

out070628.txt

Fri Oct 26 16:06:44 2018

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./run070628.sh

TEST DATE: 070628

LIST OF INITIALIZATION PARAMETERS

-----[General]

Program Name = prog070628
Silent = no
Interactive = no
Batch File = yes

-----[Architecture]

Logical Registers = 8
Physical Registers = 24
Pipeline Structure = FDPXWC
Unified LSU = yes
In-Order Issue = no
In-Order Complete = no
Unified Dispatch/Issue = yes
Fetch Width = 4
Decode Width = 4
Issue Width = 4
Write-Back Width = 4
Commit Width = 4
Window Size = 16
ROB Size = 99
Integer ALU Units = 4
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

-----[Program Defaults]

Log File Name = def.log

* Input program: 'prog070628'

000) 35 2 1 0 --> LW R2,0(R1)
001) 35 4 3 0 --> LW R4,0(R3)
002) 32 5 5 2 --> ADD R5,R5,R2
003) 32 5 5 4 --> ADD R5,R5,R4
004) 24 5 5 5 --> MUL R5,R5,R5
005) 43 5 1 0 --> SW R5,0(R1)
006) 43 5 3 0 --> SW R5,0(R3)
007) 8 1 1 4 --> ADDI R1,R1,4
008) 8 3 3 4 --> ADDI R3,R3,4
009) 8 7 7 -1 --> ADDI R7,R7,-1
010) 5 7 0 -11 --> BNE R7,R0,-11

* TOTAL_INSTRUCTIONS=11

* DEFAULT_NUMBER_OF_ITERATIONS=3

- STAGE = 4 entries.
FETCH STAGE = 4 entries.
DECODE STAGE = 4 entries.
DISPATCH STAGE = 16 entries.
ISSUE STAGE = 4 entries.
EXECUTE STAGE = 12 entries.
COMPLETE STAGE = 4 entries.
COMMIT STAGE = 4 entries.

=====

Consider the following snippet of code running on 4-ways out-of-order superscalar processor.
Initially, R1=0x1000, R3=0x3000, R7=0x0003 and the other registers contain zero.

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```
lab1:    LW     R2,0(R1)
         LW     R4,0(R3)
         ADD   R5,R5,R2
         ADD   R5,R5,R4
         MUL   R5,R5,R5
         SW     R5,0(R1)
         SW     R5,0(R3)
         ADDI  R1,R1,4
         ADDI  R3,R3,4
         ADDI  R7,R7,-1
         BNE   R7,R0,lab1
```

Working hypothesis:

- * the fetch, decode and commit stages are 4 instructions wide
- * the instruction window has 16 slots
- * we have 24 physical registers in the free pool
- * the reorder buffer has unlimited size
- * the integer multiplier has 4 stages
- * the load/store queues have 3 slots each and a common effective-address calculation unit
- * there are 4 ALUs for arithmetic and logic operations and for branching
- * an ALU performs its operation in the same cycle when the operation is issued
- * reads require 1 clock cycle (after the addressing phase)
- * the register file has 4 input- and 4 output-ports
- * there are 9 logical registers (including R0 which is hardwired to 0)
- * the store operation leaves the issue stage as it is inserted in the store queue

In order to calculate the total cycles needed to execute 3 iterations of the above loop on such machine, complete the following chart until the end of the third iteration of the code fragment above, including the renamed stream the precise evolution of the free pool of the physical registers (the register map), the Instruction Window, the Reorder Buffer (ROB) and the Load Queue (LQ) and Store Queue (SQ).

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:    1  1  1  1  1  1  1  1  1  1  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:	Ri:	1	2	3	4	5	6	7	8
	Pi:	-	-	-	-	-	-	-	-
	Qi:	0	0	0	0	0	0	0	0
	Vi:	00001000	00000000	00003000	00000000	00000000	00000000	00000003	00000000

[illegible]

- Press ENTER to continue (PC=4,IC=4,CK=0,CTOT=1,IPC=4.00)...

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  0  1  1  1  1  1  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:	Ri:	1	2	3	4	5	6	7	8
	Pi:	1	2	3	4	7	-	-	-
	Qi:	0	1	0	1	1	0	0	0
	Vi:	00001000	00000000	00003000	00000000	00000000	00000000	00000003	00000000

STAGES:										INSTRUCTION-WINDOW										REORDER-BUFFER										A M L S B F X									
TOTAL SLOTS:										16										99										4 1 1 0 1 4 1									
BUSY SLOTS:										0										0										0 0 0 0 0 0 0									
STALLS:										0										0										0 0 0 0 0 0 0									
=====																																							
PC INSTRUCTION										IW# OPCODE Pi Pj Pk I/P1 Cj Ck Cl										ROB# PC Ri oPi x s c										+-----+									
000) LW R2,0(R1)										0 1 P2,0(P1)																				LQ(0)									

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```
001] LW  R4,0(R3)      0 1          P4,0(P3)          |PC  OP Pi  EFAD Ci|
002] ADD  R5,R5,R2      0 1          P6,P5,P2          +-----+
003] ADD  R5,R5,R4      0 1          P7,P6,P4          +-----+
004] MUL  R5,R5,R5      1          +-----+
005] SW   R5,0(R1)      1          |SQ(0 )          |
006] SW   R5,0(R3)      1          |PC  OP Pi  EFAD Cl|
007] ADDI R1,R1,4       1          +-----+

----- Press ENTER to continue (PC=8,IC=8,CK=1,CTOT=2,IPC=4.00)...
```

```
=====
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  0  1  1  1  1  1  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 00

=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
          Pi:      9      2      3      4      8      -      -      -
          Qi:      1      1      0      1      1      0      0      0
          Vi:  00001000 00000000 00003000 00000000 00000000 00000000 00000003 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 16  4 12  4  4 24          16          99          4  1  1  0  1  4  1
BUSY SLOTS:       3  4  4  0  0  0  0  9          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 P1  IW#  OPCD Pi  Pj  Pk I/P1  Cj  Ck  Cl  ROB#  PC  Ri  oPi  x  s  c  +-----+
000] LW  R2,0(R1)    0  1  2          P2,0(P1)    000)  LW  P2  P1  -  0  2  -  -  000) 000 R2  -  0  0  0  |LQ(0 )          |
001] LW  R4,0(R3)    0  1  2          P4,0(P3)    001)  LW  P4  P3  -  0  2  -  -  001) 001 R4  -  0  0  0  |PC  OP Pi  EFAD Ci|
002] ADD  R5,R5,R2    0  1  2          P6,P5,P2    002)  ADD  P6  P5  P2  -  2  .  -  002) 002 R5  P5  0  0  0  +-----+
003] ADD  R5,R5,R4    0  1  2          P7,P6,P4    003)  ADD  P7  P6  P4  -  .  .  -  003) 003 R5  P6  0  0  0  +-----+
004] MUL  R5,R5,R5    1  2          P8,P7,P7          +-----+
005] SW   R5,0(R1)    1  2          ,P0(P1)<~P8          |SQ(0 )          |
006] SW   R5,0(R3)    1  2          ,P0(P3)<~P8          |PC  OP Pi  EFAD Cl|
007] ADDI R1,R1,4     1  2          P9,P1,4          +-----+
008] ADDI R3,R3,4     2
009] ADDI R7,R7,-1    2
010] BNE  R7,R0,-11   2

----- Press ENTER to continue (PC=0,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  0  1  1  1  1  1  0  1  1  1  1  1  1  1  1  1  1  1  1  1
vi:  00 00 00 00 00 00 00 00 00 00 03 00 00 00 00 00 00 00 00 00 00 00 00 00

=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
          Pi:      9      2      10     4      8      -      12     -
          Qi:      1      1      1      1      1      0      1      0
          Vi:  00001000 00000000 00003000 00000000 00000000 00000000 00000003 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 16  4 12  4  4 24          16          99          4  1  1  0  1  4  1
BUSY SLOTS:       4  3  7  1  0  0  0 12          7          8          0  0  0  0  0  0  0
STALLS:          0  0  0  3  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 P1  IW#  OPCD Pi  Pj  Pk I/P1  Cj  Ck  Cl  ROB#  PC  Ri  oPi  x  s  c  +-----+
000] LW  R2,0(R1)    0  1  2  3          P2,0(P1)    000>  LW  P2  P1  -  0  2  -  -  000) 000 R2  -  0  0  0  |LQ(1 )          |
001] LW  R4,0(R3)    0  1  2          P4,0(P3)    001)  LW  P4  P3  -  0  2  -  -  001) 001 R4  -  0  0  0  |PC  OP Pi  EFAD Ci|
002] ADD  R5,R5,R2    0  1  2          P6,P5,P2    002)  ADD  P6  P5  P2  -  2  .  -  002) 002 R5  P5  0  0  0  |000] LW P2 0000 .|
003] ADD  R5,R5,R4    0  1  2          P7,P6,P4    003)  ADD  P7  P6  P4  -  .  .  -  003) 003 R5  P6  0  0  0  +-----+
004] MUL  R5,R5,R5    1  2  3          P8,P7,P7    000)  MUL  P8  P7  P7  -  .  .  -  004) 004 R5  P7  0  0  0  +-----+
005] SW   R5,0(R1)    1  2  3          ,P0(P1)<~P8    004)  SW  -  P8  P1  0  -  3  -  005) 005 -  -  1  0  0  +-----+
006] SW   R5,0(R3)    1  2  3          ,P0(P3)<~P8    005)  SW  -  P8  P3  0  -  3  -  006) 006 -  -  1  0  0  |SQ(0 )          |
007] ADDI R1,R1,4     1  2  3          P9,P1,4     006)  ADDI P9  P1  -  4  3  -  -  007) 007 R1  P1  0  0  0  |PC  OP Pi  EFAD Cl|
008] ADDI R3,R3,4     2  3          P10,P3,4          +-----+
009] ADDI R7,R7,-1    2  3          P12,P11,-1
010] BNE  R7,R0,-11   2  3          ,P12,P0,-11
011] LW  R2,0(R1)    3
012] LW  R4,0(R3)    3
013] ADD  R5,R5,R2    3
```

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014] ADD R5,R5,R4 3

----- Press ENTER to continue (PC=4,IC=15,CK=3,CTOT=4,IPC=3.75)...

@003 stall due to no L-unit available

@003 stall due to NO SLOTS when trying to move instuction LW/001 from stage P to stage I.

@003 stall due to NO SLOTS when trying to move instuction ADD/002 from stage P to stage I.

