2(P1)  ---- LW P2 P1 - 2  3  3 - ---- 000 x3 - 0 0 1 |LQ(0 )
001] LW  x7,2(x5)     0  1  2  5  5  7  8 P4,2(P3)  ---- LW P4 P3 - 2  5  5 - ---- 001 x7 - 0 0 1 |PC  OP Pi  EFAD Ci
002] MUL  x7,x7,x3     0  1  2  7  7 12 13 P5,P4,P2  ---- MUL P5 P4 P2 - 7  7 - ---- 002 x7 P4 0 0 1 |---- LW P2 4002 5
003] ADDI x1,x1,-1     0  1  2  3  3  4 13 P7,P6,-1  ---- ADDI P7 P6 - -1  3  3 - ---- 003 x1 P6 0 0 1 |---- LW P4 5002 7
=====
```

out-ex1.txt

Sat May 10 13:57:43 2025

14

004]

SW

x7,2(x6)

1

2

3

4

4

12

13

,2(P8)<-P5

SW

-

P5

P8

2

-

4

-

004

-

-

1

0

1

|

LW

P11

4002

8

|

005]

ADDI

x2,x2,8

1

2

3

4

4

5

13

P10,P9,8

ADDI

P10

P9

-

8

4

4

-

005

x2

P9

0

0

1

|

LW

P12

5002

9

|

006]

BNE

x1,x0,-7

1

2

4

5

5

6

14

,P7,P0,-7

BNE

-

P7

P0

-7

5

5

-

006

-

-

0

0

1

|

LW

P16

4002

11

|

007]

LW

x3,2(x4)

2

3

4

6

6

8

14

P11,2(P1)

LW

P11

P1

-

2

6

6

-

000

x3

P2

0

0

1

|

LW

P17

5002

12

|

008]

LW

x7,2(x5)

2

3

5

7

7

9

14

P12,2(P3)

LW

P12

P3

-

2

7

7

-

001

x7

P5

0

0

1

|

+

009]

MUL

x7,x7,x3

2

3

5

9

9

14

15

P13,P12,P11

MUL

P13

P12

P11

-

9

9

-

002

x7

P12

0

0

1

|

+

010]

ADDI

x1,x1,-1

2

4

6

7

7

8

15

P14,P7,-1

ADDI

P14

P7

-

-1

7

7

-

003

x1

P7

0

0

1

|

+

011]

SW

x7,2(x6)

3

4

7

8

8

14

15

,2(P8)<-P13

SW

-

P13

P8

2

-

8

-

004

-

-

1

0

1

|

SQ(0)

|

012]

ADDI

x2,x2,8

3

5

7

8

8

9

15

P15,P10,8

ADDI

P15

P10

-

8

8

8

-

005

x2

P10

0

0

1

|

PC

OP

P1

EFAD

C1

|

013]

BNE

x1,x0,-7

3

5

7

8

8

9

16

,P14,P0,-7

BNE

-

P14

P0

-7

8

8

-

006

-

-

0

0

1

|

SW

P5

6002

12

|

014]

LW

x3,2(x4)

4

6

8

9

9

11

16

P16,2(P1)

LW

P16

P1

-

2

9

9

-

000

x3

P11

0

0

1

|

SW

P13

6002

14

|

015]

LW

x7,2(x5)

4

7

8

10

10

12

16

P17,2(P3)

LW

P17

P3

-

2

10

10

-

001

x7

P13

0

0

1

|

SW

P18

6002

17

|

016]

MUL

x7,x7,x3

5

7

8

12

12

17

18

P18,P17,P16

MUL

P18

P17

P16

-

12

12

-

002

x7

P17

0

0

1

|

+

017]

ADDI

x1,x1,-1

5

7

9

10

10

11

18

P19,P14,-1

ADDI

P19

P14

-

-1

10

10

-

003

x1

P14

0

0

1

|

+

018]

SW

x7,2(x6)

6

8

9

11

11

17

18

,2(P8)<-P18

SW

-

P18

P8

2

-

11

-

004

-

-

1

0

1

|

+

019]

ADDI

x2,x2,8

7

8

10

11

11

12

18

P20,P15,8

ADDI

P20

P15

-

8

11

11

-

005

x2

P15

0

0

1

|

+

020]

BNE

x1,x0,-7

7

8

10

11

11

12

19

,P19,P0,-7

BNE

-

P19

P0

-7

11

11

-

006

-

-

0

0

1

|

+

Press ENTER to continue (PC=8,IC=21,CK=19,CTOT=20,IPC=1.05)...

Program 'program-ex1' FINISHED

PC=8,IC=21,CK=20,IPC=1.05

Goodbye.