@003 stall due to NO SLOTS when trying to move instuction ADD/003 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  1  0  1  0  1  1  1  1  1  0  1  1  1  1  1  1  1  1  1  1  1  1  1
vi:  00 00 00 00 00 00 00 00 00 04 00 03 00 00 00 00 00 00 00 00 00 00 00 00
=====
```

```
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
          Pi:      9     13     10     14     16      -     12      -
          Qi:      1      1      1      1      1      0      1      0
          Vi:  00001000 00000000 00003000 00000000 00000000 00000000 00000003 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 16  4 12  4  4 24         16                99          4  1  1  0  1  4  1
BUSY SLOTS:      4  4  8  1  2  0  0 16          8                11          0  0  0  0  0  0  0
STALLS:          0  0  0  8  0  0  0 0          0                0          0  0  1  2  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  Ri  oPi x s c  +-----+
000] LW  R2,0(R1)     0  1  2  3  4      P2,0(P1)  ---  LW P2 P1 -  0  2 - -  000) 000 R2 -  0 0 0  |LQ(2 )|
001] LW  R4,0(R3)     0  1  2  4      P4,0(P3)  001>  LW P4 P3 -  0  2 - -  001) 001 R4 -  0 0 0  |PC  OP Pi  EFAD Ci|
002] ADD R5,R5,R2     0  1  2      P6,P5,P2  002)  ADD P6 P5 P2 -  2  - -  002) 002 R5 P5 0 0 0  |000] LW P2 1000 .|
003] ADD R5,R5,R4     0  1  2      P7,P6,P4  003)  ADD P7 P6 P4 -  .  - -  003) 003 R5 P6 0 0 0  |001] LW P4 0000 .|
004] MUL R5,R5,R5     1  2  3      P8,P7,P7  000)  MUL P8 P7 P7 -  .  - -  004) 004 R5 P7 0 0 0  +-----+
005] SW  R5,0(R1)     1  2  3      ,P0(P1)<-P8  004)  SW - P8 P1 0 -  3 - -  005) 005 - -  1 0 0
006] SW  R5,0(R3)     1  2  3      ,P0(P3)<-P8  005)  SW - P8 P3 0 -  3 - -  006) 006 - -  1 0 0  +-----+
007] ADDI R1,R1,4     1  2  3  4  4      P9,P1,4  006>  ADDI P9 P1 -  4  3 - -  007) 007 R1 P1 0 0 0  |SQ(0 )|
008] ADDI R3,R3,4     2  3  4      P10,P3,4  001)  ADDI P10 P3 -  4  4 - -  008) 008 R3 P3 0 0 0  |PC  OP Pi  EFAD Cl|
009] ADDI R7,R7,-1    2  3  4      P12,P11,-1  006)  ADDI P12 P11 -  -1  4 - -  009) 009 R7 P11 0 0 0  +-----+
010] BNE R7,R0,-11    2  3  4      ,P12,P0,-11  007)  BNE - P12 P0 -11 -  4 - -  010) 010 - -  0 0 0
011] LW  R2,0(R1)     3  4      P13,0(P9)
012] LW  R4,0(R3)     3  4      P14,0(P10)
013] ADD R5,R5,R2     3  4      P15,P8,P13
014] ADD R5,R5,R4     3  4      P16,P15,P14
015] MUL R5,R5,R5     4
016] SW  R5,0(R1)     4
017] SW  R5,0(R3)     4
018] ADDI R1,R1,4     4
=====
```

----- Press ENTER to continue (PC=8,IC=19,CK=4,CTOT=5,IPC=3.80)...

@004 stall due to NO SLOTS when trying to move instuction ADD/002 from stage P to stage I.

@004 stall due to NO SLOTS when trying to move instuction ADD/003 from stage P to stage I.

@004 stall due to NO SLOTS when trying to move instuction MUL/004 from stage P to stage I.

@004 stall due to no S-unit available

@004 stall due to NO SLOTS when trying to move instuction SW/005 from stage P to stage I.

@004 stall due to no S-unit available

@004 stall due to NO SLOTS when trying to move instuction SW/006 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  1  0  1  0  1  1  1  1  0  1  0  1  1  1  1  1  1  1  1  1  1  1  1
vi:  00 00 00 00 00 00 00 00 00 04 04 03 02 00 00 00 00 00 00 00 00 00 00 00
=====
```

```
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
          Pi:     18     13     10     14     17      -     12      -
          Qi:      1      1      1      1      1      0      1      0
          Vi:  00001004 00000000 00003000 00000000 00000000 00000000 00000003 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 16  4 12  4  4 24         16                99          4  1  1  0  1  4  1
BUSY SLOTS:      3  4  9  1  4  1  0 18          9                15          0  0  0  0  0  0  0
STALLS:          0  0  0 13  0  0  0 0          0                0          0  0  1  3  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  Ri  oPi x s c  +-----+
=====
```

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```
000] LW    R2,0(R1)      0 1 2 3 4      P2,0(P1)      ---- LW P2 P1 - 0 2 - - 000) 000 R2 - 0 0 0 |LQ(2 ) |
001] LW    R4,0(R3)      0 1 2 4 5      P4,0(P3)      ---- LW P4 P3 - 0 2 - - 001) 001 R4 - 0 0 0 |PC  OP Pi EFAD Ci |
002] ADD   R5,R5,R2      0 1 2          P6,P5,P2      002) ADD P6 P5 P2 - 2 . - 002) 002 R5 P5 0 0 0 |000] LW P2 1000 . |
003] ADD   R5,R5,R4      0 1 2          P7,P6,P4      003) ADD P7 P6 P4 - . . - 003) 003 R5 P6 0 0 0 |001] LW P4 3000 . |
004] MUL   R5,R5,R5      1 2 3          P8,P7,P7      000) MUL P8 P7 P7 - . . - 004) 004 R5 P7 0 0 0 +-----+
005] SW    R5,0(R1)      1 2 3 5          ,P0(P1)<--P8 004> SW - P8 P1 0 - 3 - 005) 005 - - 1 0 0
006] SW    R5,0(R3)      1 2 3          ,P0(P3)<--P8 005) SW - P8 P3 0 - 3 - 006) 006 - - 1 0 0 +-----+
007] ADDI  R1,R1,4        1 2 3 4 4 5      P9,P1,4        ---- ADDI P9 P1 - 4 3 - - 007) 007 R1 P1 0 0 1 |SQ(1 ) |
008] ADDI  R3,R3,4        2 3 4 5 5      P10,P3,4       001> ADDI P10 P3 - 4 4 - - 008) 008 R3 P3 0 0 0 |PC  OP Pi EFAD Cl |
009] ADDI  R7,R7,-1       2 3 4 5 5      P12,P11,-1     006> ADDI P12 P11 - -1 4 - - 009) 009 R7 P11 0 0 0 |005] SW P0 0000 . |
010] BNE   R7,R0,-11     2 3 4          ,P12,P0,-11    007) BNE - P12 P0 -11 - 4 - 010) 010 - - 0 0 0 +-----+
011] LW    R2,0(R1)      3 4 5          P13,0(P9)      001) LW P13 P9 - 0 5 - - 011) 000 R2 P2 0 0 0
012] LW    R4,0(R3)      3 4 5          P14,0(P10)     004) LW P14 P10 - 0 . - - 012) 001 R4 P4 0 0 0
013] ADD   R5,R5,R2      3 4 5          P15,P8,P13     006) ADD P15 P8 P13 - . . - 013) 002 R5 P8 0 0 0
014] ADD   R5,R5,R4      3 4 5          P16,P15,P14    008) ADD P16 P15 P14 - . . - 014) 003 R5 P15 0 0 0
015] MUL   R5,R5,R5      4 5          P17,P16,P16
016] SW    R5,0(R1)      4 5          ,P0(P9)<--P17
017] SW    R5,0(R3)      4 5          ,P0(P10)<--P17
018] ADDI  R1,R1,4        4 5          P18,P9,4
019] ADDI  R3,R3,4        5
020] ADDI  R7,R7,-1       5
021] BNE   R7,R0,-11     5
```

----- Press ENTER to continue (PC=0,IC=22,CK=5,CTOT=6,IPC=3.67)...

@005 stall due to NO SLOTS when trying to move instnction ADD/002 from stage P to stage I.
@005 stall due to NO SLOTS when trying to move instnction ADD/003 from stage P to stage I.
@005 stall due to NO SLOTS when trying to move instnction MUL/004 from stage P to stage I.
@005 stall due to no S-unit available
@005 stall due to NO SLOTS when trying to move instnction SW/006 from stage P to stage I.
@005 stall due to NO SLOTS when trying to move instnction BNE/010 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 1 0 1 0 1 1 1 0 0 0 0 1 1 1 1 1 1 1 1 1 1
vi:  00 00 00 00 00 00 00 00 04 04 03 02 00 00 00 00 00 00 00 00 00 00 00 00
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
          Pi:     18     13     19     14     17     -     20     -
          Qi:      1      1      1      1      1      0      1      0
          Vi:  00001004 00000000 00003004 00000000 00000000 00000000 00000002 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 16 4 12 4 4 24        16                    99                    4 1 1 0 1 4 1
BUSY SLOTS:       4 3 10 1 3 1 0 20          10                    19                    0 0 0 0 0 0 0
STALLS:           0 0 0 19 0 0 1 0            0                    0                    0 0 1 3 0 0 0
=====
```

```
PC  INSTRUCTION      F D P I X W C Pi,Pj Pk Pl  IW#  OPCODE Pi Pj Pk I/P1 Cj Ck Cl  ROB# PC Ri oPi x s c +-----+
000] LW    R2,0(R1)    0 1 2 3 4 6      P2,0(P1)      ---- LW P2 P1 - 0 2 - - 000) 000 R2 - 0 0 1 |LQ(1 ) |
001] LW    R4,0(R3)    0 1 2 4 5      P4,0(P3)      ---- LW P4 P3 - 0 2 - - 001) 001 R4 - 0 0 0 |PC  OP Pi EFAD Ci |
002] ADD   R5,R5,R2    0 1 2 6 6      P6,P5,P2      002> ADD P6 P5 P2 - 2 6 - 002) 002 R5 P5 0 0 0 |---- LW P2 1000 6 |
003] ADD   R5,R5,R4    0 1 2          P7,P6,P4      003) ADD P7 P6 P4 - . . - 003) 003 R5 P6 0 0 0 |001] LW P4 3000 . |
004] MUL   R5,R5,R5    1 2 3          P8,P7,P7      000) MUL P8 P7 P7 - . . - 004) 004 R5 P7 0 0 0 +-----+
005] SW    R5,0(R1)    1 2 3 5 6      ,P0(P1)<--P8 005> SW - P8 P1 0 - 3 - 005) 005 - - 1 0 0
006] SW    R5,0(R3)    1 2 3 6      ,P0(P3)<--P8 005> SW - P8 P3 0 - 3 - 006) 006 - - 1 0 0 +-----+
007] ADDI  R1,R1,4      1 2 3 4 4 5      P9,P1,4        ---- ADDI P9 P1 - 4 3 - - 007) 007 R1 P1 0 0 1 |SQ(2 ) |
008] ADDI  R3,R3,4      2 3 4 5 5 6      P10,P3,4       ---- ADDI P10 P3 - 4 4 - - 008) 008 R3 P3 0 0 1 |PC  OP Pi EFAD Cl |
009] ADDI  R7,R7,-1     2 3 4 5 5 6      P12,P11,-1     ---- ADDI P12 P11 - -1 4 - - 009) 009 R7 P11 0 0 1 |005] SW P0 1000 . |
010] BNE   R7,R0,-11   2 3 4 6 6      ,P12,P0,-11    007> BNE - P12 P0 -11 6 4 - 010) 010 - - 0 0 0 |006] SW P0 0000 . |
011] LW    R2,0(R1)    3 4 5          P13,0(P9)      001) LW P13 P9 - 0 5 - - 011) 000 R2 P2 0 0 0 +-----+
012] LW    R4,0(R3)    3 4 5          P14,0(P10)     004) LW P14 P10 - 0 6 - - 012) 001 R4 P4 0 0 0
013] ADD   R5,R5,R2    3 4 5          P15,P8,P13     006) ADD P15 P8 P13 - . . - 013) 002 R5 P8 0 0 0
014] ADD   R5,R5,R4    3 4 5          P16,P15,P14    008) ADD P16 P15 P14 - . . - 014) 003 R5 P15 0 0 0
015] MUL   R5,R5,R5    4 5 6          P17,P16,P16    002) MUL P17 P16 P16 - . . - 015) 004 R5 P16 0 0 0
016] SW    R5,0(R1)    4 5 6          ,P0(P9)<--P17 005) SW - P17 P9 0 - 6 - 016) 005 - - 1 0 0
017] SW    R5,0(R3)    4 5 6          ,P0(P10)<--P17 007) SW - P17 P10 0 - 6 - 017) 006 - - 1 0 0
018] ADDI  R1,R1,4      4 5 6          P18,P9,4       009) ADDI P18 P9 - 4 6 - - 018) 007 R1 P9 0 0 0
019] ADDI  R3,R3,4      5
020] ADDI  R7,R7,-1     5
021] BNE   R7,R0,-11   5 6          ,P20,P0,-11
```

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```
022] LW   R2,0(R1)      6
023] LW   R4,0(R3)      6
024] ADD  R5,R5,R2      6
025] ADD  R5,R5,R4      6
```

----- Press ENTER to continue (PC=4,IC=26,CK=6,CTOT=7,IPC=3.71)...

```
@006 stall due to NO SLOTS when trying to move instnction ADDI/007 from stage W to stage C.
@006 stall due to NO SLOTS when trying to move instnction ADD/003 from stage P to stage I.
@006 stall due to NO SLOTS when trying to move instnction MUL/004 from stage P to stage I.
@006 stall due to NO SLOTS when trying to move instnction LW/011 from stage P to stage I.
@006 stall due to NO SLOTS when trying to move instnction LW/012 from stage P to stage I.
@006 stall due to NO SLOTS when trying to move instnction ADD/013 from stage P to stage I.
@006 stall due to NO SLOTS when trying to move instnction ADD/014 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  1  1  0  0  0  1  1  1  1  1  1  1  1  1  1  1  1
vi:  00 00 00 00 00 00 00 00 04 04 03 02 00 00 00 00 00 08 00 00 00 00 00 00
=====
```

```
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
          Pi:     18     21     19     22     24      -     20      -
          Qi:      1      1      1      1      1      0      1      0
          Vi:  00001004 00000000 00003004 00000000 00000000 00000000 00000002 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 16  4 12  4  4 24          16          99          4  1  1  0  1  4  1
BUSY SLOTS:      4  4 10  1  2  1  0 24          10          21          0  0  0  0  0  0  0
STALLS:          0  0  0 26  0  0  1  0           0           0          0  0  2  5  0  0  0
=====
```

```
=====
PC  INSTRUCTION      F  D  P  I  X  W  C  Pi,Pj Pk Pl  IW#  OPCODE Pi  Pj  Pk I/Pl  Cj  Ck  Cl  ROB#  PC  Ri  oPi  x  s  c  +-----+
000] LW   R2,0(R1)    0  1  2  3  4  6  7  P2,0(P1)  ----  LW  P2  P1  -  0  2  -  -  ----  000  R2  -  0  0  1  |LQ(1 )|
001] LW   R4,0(R3)    0  1  2  4  5  7  P4,0(P3)  ----  LW  P4  P3  -  0  2  -  -  001) 001  R4  -  0  0  1  |PC  OP Pi  EFAD Ci|
002] ADD  R5,R5,R2    0  1  2  6  6  7  P6,P5,P2  ----  ADD  P6  P5  P2  -  2  6  -  -  002) 002  R5  P5  0  0  1  |---- LW P2 1000 6|
003] ADD  R5,R5,R4    0  1  2  7  7  P7,P6,P4  003>  ADD  P7  P6  P4  -  7  7  -  -  003) 003  R5  P6  0  0  0  |---- LW P4 3000 7|
004] MUL  R5,R5,R5    1  2  3  P8,P7,P7  000)  MUL  P8  P7  P7  -  .  .  -  -  004) 004  R5  P7  0  0  0  |011] LW P13 0000 .|
005] SW   R5,0(R1)    1  2  3  5  6  ,P0(P1)<-P8  ----  SW   -  P8  P1  0  -  3  -  -  005) 005  -  -  1  0  0  +-----+
006] SW   R5,0(R3)    1  2  3  6  7  ,P0(P3)<-P8  ----  SW   -  P8  P3  0  -  3  -  -  006) 006  -  -  1  0  0
007] ADDI R1,R1,4     1  2  3  4  4  5  P9,P1,4  ----  ADDI  P9  P1  -  4  3  -  -  007) 007  R1  P1  0  0  1  +-----+
008] ADDI R3,R3,4     2  3  4  5  5  6  P10,P3,4  ----  ADDI  P10 P3  -  4  4  -  -  008) 008  R3  P3  0  0  1  |SQ(2 )|
009] ADDI R7,R7,-1    2  3  4  5  5  6  P12,P11,-1  ----  ADDI  P12 P11  -  -1  4  -  -  009) 009  R7  P11 0  0  1  |PC  OP Pi  EFAD Cl|
010] BNE  R7,R0,-11   2  3  4  6  6  7  ,P12,P0,-11  ----  BNE  -  P12 P0  -11  6  4  -  -  010) 010  -  -  0  0  1  |005] SW P0 1000 .|
011] LW   R2,0(R1)    3  4  5  7  P13,0(P9)  001>  LW  P13 P9  -  0  5  -  -  011) 000  R2  P2  0  0  0  |006] SW P0 3000 .|
012] LW   R4,0(R3)    3  4  5  P14,0(P10)  004)  LW  P14 P10  -  0  6  -  -  012) 001  R4  P4  0  0  0  +-----+
013] ADD  R5,R5,R2    3  4  5  P15,P8,P13  006)  ADD  P15 P8  P13  -  .  .  -  -  013) 002  R5  P8  0  0  0
014] ADD  R5,R5,R4    3  4  5  P16,P15,P14  008)  ADD  P16 P15 P14  -  .  .  -  -  014) 003  R5  P15 0  0  0
015] MUL  R5,R5,R5    4  5  6  P17,P16,P16  002)  MUL  P17 P16 P16  -  .  .  -  -  015) 004  R5  P16 0  0  0
016] SW   R5,0(R1)    4  5  6  ,P0(P9)<-P17  005)  SW   -  P17 P9  0  -  6  -  -  016) 005  -  -  1  0  0
017] SW   R5,0(R3)    4  5  6  ,P0(P10)<-P17  007)  SW   -  P17 P10 0  -  6  -  -  017) 006  -  -  1  0  0
018] ADDI R1,R1,4     4  5  6  7  7  P18,P9,4  009>  ADDI  P18 P9  -  4  6  -  -  018) 007  R1  P9  0  0  0
019] ADDI R3,R3,4     5  6  7  P19,P10,4  001)  ADDI  P19 P10  -  4  7  -  -  019) 008  R3  P10 0  0  0
020] ADDI R7,R7,-1    5  6  7  P20,P12,-1  003)  ADDI  P20 P12  -  -1  7  -  -  020) 009  R7  P12 0  0  0
021] BNE  R7,R0,-11   5  6  7  ,P20,P0,-11  009)  BNE  -  P20 P0  -11  -  7  -  -  021) 010  -  -  0  0  0
022] LW   R2,0(R1)    6  7  P21,0(P18)
023] LW   R4,0(R3)    6  7  P22,0(P19)
024] ADD  R5,R5,R2    6  7  P23,P17,P21
025] ADD  R5,R5,R4    6  7  P24,P23,P22
026] MUL  R5,R5,R5    7
027] SW   R5,0(R1)    7
028] SW   R5,0(R3)    7
029] ADDI R1,R1,4     7
=====
```

----- Press ENTER to continue (PC=8,IC=30,CK=7,CTOT=8,IPC=3.75)...

```
@007 stall due to NO SLOTS when trying to move instnction MUL/004 from stage P to stage I.
@007 stall due to no L-unit available
@007 stall due to NO SLOTS when trying to move instnction LW/012 from stage P to stage I.
@007 stall due to NO SLOTS when trying to move instnction ADD/013 from stage P to stage I.
@007 stall due to NO SLOTS when trying to move instnction ADD/014 from stage P to stage I.
@007 stall due to NO SLOTS when trying to move instnction MUL/015 from stage P to stage I.
@007 stall due to no S-unit available
@007 stall due to NO SLOTS when trying to move instnction SW/016 from stage P to stage I.
```


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```
qi: 0 0 0 0 1 1 0 1 0 0 0 1 1 1 1 0 0 1 1 1 1 1
vi: 00 00 00 00 00 00 00 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00

=====
REG.FILE: R1: 1 2 3 4 5 6 7 8
          Pi: 6 21 19 22 5 - 20 -
          Qi: 1 1 0 1 1 0 1 0
          Vi: 00001008 00000000 00003008 00000000 00000000 00000000 00000002 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 16 4 12 4 4 24 16 99 4 1 1 0 1 4 1
BUSY SLOTS: 3 1 11 1 5 1 0 24 11 25 0 0 0 0 0 0 0
STALLS: 0 2 0 41 0 0 1 2 0 0 0 0 0 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 Ri oPi x s c +-----+
000] LW R2,0(R1) 0 1 2 3 4 6 7 P2,0(P1) ---- LW P2 P1 - 0 2 - - - 000 R2 - 0 0 1 |LQ(2 )|
001] LW R4,0(R3) 0 1 2 4 5 7 8 P4,0(P3) ---- LW P4 P3 - 0 2 - - - 001 R4 - 0 0 1 |PC OP Pi EFAD Ci|
002] ADD R5,R5,R2 0 1 2 6 6 7 8 P6,P5,P2 ---- ADD P6 P5 P2 - 2 6 - - - 002 R5 P5 0 0 1 |---- LW P2 1000 6|
003] ADD R5,R5,R4 0 1 2 7 7 8 9 P7,P6,P4 ---- ADD P7 P6 P4 - 7 7 - - - 003 R5 P6 0 0 1 |---- LW P4 3000 7|
004] MUL R5,R5,R5 1 2 3 8 8 8 P8,P7,P7 ---- MUL P8 P7 P7 - 8 8 - - 004 R5 P7 0 0 0 |011] LW P13 1004 .|
005] SW R5,0(R1) 1 2 3 5 6 ,P0(P1)<--P8 ---- SW - P8 P1 0 - 3 - - 005 R5 - - 1 0 0 |012] LW P14 3004 6|
006] SW R5,0(R3) 1 2 3 6 7 ,P0(P3)<--P8 ---- SW - P8 P3 0 - 3 - - 006 R5 - - 1 0 0 +-----+
007] ADDI R1,R1,4 1 2 3 4 4 5 P9,P1,4 ---- ADDI P9 P1 - 4 3 - - - 007 R1 P1 0 0 1
008] ADDI R3,R3,4 2 3 4 5 5 6 P10,P3,4 ---- ADDI P10 P3 - 4 4 - - - 008 R3 P3 0 0 1 +-----+
009] ADDI R7,R7,-1 2 3 4 5 5 6 P12,P11,-1 ---- ADDI P12 P11 - -1 4 - - - 009 R7 P11 0 0 1 |SQ(3 )|
010] BNE R7,R0,-11 2 3 4 6 6 7 ,P12,P0,-11 ---- BNE - P12 P0 -11 6 4 - - 010 R7 - - 0 0 1 |PC OP Pi EFAD Cl|
011] LW R2,0(R1) 3 4 5 7 8 P13,0(P9) ---- LW P13 P9 - 0 5 - - - 011 R2 P2 0 0 0 |005] SW P0 1000 .|
012] LW R4,0(R3) 3 4 5 8 9 P14,0(P10) ---- LW P14 P10 - 0 6 - - - 012 R4 P4 0 0 0 |006] SW P0 3000 .|
013] ADD R5,R5,R2 3 4 5 P15,P8,P13 006] ADD P15 P8 P13 - . - - 013 R5 P8 0 0 0 |016] SW P0 0000 .|
014] ADD R5,R5,R4 3 4 5 P16,P15,P14 008] ADD P16 P15 P14 - . - - 014 R5 P15 0 0 0 +-----+
015] MUL R5,R5,R5 4 5 6 P17,P16,P16 002] MUL P17 P16 P16 - . - - 015 R5 P16 0 0 0
016] SW R5,0(R1) 4 5 6 9 ,P0(P9)<--P17 005> SW - P17 P9 0 - 6 - - 016 R5 - - 1 0 0
017] SW R5,0(R3) 4 5 6 ,P0(P10)<--P17 007] SW - P17 P10 0 - 6 - - 017 R5 - - 1 0 0
018] ADDI R1,R1,4 4 5 6 7 7 8 P18,P9,4 ---- ADDI P18 P9 - 4 6 - - - 018 R1 P9 0 0 1
019] ADDI R3,R3,4 5 6 7 8 8 9 P19,P10,4 ---- ADDI P19 P10 - 4 7 - - - 019 R3 P10 0 0 1
020] ADDI R7,R7,-1 5 6 7 9 9 P20,P12,-1 003> ADDI P20 P12 - -1 7 - - - 020 R7 P12 0 0 0
021] BNE R7,R0,-11 5 6 7 9 9 ,P20,P0,-11 009> BNE - P20 P0 -11 - 7 - - - 021 R7 - - 0 0 0
022] LW R2,0(R1) 6 7 8 P21,0(P18) 000] LW P21 P18 - 0 8 - - - 022 R2 P13 0 0 0
023] LW R4,0(R3) 6 7 8 P22,0(P19) 001] LW P22 P19 - 0 9 - - - 023 R4 P14 0 0 0
024] ADD R5,R5,R2 6 7 8 P23,P17,P21 004] ADD P23 P17 P21 - . - - 024 R5 P17 0 0 0
025] ADD R5,R5,R4 6 7 8 P24,P23,P22 010] ADD P24 P23 P22 - . - - 025 R5 P23 0 0 0
026] MUL R5,R5,R5 7 8 9 P5,P24,P24 003] MUL P5 P24 P24 - . - - 026 R5 P24 0 0 0
027] SW R5,0(R1) 7 8 9 ,P0(P18)<--P5 005] SW - P5 P18 0 - 9 - - 027 R5 - - 1 0 0
028] SW R5,0(R3) 7 8 9 ,P0(P19)<--P5 009] SW - P5 P19 0 - 9 - - 028 R5 - - 1 0 0
029] ADDI R1,R1,4 7 9 P6,P18,4
030] ADDI R3,R3,4 8
031] ADDI R7,R7,-1 8
032] BNE R7,R0,-11 8

----- Press ENTER to continue (PC=12,IC=33,CK=9,CTOT=10,IPC=3.30)...

@009 stall due to NO SLOTS when trying to move instnction ADD/013 from stage P to stage I.
@009 stall due to NO SLOTS when trying to move instnction ADD/014 from stage P to stage I.
@009 stall due to NO SLOTS when trying to move instnction MUL/015 from stage P to stage I.
@009 stall due to no S-unit available
@009 stall due to NO SLOTS when trying to move instnction SW/017 from stage P to stage I.
@009 stall due to NO SLOTS when trying to move instnction LW/022 from stage P to stage I.
@009 stall due to NO SLOTS when trying to move instnction LW/023 from stage P to stage I.
@009 stall due to NO SLOTS when trying to move instnction ADD/024 from stage P to stage I.
@009 stall due to NO SLOTS when trying to move instnction ADD/025 from stage P to stage I.
@009 stall due to Physical registers not available
@009 stall due to NO SLOTS when trying to move instnction ADDI/030 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 0 1 1 0 1 0 0 0 0 0 1 1 1 1 0 0 0 1 1 1 1
vi: 00 00 00 00 00 00 00 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00

=====
REG.FILE: R1: 1 2 3 4 5 6 7 8
          Pi: 6 21 19 22 5 - 20 -
          Qi: 1 1 0 1 1 0 0 0
```


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Vi: 00001008 00000000 00003008 00000000 00000000 00000000 00000001 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 16 4 12 4 4 24 16 99 4 1 1 0 1 4 1
BUSY SLOTS:      3 0 11 1 2 1 0 24 11 26 0 0 0 0 0 0 0
STALLS:          0 3 0 51 0 0 2 3 0 0 0 0 3 11 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 Ri oPi x s c +-----+
000] LW R2,0(R1)  0 1 2 3 4 6 7 P2,0(P1) ---- LW P2 P1 - 0 2 - - - 000 R2 - 0 0 1 |LQ(2 )|
001] LW R4,0(R3)  0 1 2 4 5 7 8 P4,0(P3) ---- LW P4 P3 - 0 2 - - - 001 R4 - 0 0 1 |PC OP Pi EFAD Ci|
002] ADD R5,R5,R2 0 1 2 6 6 7 8 P6,P5,P2 ---- ADD P6 P5 P2 - 2 6 - - - 002 R5 P5 0 0 1 |---- LW P2 1000 6|
003] ADD R5,R5,R4 0 1 2 7 7 8 9 P7,P6,P4 ---- ADD P7 P6 P4 - 7 7 - - - 003 R5 P6 0 0 1 |---- LW P4 3000 7|
004] MUL R5,R5,R5 1 2 3 8 8 P8,P7,P7 ---- MUL P8 P7 P7 - 8 8 - 004) 004 R5 P7 0 0 0 |---- LW P13 1004 10|
005] SW R5,0(R1)  1 2 3 5 6 ,P0(P1)<-P8 ---- SW - P8 P1 0 - 3 - 005) 005 - - 1 0 0 |012] LW P14 3004 6|
006] SW R5,0(R3)  1 2 3 6 7 ,P0(P3)<-P8 ---- SW - P8 P3 0 - 3 - 006) 006 - - 1 0 0 |022] LW P21 0000 .|
007] ADDI R1,R1,4 1 2 3 4 4 5 P9,P1,4 ---- ADDI P9 P1 - 4 3 - - 007) 007 R1 P1 0 0 1 +-----+
008] ADDI R3,R3,4 2 3 4 5 5 6 P10,P3,4 ---- ADDI P10 P3 - 4 4 - - 008) 008 R3 P3 0 0 1 |SQ(3 )|
009] ADDI R7,R7,-1 2 3 4 5 5 6 P12,P11,-1 ---- ADDI P12 P11 - -1 4 - - 009) 009 R7 P11 0 0 1 |PC OP Pi EFAD Cl|
010] BNE R7,R0,-11 2 3 4 6 6 7 ,P12,P0,-11 ---- BNE - P12 P0 -11 6 4 - 010) 010 - - 0 0 1 |005] SW P0 1000 .|
011] LW R2,0(R1)  3 4 5 7 8 10 P13,0(P9) ---- LW P13 P9 - 0 5 - - 011) 000 R2 P2 0 0 1 |006] SW P0 3000 .|
012] LW R4,0(R3)  3 4 5 8 9 P14,0(P10) ---- LW P14 P10 - 0 6 - - 012) 001 R4 P4 0 0 0 |016] SW P0 1004 .|
013] ADD R5,R5,R2 3 4 5 P15,P8,P13 006) ADD P15 P8 P13 - . 10 - 013) 002 R5 P8 0 0 0 +-----+
014] ADD R5,R5,R4 3 4 5 P16,P15,P14 008) ADD P16 P15 P14 - . - 014) 003 R5 P15 0 0 0
015] MUL R5,R5,R5 4 5 6 P17,P16,P16 002) MUL P17 P16 P16 - . - 015) 004 R5 P16 0 0 0
016] SW R5,0(R1)  4 5 6 9 10 ,P0(P9)<-P17 ---- SW - P17 P9 0 - 6 - 016) 005 - - 1 0 0
017] SW R5,0(R3)  4 5 6 ,P0(P10)<-P17 007) SW - P17 P10 0 - 6 - 017) 006 - - 1 0 0
018] ADDI R1,R1,4 4 5 6 7 7 8 P18,P9,4 ---- ADDI P18 P9 - 4 6 - - 018) 007 R1 P9 0 0 1
019] ADDI R3,R3,4 5 6 7 8 8 9 P19,P10,4 ---- ADDI P19 P10 - 4 7 - - 019) 008 R3 P10 0 0 1
020] ADDI R7,R7,-1 5 6 7 9 9 10 P20,P12,-1 ---- ADDI P20 P12 - -1 7 - - 020) 009 R7 P12 0 0 1
021] BNE R7,R0,-11 5 6 7 9 9 10 ,P20,P0,-11 ---- BNE - P20 P0 -11 - 7 - 021) 010 - - 0 0 1
022] LW R2,0(R1)  6 7 8 10 P21,0(P18) 000> LW P21 P18 - 0 8 - - 022) 000 R2 P13 0 0 0
023] LW R4,0(R3)  6 7 8 P22,0(P19) 001) LW P22 P19 - 0 9 - - 023) 001 R4 P14 0 0 0
024] ADD R5,R5,R2 6 7 8 P23,P17,P21 004) ADD P23 P17 P21 - . - 024) 002 R5 P17 0 0 0
025] ADD R5,R5,R4 6 7 8 P24,P23,P22 010) ADD P24 P23 P22 - . - 025) 003 R5 P23 0 0 0
026] MUL R5,R5,R5 7 8 9 P5,P24,P24 003) MUL P5 P24 P24 - . - 026) 004 R5 P24 0 0 0
027] SW R5,0(R1)  7 8 9 ,P0(P18)<-P5 005) SW - P5 P18 0 - 9 - 027) 005 - - 1 0 0
028] SW R5,0(R3)  7 8 9 ,P0(P19)<-P5 009) SW - P5 P19 0 - 9 - 028) 006 - - 1 0 0
029] ADDI R1,R1,4 7 9 10 P6,P18,4 000) ADDI P6 P18 - 4 10 - - 029) 007 R1 P18 0 0 0
030] ADDI R3,R3,4 8
031] ADDI R7,R7,-1 8
032] BNE R7,R0,-11 8
=====
```

Press ENTER to continue (PC=12,IC=33,CK=10,CTOT=11,IPC=3.00)...

```
@010 stall due to NO SLOTS when trying to move instnction ADDI/019 from stage W to stage C.
@010 stall due to NO SLOTS when trying to move instnction ADD/013 from stage P to stage I.
@010 stall due to NO SLOTS when trying to move instnction ADD/014 from stage P to stage I.
@010 stall due to NO SLOTS when trying to move instnction MUL/015 from stage P to stage I.
@010 stall due to SQ full
@010 stall due to no S-unit available
@010 stall due to NO SLOTS when trying to move instnction SW/017 from stage P to stage I.
@010 stall due to no L-unit available
@010 stall due to NO SLOTS when trying to move instnction LW/023 from stage P to stage I.
@010 stall due to NO SLOTS when trying to move instnction ADD/024 from stage P to stage I.
@010 stall due to NO SLOTS when trying to move instnction ADD/025 from stage P to stage I.
@010 stall due to NO SLOTS when trying to move instnction MUL/026 from stage P to stage I.
@010 stall due to SQ full
@010 stall due to no S-unit available
@010 stall due to NO SLOTS when trying to move instnction SW/027 from stage P to stage I.
@010 stall due to SQ full
@010 stall due to no S-unit available
@010 stall due to NO SLOTS when trying to move instnction SW/028 from stage P to stage I.
@010 stall due to Physical registers not available
@010 stall due to NO SLOTS when trying to move instnction ADDI/030 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 0 0 1 1 0 1 0 0 0 0 0 0 1 1 1 0 0 0 1 1 1 1
vi:  00 00 00 00 00 0C 00 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00
=====
```

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```
REG.FILE: Ri:      1      2      3      4      5      6      7      8
           Pi:      6      21     19     22     5      -     20     -
           Qi:      1      1      0      1      1      0      0      0
           Vi: 00001008 00000000 00003008 00000000 00000000 00000000 00000001 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 16 4 12 4 4 24 16 99 4 1 1 0 1 4 1
BUSY SLOTS:  3 0 9 1 3 1 0 24 9 26 0 0 0 0 0 0 0
STALLS:      0 4 0 60 0 0 3 4 0 0 0 0 3 14 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 Ri oPi x s c +-----+
000] LW R2,0(R1)     0 1 2 3 4 6 7 P2,0(P1) ---- LW P2 P1 - 0 2 - - ---- 000 R2 - 0 0 1 |LQ(2 )|
001] LW R4,0(R3)     0 1 2 4 5 7 8 P4,0(P3) ---- LW P4 P3 - 0 2 - - ---- 001 R4 - 0 0 1 |PC OP Pi EFAD Ci|
002] ADD R5,R5,R2    0 1 2 6 6 7 8 P6,P5,P2 ---- ADD P6 P5 P2 - 2 6 - - ---- 002 R5 P5 0 0 1 |---- LW P2 1000 6|
003] ADD R5,R5,R4    0 1 2 7 7 8 9 P7,P6,P4 ---- ADD P7 P6 P4 - 7 7 - - ---- 003 R5 P6 0 0 1 |---- LW P4 3000 7|
004] MUL R5,R5,R5    1 2 3 8 8 P8,P7,P7 ---- MUL P8 P7 P7 - 8 8 - - 004) 004 R5 P7 0 0 0 |---- LW P13 1004 10|
005] SW R5,0(R1)     1 2 3 5 6 P0(P1)<-P8 ---- SW - P8 P1 0 - 3 - - 005) 005 - - 1 0 0 |---- LW P14 3004 11|
006] SW R5,0(R3)     1 2 3 6 7 P0(P3)<-P8 ---- SW - P8 P3 0 - 3 - - 006) 006 - - 1 0 0 |022] LW P21 1008 .|
007] ADDI R1,R1,4    1 2 3 4 4 5 P9,P1,4 ---- ADDI P9 P1 - 4 3 - - 007) 007 R1 P1 0 0 1 |023] LW P22 0000 9|
008] ADDI R3,R3,4    2 3 4 5 5 6 P10,P3,4 ---- ADDI P10 P3 - 4 4 - - 008) 008 R3 P3 0 0 1 +-----+
009] ADDI R7,R7,-1   2 3 4 5 5 6 P12,P11,-1 ---- ADDI P12 P11 - -1 4 - - 009) 009 R7 P11 0 0 1 +-----+
010] BNE R7,R0,-11  2 3 4 6 6 7 P12,P0,-11 ---- BNE - P12 P0 -11 6 4 - - 010) 010 - - 0 0 1 |SQ(3 )|
011] LW R2,0(R1)     3 4 5 7 8 10 P13,0(P9) ---- LW P13 P9 - 0 5 - - 011) 000 R2 P2 0 0 1 |PC OP Pi EFAD Cl|
012] LW R4,0(R3)     3 4 5 8 9 11 P14,0(P10) ---- LW P14 P10 - 0 6 - - 012) 001 R4 P4 0 0 1 |005] SW P0 1000 .|
013] ADD R5,R5,R2    3 4 5 P15,P8,P13 006) ADD P15 P8 P13 - . 10 - - 013) 002 R5 P8 0 0 0 |006] SW P0 3000 .|
014] ADD R5,R5,R4    3 4 5 P16,P15,P14 008) ADD P16 P15 P14 - . 11 - - 014) 003 R5 P15 0 0 0 |016] SW P0 1004 .|
015] MUL R5,R5,R5    4 5 6 P17,P16,P16 002) MUL P17 P16 P16 - . - - 015) 004 R5 P16 0 0 0 +-----+
016] SW R5,0(R1)     4 5 6 9 10 P0(P9)<-P17 ---- SW - P17 P9 0 - 6 - - 016) 005 - - 1 0 0
017] SW R5,0(R3)     4 5 6 P0(P10)<-P17 007) SW - P17 P10 0 - 6 - - 017) 006 - - 1 0 0
018] ADDI R1,R1,4    4 5 6 7 7 8 P18,P9,4 ---- ADDI P18 P9 - 4 6 - - 018) 007 R1 P9 0 0 1
019] ADDI R3,R3,4    5 6 7 8 8 9 P19,P10,4 ---- ADDI P19 P10 - 4 7 - - 019) 008 R3 P10 0 0 1
020] ADDI R7,R7,-1   5 6 7 9 9 10 P20,P12,-1 ---- ADDI P20 P12 - -1 7 - - 020) 009 R7 P12 0 0 1
021] BNE R7,R0,-11  5 6 7 9 9 10 P20,P0,-11 ---- BNE - P20 P0 -11 7 - - 021) 010 - - 0 0 1
022] LW R2,0(R1)     6 7 8 10 11 P21,0(P18) ---- LW P21 P18 - 0 8 - - 022) 000 R2 P13 0 0 0
023] LW R4,0(R3)     6 7 8 11 P22,0(P19) 001> LW P22 P19 - 0 9 - - 023) 001 R4 P14 0 0 0
024] ADD R5,R5,R2    6 7 8 P23,P17,P21 004) ADD P23 P17 P21 - . - - 024) 002 R5 P17 0 0 0
025] ADD R5,R5,R4    6 7 8 P24,P23,P22 010) ADD P24 P23 P22 - . - - 025) 003 R5 P23 0 0 0
026] MUL R5,R5,R5    7 8 9 P5,P24,P24 003) MUL P5 P24 P24 - . - - 026) 004 R5 P24 0 0 0
027] SW R5,0(R1)     7 8 9 P0(P18)<-P5 005) SW - P5 P18 0 - 9 - - 027) 005 - - 1 0 0
028] SW R5,0(R3)     7 8 9 P0(P19)<-P5 009) SW - P5 P19 0 - 9 - - 028) 006 - - 1 0 0
029] ADDI R1,R1,4    7 9 10 11 11 P6,P18,4 000> ADDI P6 P18 - 4 10 - - 029) 007 R1 P18 0 0 0
030] ADDI R3,R3,4    8
031] ADDI R7,R7,-1   8
032] BNE R7,R0,-11  8

----- Press ENTER to continue (PC=12,IC=33,CK=11,CTOT=12,IPC=2.75)...

@011 stall due to NO SLOTS when trying to move instnction BNE/021 from stage W to stage C.
@011 stall due to NO SLOTS when trying to move instnction ADD/013 from stage P to stage I.
@011 stall due to NO SLOTS when trying to move instnction ADD/014 from stage P to stage I.
@011 stall due to NO SLOTS when trying to move instnction MUL/015 from stage P to stage I.
@011 stall due to SQ full
@011 stall due to no S-unit available
@011 stall due to NO SLOTS when trying to move instnction SW/017 from stage P to stage I.
@011 stall due to NO SLOTS when trying to move instnction ADD/024 from stage P to stage I.
@011 stall due to NO SLOTS when trying to move instnction ADD/025 from stage P to stage I.
@011 stall due to NO SLOTS when trying to move instnction MUL/026 from stage P to stage I.
@011 stall due to SQ full
@011 stall due to no S-unit available
@011 stall due to NO SLOTS when trying to move instnction SW/027 from stage P to stage I.
@011 stall due to SQ full
@011 stall due to no S-unit available
@011 stall due to NO SLOTS when trying to move instnction SW/028 from stage P to stage I.
@011 stall due to Physical registers not available
@011 stall due to NO SLOTS when trying to move instnction ADDI/030 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 0 1 0 0 0 1 0 0 0 0 0 0 0 1 1 1 0 0 0 1 1 1 1
vi: 00 00 00 00 00 0C 00 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00

=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
```

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```
Pi:      6      21      19      22      5      -      20      -
Qi:      0      1      0      1      1      0      0      0
Vi: 0000100C 00000000 00003008 00000000 00000000 00000000 00000001 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 16 4 12 4 4 24 16 99 4 1 1 0 1 4 1
BUSY SLOTS:  3 0 9 0 3 1 0 24 9 26 0 0 0 0 0 0 0
STALLS:      0 5 0 69 0 0 4 5 0 0 0 0 3 17 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 Ri oPi x s c +-----+
000] LW R2,0(R1) 0 1 2 3 4 6 7 P2,0(P1) ---- LW P2 P1 - 0 2 - - ---- 000 R2 - 0 0 1 |LQ(2 )|
001] LW R4,0(R3) 0 1 2 4 5 7 8 P4,0(P3) ---- LW P4 P3 - 0 2 - - ---- 001 R4 - 0 0 1 |PC OP Pi EFAD Ci|
002] ADD R5,R5,R2 0 1 2 6 6 7 8 P6,P5,P2 ---- ADD P6 P5 P2 - 2 6 - - ---- 002 R5 P5 0 0 1 |---- LW P2 1000 6|
003] ADD R5,R5,R4 0 1 2 7 7 8 9 P7,P6,P4 ---- ADD P7 P6 P4 - 7 7 - - ---- 003 R5 P6 0 0 1 |---- LW P4 3000 7|
004] MUL R5,R5,R5 1 2 3 8 8 8 P8,P7,P7 ---- MUL P8 P7 P7 - 8 8 - - 004] 004 R5 P7 0 0 0 |---- LW P13 1004 10|
005] SW R5,0(R1) 1 2 3 5 6 6 ,P0(P1)<-P8 ---- SW - P8 P1 0 - 3 - - 005] 005 - - 1 0 0 |---- LW P14 3004 11|
006] SW R5,0(R3) 1 2 3 6 7 7 ,P0(P3)<-P8 ---- SW - P8 P3 0 - 3 - - 006] 006 - - 1 0 0 |022] LW P21 1008 .|
007] ADDI R1,R1,4 1 2 3 4 4 5 P9,P1,4 ---- ADDI P9 P1 - 4 3 - - 007] 007 R1 P1 0 0 1 |023] LW P22 3008 9|
008] ADDI R3,R3,4 2 3 4 5 5 6 P10,P3,4 ---- ADDI P10 P3 - 4 4 - - 008] 008 R3 P3 0 0 1 +-----+
009] ADDI R7,R7,-1 2 3 4 5 5 6 P12,P11,-1 ---- ADDI P12 P11 - -1 4 - - 009] 009 R7 P11 0 0 1 +-----+
010] BNE R7,R0,-11 2 3 4 6 6 7 ,P12,P0,-11 ---- BNE - P12 P0 -11 6 4 - - 010] 010 - - 0 0 1 |SQ(3 )|
011] LW R2,0(R1) 3 4 5 7 8 10 P13,0(P9) ---- LW P13 P9 - 0 5 - - 011] 000 R2 P2 0 0 1 |PC OP Pi EFAD Cl|
012] LW R4,0(R3) 3 4 5 8 9 11 P14,0(P10) ---- LW P14 P10 - 0 6 - - 012] 001 R4 P4 0 0 1 |005] SW P0 1000 .|
013] ADD R5,R5,R2 3 4 5 P15,P8,P13 006] ADD P15 P8 P13 - . 10 - - 013] 002 R5 P8 0 0 0 |006] SW P0 3000 .|
014] ADD R5,R5,R4 3 4 5 P16,P15,P14 008] ADD P16 P15 P14 - . 11 - - 014] 003 R5 P15 0 0 0 |016] SW P0 1004 .|
015] MUL R5,R5,R5 4 5 6 P17,P16,P16 002] MUL P17 P16 P16 - . - - 015] 004 R5 P16 0 0 0 +-----+
016] SW R5,0(R1) 4 5 6 9 10 ,P0(P9)<-P17 ---- SW - P17 P9 0 - 6 - - 016] 005 - - 1 0 0
017] SW R5,0(R3) 4 5 6 ,P0(P10)<-P17 007] SW - P17 P10 0 - 6 - - 017] 006 - - 1 0 0
018] ADDI R1,R1,4 4 5 6 7 7 8 P18,P9,4 ---- ADDI P18 P9 - 4 6 - - 018] 007 R1 P9 0 0 1
019] ADDI R3,R3,4 5 6 7 8 8 9 P19,P10,4 ---- ADDI P19 P10 - 4 7 - - 019] 008 R3 P10 0 0 1
020] ADDI R7,R7,-1 5 6 7 9 9 10 P20,P12,-1 ---- ADDI P20 P12 - -1 7 - - 020] 009 R7 P12 0 0 1
021] BNE R7,R0,-11 5 6 7 9 9 10 ,P20,P0,-11 ---- BNE - P20 P0 -11 - 7 - - 021] 010 - - 0 0 1
022] LW R2,0(R1) 6 7 8 10 11 P21,0(P18) ---- LW P21 P18 - 0 8 - - 022] 000 R2 P13 0 0 0
023] LW R4,0(R3) 6 7 8 11 12 P22,0(P19) ---- LW P22 P19 - 0 9 - - 023] 001 R4 P14 0 0 0
024] ADD R5,R5,R2 6 7 8 P23,P17,P21 004] ADD P23 P17 P21 - . - - 024] 002 R5 P17 0 0 0
025] ADD R5,R5,R4 6 7 8 P24,P23,P22 010] ADD P24 P23 P22 - . - - 025] 003 R5 P23 0 0 0
026] MUL R5,R5,R5 7 8 9 P5,P24,P24 003] MUL P5 P24 P24 - . - - 026] 004 R5 P24 0 0 0
027] SW R5,0(R1) 7 8 9 ,P0(P18)<-P5 005] SW - P5 P18 0 - 9 - - 027] 005 - - 1 0 0
028] SW R5,0(R3) 7 8 9 ,P0(P19)<-P5 009] SW - P5 P19 0 - 9 - - 028] 006 - - 1 0 0
029] ADDI R1,R1,4 7 9 10 11 11 12 P6,P18,4 ---- ADDI P6 P18 - 4 10 - - 029] 007 R1 P18 0 0 1
030] ADDI R3,R3,4 8
031] ADDI R7,R7,-1 8
032] BNE R7,R0,-11 8
----- Press ENTER to continue (PC=12,IC=33,CK=12,CTOT=13,IPC=2.54)...
@012 stall due to NO SLOTS when trying to move instuction LW/012 from stage W to stage C.
@012 stall due to NO SLOTS when trying to move instuction ADD/013 from stage P to stage I.
@012 stall due to NO SLOTS when trying to move instuction ADD/014 from stage P to stage I.
@012 stall due to NO SLOTS when trying to move instuction MUL/015 from stage P to stage I.
@012 stall due to SQ full
@012 stall due to no S-unit available
@012 stall due to NO SLOTS when trying to move instuction SW/017 from stage P to stage I.
@012 stall due to NO SLOTS when trying to move instuction ADD/024 from stage P to stage I.
@012 stall due to NO SLOTS when trying to move instuction ADD/025 from stage P to stage I.
@012 stall due to NO SLOTS when trying to move instuction MUL/026 from stage P to stage I.
@012 stall due to SQ full
@012 stall due to no S-unit available
@012 stall due to NO SLOTS when trying to move instuction SW/027 from stage P to stage I.
@012 stall due to SQ full
@012 stall due to no S-unit available
@012 stall due to NO SLOTS when trying to move instuction SW/028 from stage P to stage I.
@012 stall due to Physical registers not available
@012 stall due to NO SLOTS when trying to move instuction ADDI/030 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 0 1 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 0 0 0 1 1 1
vi: 00 00 00 00 00 0C 00 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00
```

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12

```
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
           Pi:      6      21     19     22     5      -     20     -
           Qi:      0      0      0      1      1      0      0      0
           Vi: 0000100C 00000000 00003008 00000000 00000000 00000000 00000001 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 16 4 12 4 4 24      16      99      4 1 1 0 1 4 1
BUSY SLOTS:      3 0 7 1 2 1 0 24      7      26      0 0 0 0 0 0 0
STALLS:          0 6 0 76 0 0 5 6      0      0      0 0 3 19 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 Ri oPi x s c +-----+
000] LW R2,0(R1)  0 1 2 3 4 6 7 P2,0(P1) ---- LW P2 P1 - 0 2 - - ---- 000 R2 - 0 0 1 |LQ(1 )|
001] LW R4,0(R3)  0 1 2 4 5 7 8 P4,0(P3) ---- LW P4 P3 - 0 2 - - ---- 001 R4 - 0 0 1 |PC OP Pi EFAD Ci|
002] ADD R5,R5,R2 0 1 2 6 6 7 8 P6,P5,P2 ---- ADD P6 P5 P2 - 2 6 - - ---- 002 R5 P5 0 0 1 |---- LW P2 1000 6|
003] ADD R5,R5,R4 0 1 2 7 7 8 9 P7,P6,P4 ---- ADD P7 P6 P4 - 7 7 - - ---- 003 R5 P6 0 0 1 |---- LW P4 3000 7|
004] MUL R5,R5,R5 1 2 3 8 8 13 P8,P7,P7 ---- MUL P8 P7 P7 - 8 8 - 004) 004 R5 P7 0 0 1 |---- LW P13 1004 10|
005] SW R5,0(R1)  1 2 3 5 6 13 ,P0(P1)<-P8 ---- SW - P8 P1 0 - 3 - 005) 005 - - 1 0 1 |---- LW P14 3004 11|
006] SW R5,0(R3)  1 2 3 6 7 13 ,P0(P3)<-P8 ---- SW - P8 P3 0 - 3 - 006) 006 - - 1 0 1 |---- LW P21 1008 13|
007] ADDI R1,R1,4 1 2 3 4 4 5 P9,P1,4 ---- ADDI P9 P1 - 4 3 - - 007) 007 R1 P1 0 0 1 |023] LW P22 3008 9|
008] ADDI R3,R3,4 2 3 4 5 5 6 P10,P3,4 ---- ADDI P10 P3 - 4 4 - - 008) 008 R3 P3 0 0 1 +-----+
009] ADDI R7,R7,-1 2 3 4 5 5 6 P12,P11,-1 ---- ADDI P12 P11 - -1 4 - - 009) 009 R7 P11 0 0 1 |SQ(3 )|
010] BNE R7,R0,-11 2 3 4 6 6 7 ,P12,P0,-11 ---- BNE - P12 P0 -11 6 4 - 010) 010 - - 0 0 1 |PC OP Pi EFAD Cl|
011] LW R2,0(R1)  3 4 5 7 8 10 P13,0(P9) ---- LW P13 P9 - 0 5 - - 011) 000 R2 P2 0 0 1 |---- SW P0 1000 13|
012] LW R4,0(R3)  3 4 5 8 9 11 P14,0(P10) ---- LW P14 P10 - 0 6 - - 012) 001 R4 P4 0 0 1 |006] SW P0 3000 13|
013] ADD R5,R5,R2 3 4 5 13 13 P15,P8,P13 006> ADD P15 P8 P13 - 13 10 - 013) 002 R5 P8 0 0 0 |016] SW P0 1004 .|
014] ADD R5,R5,R4 3 4 5 P16,P15,P14 008) ADD P16 P15 P14 - . 11 - 014) 003 R5 P15 0 0 0 |017] SW P0 0000 .|
015] MUL R5,R5,R5 4 5 6 P17,P16,P16 002) MUL P17 P16 P16 - . - 015) 004 R5 P16 0 0 0 +-----+
016] SW R5,0(R1)  4 5 6 9 10 ,P0(P9)<-P17 ---- SW - P17 P9 0 - 6 - 016) 005 - - 1 0 0
017] SW R5,0(R3)  4 5 6 13 ,P0(P10)<-P17 007> SW - P17 P10 0 - 6 - 017) 006 - - 1 0 0
018] ADDI R1,R1,4 4 5 6 7 7 8 P18,P9,4 ---- ADDI P18 P9 - 4 6 - - 018) 007 R1 P9 0 0 1
019] ADDI R3,R3,4 5 6 7 8 8 9 P19,P10,4 ---- ADDI P19 P10 - 4 7 - - 019) 008 R3 P10 0 0 1
020] ADDI R7,R7,-1 5 6 7 9 9 10 P20,P12,-1 ---- ADDI P20 P12 - -1 7 - - 020) 009 R7 P12 0 0 1
021] BNE R7,R0,-11 5 6 7 9 9 10 ,P20,P0,-11 ---- BNE - P20 P0 -11 - 7 - 021) 010 - - 0 0 1
022] LW R2,0(R1)  6 7 8 10 11 13 P21,0(P18) ---- LW P21 P18 - 0 8 - - 022) 000 R2 P13 0 0 1
023] LW R4,0(R3)  6 7 8 11 12 P22,0(P19) ---- LW P22 P19 - 0 9 - - 023) 001 R4 P14 0 0 0
024] ADD R5,R5,R2 6 7 8 P23,P17,P21 004) ADD P23 P17 P21 - . 13 - 024) 002 R5 P17 0 0 0
025] ADD R5,R5,R4 6 7 8 P24,P23,P22 010) ADD P24 P23 P22 - . - 025) 003 R5 P23 0 0 0
026] MUL R5,R5,R5 7 8 9 P5,P24,P24 003) MUL P5 P24 P24 - . - 026) 004 R5 P24 0 0 0
027] SW R5,0(R1)  7 8 9 ,P0(P18)<-P5 005) SW - P5 P18 0 - 9 - 027) 005 - - 1 0 0
028] SW R5,0(R3)  7 8 9 ,P0(P19)<-P5 009) SW - P5 P19 0 - 9 - 028) 006 - - 1 0 0
029] ADDI R1,R1,4 7 9 10 11 11 12 P6,P18,4 ---- ADDI P6 P18 - 4 10 - - 029) 007 R1 P18 0 0 1
030] ADDI R3,R3,4 8
031] ADDI R7,R7,-1 8
032] BNE R7,R0,-11 8
----- Press ENTER to continue (PC=12,IC=33,CK=13,CTOT=14,IPC=2.36)...
@013 stall due to NO SLOTS when trying to move instnction ADDI/029 from stage W to stage C.
@013 stall due to NO SLOTS when trying to move instnction ADD/014 from stage P to stage I.
@013 stall due to NO SLOTS when trying to move instnction MUL/015 from stage P to stage I.
@013 stall due to NO SLOTS when trying to move instnction ADD/024 from stage P to stage I.
@013 stall due to NO SLOTS when trying to move instnction ADD/025 from stage P to stage I.
@013 stall due to NO SLOTS when trying to move instnction MUL/026 from stage P to stage I.
@013 stall due to no S-unit available
@013 stall due to NO SLOTS when trying to move instnction SW/027 from stage P to stage I.
@013 stall due to no S-unit available
@013 stall due to NO SLOTS when trying to move instnction SW/028 from stage P to stage I.
@013 stall due to Physical registers not available
@013 stall due to NO SLOTS when trying to move instnction ADDI/030 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: 1 0 0 0 1 0 1 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 1 1
vi: 00 00 00 00 00 0C 00 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
           Pi:      6      21     7     22     5      -      1      -
           Qi:      0      0      1      0      1      0      1      0
```

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```
Vi: 00001000 00000000 00003008 00000000 00000000 00000000 00000001 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 16 4 12 4 4 24      16                      99                4 1 1 0 1 4 1
BUSY SLOTS:      0 3 5 1 1 1 0 24         5                      22                0 0 0 0 0 0 0
STALLS:          0 6 0 81 0 0 5 6          0                      0                0 0 3 20 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 Ri  oPi x s c  +-----+
000] LW  R2,0(R1)    0 1 2 3 4 6 7 P2,0(P1)  ----  LW P2 P1 - 0 2 - -  ---- 000 R2 - 0 0 1 |LQ(0 )|
001] LW  R4,0(R3)    0 1 2 4 5 7 8 P4,0(P3)  ----  LW P4 P3 - 0 2 - -  ---- 001 R4 - 0 0 1 |PC  OP Pi  EFAD Ci|
002] ADD  R5,R5,R2   0 1 2 6 6 7 8 P6,P5,P2  ----  ADD P6 P5 P2 - 2 6 -  ---- 002 R5 P5 0 0 1 |---- LW P2 1000 6|
003] ADD  R5,R5,R4   0 1 2 7 7 8 9 P7,P6,P4  ----  ADD P7 P6 P4 - 7 7 -  ---- 003 R5 P6 0 0 1 |---- LW P4 3000 7|
004] MUL  R5,R5,R5   1 2 3 8 8 13 14 P8,P7,P7  ----  MUL P8 P7 P7 - 8 8 -  ---- 004 R5 P7 0 0 1 |---- LW P13 1004 10|
005] SW  R5,0(R1)    1 2 3 5 6 13 14 ,P0(P1)<-P8  ----  SW - P8 P1 0 - 3 -  ---- 005 - - 1 0 1 |---- LW P14 3004 11|
006] SW  R5,0(R3)    1 2 3 6 7 13 14 ,P0(P3)<-P8  ----  SW - P8 P3 0 - 3 -  ---- 006 - - 1 0 1 |---- LW P21 1008 13|
007] ADDI R1,R1,4    1 2 3 4 4 5 14 P9,P1,4  ----  ADDI P9 P1 - 4 3 - -  ---- 007 R1 P1 0 0 1 |---- LW P22 3008 14|
008] ADDI R3,R3,4    2 3 4 5 5 6 P10,P3,4  ----  ADDI P10 P3 - 4 4 - -  ---- 008 R3 P3 0 0 1 +-----+
009] ADDI R7,R7,-1   2 3 4 5 5 6 P12,P11,-1  ----  ADDI P12 P11 - -1 4 - - 009) 009 R7 P11 0 0 1
010] BNE  R7,R0,-11  2 3 4 6 6 7 ,P12,P0,-11  ----  BNE - P12 P0 -11 6 4 - - 010) 010 - - 0 0 1 +-----+
011] LW  R2,0(R1)    3 4 5 7 8 10 P13,0(P9)  ----  LW P13 P9 - 0 5 - - 011) 000 R2 P2 0 0 1 |SQ(3 )|
012] LW  R4,0(R3)    3 4 5 8 9 11 P14,0(P10)  ----  LW P14 P10 - 0 6 - - 012) 001 R4 P4 0 0 1 |PC  OP Pi  EFAD Cl|
013] ADD  R5,R5,R2   3 4 5 13 13 14 P15,P8,P13  ----  ADD P15 P8 P13 - 13 10 - 013) 002 R5 P8 0 0 1 |---- SW P0 1000 13|
014] ADD  R5,R5,R4   3 4 5 14 14 P16,P15,P14 008>  ADD P16 P15 P14 - 14 11 - 014) 003 R5 P15 0 0 0 |---- SW P0 3000 13|
015] MUL  R5,R5,R5   4 5 6 P17,P16,P16 002)  MUL P17 P16 P16 - . . - 015) 004 R5 P16 0 0 0 |016] SW P0 1004 .|
016] SW  R5,0(R1)    4 5 6 9 10 ,P0(P9)<-P17  ----  SW - P17 P9 0 - 6 - 016) 005 - - 1 0 0 |017] SW P0 3004 .|
017] SW  R5,0(R3)    4 5 6 13 14 ,P0(P10)<-P17  ----  SW - P17 P10 0 - 6 - 017) 006 - - 1 0 0 |027] SW P0 0000 .|
018] ADDI R1,R1,4    4 5 6 7 7 8 P18,P9,4  ----  ADDI P18 P9 - 4 6 - - 018) 007 R1 P9 0 0 1 +-----+
019] ADDI R3,R3,4    5 6 7 8 8 9 P19,P10,4  ----  ADDI P19 P10 - 4 7 - - 019) 008 R3 P10 0 0 1
020] ADDI R7,R7,-1   5 6 7 9 9 10 P20,P12,-1  ----  ADDI P20 P12 - -1 7 - - 020) 009 R7 P12 0 0 1
021] BNE  R7,R0,-11  5 6 7 9 9 10 ,P20,P0,-11  ----  BNE - P20 P0 -11 - 7 - 021) 010 - - 0 0 1
022] LW  R2,0(R1)    6 7 8 10 11 13 P21,0(P18)  ----  LW P21 P18 - 0 8 - - 022) 000 R2 P13 0 0 1
023] LW  R4,0(R3)    6 7 8 11 12 14 P22,0(P19)  ----  LW P22 P19 - 0 9 - - 023) 001 R4 P14 0 0 1
024] ADD  R5,R5,R2   6 7 8 P23,P17,P21 004)  ADD P23 P17 P21 - . 13 - 024) 002 R5 P17 0 0 0
025] ADD  R5,R5,R4   6 7 8 P24,P23,P22 010)  ADD P24 P23 P22 - . 14 - 025) 003 R5 P23 0 0 0
026] MUL  R5,R5,R5   7 8 9 P5,P24,P24 003)  MUL P5 P24 P24 - . . - 026) 004 R5 P24 0 0 0
027] SW  R5,0(R1)    7 8 9 14 ,P0(P18)<-P5 005>  SW - P5 P18 0 - 9 - 027) 005 - - 1 0 0
028] SW  R5,0(R3)    7 8 9 ,P0(P19)<-P5 009)  SW - P5 P19 0 - 9 - 028) 006 - - 1 0 0
029] ADDI R1,R1,4    7 9 10 11 11 12 P6,P18,4  ----  ADDI P6 P18 - 4 10 - - 029) 007 R1 P18 0 0 1
030] ADDI R3,R3,4    8 14 P7,P19,4
031] ADDI R7,R7,-1   8 14 P1,P20,-1
032] BNE  R7,R0,-11  8 14 ,P1,P0,-11
=====
Press ENTER to continue (PC=12,IC=33,CK=14,CTOT=15,IPC=2.20)...
@014 stall due to NO SLOTS when trying to move instuction MUL/015 from stage P to stage I.
@014 stall due to NO SLOTS when trying to move instuction ADD/024 from stage P to stage I.
@014 stall due to NO SLOTS when trying to move instuction ADD/025 from stage P to stage I.
@014 stall due to NO SLOTS when trying to move instuction MUL/026 from stage P to stage I.
@014 stall due to no S-unit available
@014 stall due to NO SLOTS when trying to move instuction SW/028 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:  1 1 1 0 1 0 1 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 1 1
vi:  00 00 00 00 00 0C 00 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
          Pi:      6     21      7     22      5      -      1      -
          Qi:      0      0      1      0      1      0      1      0
          Vi: 00001000 00000000 00003000 00000000 00000000 00000000 00000003 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 16 4 12 4 4 24      16                      99                4 1 1 0 1 4 1
BUSY SLOTS:      0 0 7 0 1 1 0 21         7                      21                0 0 0 0 0 0 0
STALLS:          0 6 0 85 0 0 5 6          0                      0                0 0 3 21 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 Ri  oPi x s c  +-----+
000] LW  R2,0(R1)    0 1 2 3 4 6 7 P2,0(P1)  ----  LW P2 P1 - 0 2 - -  ---- 000 R2 - 0 0 1 |LQ(0 )|
001] LW  R4,0(R3)    0 1 2 4 5 7 8 P4,0(P3)  ----  LW P4 P3 - 0 2 - -  ---- 001 R4 - 0 0 1 |PC  OP Pi  EFAD Ci|
002] ADD  R5,R5,R2   0 1 2 6 6 7 8 P6,P5,P2  ----  ADD P6 P5 P2 - 2 6 -  ---- 002 R5 P5 0 0 1 |---- LW P2 1000 6|
003] ADD  R5,R5,R4   0 1 2 7 7 8 9 P7,P6,P4  ----  ADD P7 P6 P4 - 7 7 -  ---- 003 R5 P6 0 0 1 |---- LW P4 3000 7|
004] MUL  R5,R5,R5   1 2 3 8 8 13 14 P8,P7,P7  ----  MUL P8 P7 P7 - 8 8 -  ---- 004 R5 P7 0 0 1 |---- LW P13 1004 10|
```

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```
005] SW    R5,0(R1)      1  2  3  5  6 13 14 ,P0(P1)<-P8  ---- SW -   P8  P1  0  -  3  -  ---- 005 -   -  1  0  1  |---- LW P14 3004 11|
006] SW    R5,0(R3)      1  2  3  6  7 13 14 ,P0(P3)<-P8  ---- SW -   P8  P3  0  -  3  -  ---- 006 -   -  1  0  1  |---- LW P21 1008 13|
007] ADDI  R1,R1,4        1  2  3  4  4  5 14 P9,P1,4  ---- ADDI P9 P1 -   4  3  -  -  ---- 007 R1 P1  0  0  1  |---- LW P22 3008 14|
008] ADDI  R3,R3,4        2  3  4  5  5  6 15 P10,P3,4  ---- ADDI P10 P3 -   4  4  -  -  ---- 008 R3 P3  0  0  1  +-----+
009] ADDI  R7,R7,-1       2  3  4  5  5  6 15 P12,P11,-1  ---- ADDI P12 P11 -  -1  4  -  -  ---- 009 R7 P11 0  0  1  |
010] BNE   R7,R0,-11     2  3  4  6  6  7 15 ,P12,P0,-11  ---- BNE -   P12 P0 -11  6  4  -  -  ---- 010 -   -  0  0  1  +-----+
011] LW    R2,0(R1)       3  4  5  7  8 10 15 P13,0(P9)  ---- LW P13 P9 -   0  5  -  -  ---- 000 R2 P2  0  0  1  |SQ(3 )|
012] LW    R4,0(R3)       3  4  5  8  9 11  P14,0(P10)  ---- LW P14 P10 -   0  6  -  -  ---- 012) 001 R4 P4  0  0  1  |PC  OP Pi  EFAD C1|
013] ADD   R5,R5,R2       3  4  5 13 13 14  P15,P8,P13  ---- ADD P15 P8 P13 - 13 10 -  ---- 013) 002 R5 P8  0  0  1  |---- SW P0 1000 13|
014] ADD   R5,R5,R4       3  4  5 14 14 15  P16,P15,P14  ---- ADD P16 P15 P14 - 14 11 -  ---- 014) 003 R5 P15 0  0  1  |---- SW P0 3000 13|
015] MUL   R5,R5,R5       4  5  6 15 15  P17,P16,P16  002> MUL P17 P16 P16 - 15 15 -  ---- 015) 004 R5 P16 0  0  0  |016] SW P0 1004 .|
016] SW    R5,0(R1)       4  5  6  9 10  ,P0(P9)<-P17  ---- SW -   P17 P9  0  -  6  -  ---- 016) 005 -   -  1  0  0  |017] SW P0 3004 .|
017] SW    R5,0(R3)       4  5  6 13 14  ,P0(P10)<-P17  ---- SW -   P17 P10  0  -  6  -  ---- 017) 006 -   -  1  0  0  |027] SW P0 1008 .|
018] ADDI  R1,R1,4        4  5  6  7  7  8  P18,P9,4  ---- ADDI P18 P9 -   4  6  -  -  ---- 018) 007 R1 P9  0  0  1  +-----+
019] ADDI  R3,R3,4        5  6  7  8  8  9  P19,P10,4  ---- ADDI P19 P10 -   4  7  -  -  ---- 019) 008 R3 P10 0  0  1  |
020] ADDI  R7,R7,-1       5  6  7  9  9 10  P20,P12,-1  ---- ADDI P20 P12 -  -1  7  -  -  ---- 020) 009 R7 P12 0  0  1  |
021] BNE   R7,R0,-11     5  6  7  9  9 10  ,P20,P0,-11  ---- BNE -   P20 P0 -11  -  7  -  -  ---- 021) 010 -   -  0  0  1  |
022] LW    R2,0(R1)       6  7  8 10 11 13  P21,0(P18)  ---- LW P21 P18 -   0  8  -  -  ---- 022) 000 R2 P13 0  0  1  |
023] LW    R4,0(R3)       6  7  8 11 12 14  P22,0(P19)  ---- LW P22 P19 -   0  9  -  -  ---- 023) 001 R4 P14 0  0  1  |
024] ADD   R5,R5,R2       6  7  8  P23,P17,P21  004) ADD P23 P17 P21 -   . 13 -  ---- 024) 002 R5 P17 0  0  0  |
025] ADD   R5,R5,R4       6  7  8  P24,P23,P22  010) ADD P24 P23 P22 -   . 14 -  ---- 025) 003 R5 P23 0  0  0  |
026] MUL   R5,R5,R5       7  8  9  P5,P24,P24  003) MUL P5 P24 P24 -   .  -  -  ---- 026) 004 R5 P24 0  0  0  |
027] SW    R5,0(R1)       7  8  9 14 15  ,P0(P18)<-P5  ---- SW -   P5 P18  0  -  9  -  ---- 027) 005 -   -  1  0  0  |
028] SW    R5,0(R3)       7  8  9  ,P0(P19)<-P5  009) SW -   P5 P19  0  -  9  -  ---- 028) 006 -   -  1  0  0  |
029] ADDI  R1,R1,4        7  9 10 11 11 12  P6,P18,4  ---- ADDI P6 P18 -   4 10  -  -  ---- 029) 007 R1 P18 0  0  1  |
030] ADDI  R3,R3,4        8 14 15  P7,P19,4  000) ADDI P7 P19 -   4 15  -  -  ---- 030) 008 R3 P19 0  0  0  |
031] ADDI  R7,R7,-1       8 14 15  P1,P20,-1  001) ADDI P1 P20 -  -1 15  -  -  ---- 031) 009 R7 P20 0  0  0  |
032] BNE   R7,R0,-11     8 14 15  ,P1,P0,-11  002) BNE -   P1 P0 -11 - 15 -  ---- 032) 010 -   -  0  0  0  |
```

Press ENTER to continue (PC=12,IC=33,CK=15,CTOT=16,IPC=2.06)...

```
@015 stall due to NO SLOTS when trying to move instuction ADD/024 from stage P to stage I.
@015 stall due to NO SLOTS when trying to move instuction ADD/025 from stage P to stage I.
@015 stall due to NO SLOTS when trying to move instuction MUL/026 from stage P to stage I.
@015 stall due to SQ full
@015 stall due to no S-unit available
@015 stall due to NO SLOTS when trying to move instuction SW/028 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:   1  1  1  1  1  0  1  1  0  0  1  0  0  0  1  0  1  0  0  0  0  0  0  1  1
vi:   00 00 00 00 00 0C 0C 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00

=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
          Pi:      6     21      7     22      5      -      1      -
          Qi:      0      0      1      0      1      0      1      0
          Vi: 00001000 00000000 00003000 00000000 00000000 00000000 00000003 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 16  4 12  4  4 24          16                99                4  1  1  0  1  4  1
BUSY SLOTS:      0  0  4  0  4  0  0 18           4                18                0  0  0  0  0  0  0
STALLS:          0  6  0 89  0  0  5 6           0                0                0  0  3 22  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  Ri  oPi x s c  +-----+
000] LW    R2,0(R1)  0  1  2  3  4  6  7 P2,0(P1)  ---- LW P2 P1 -   0  2  -  -  ---- 000 R2 -   0  0  1  |LQ(0 )|
001] LW    R4,0(R3)  0  1  2  4  5  7  8 P4,0(P3)  ---- LW P4 P3 -   0  2  -  -  ---- 001 R4 -   0  0  1  |PC  OP Pi  EFAD Ci|
002] ADD   R5,R5,R2  0  1  2  6  6  7  8 P6,P5,P2  ---- ADD P6 P5 P2 -   2  6  -  -  ---- 002 R5 P5  0  0  1  |---- LW P2 1000 6|
003] ADD   R5,R5,R4  0  1  2  7  7  8  9 P7,P6,P4  ---- ADD P7 P6 P4 -   7  7  -  -  ---- 003 R5 P6  0  0  1  |---- LW P4 3000 7|
004] MUL   R5,R5,R5  1  2  3  8  8 13 14 P8,P7,P7  ---- MUL P8 P7 P7 -   8  8  -  -  ---- 004 R5 P7  0  0  1  |---- LW P13 1004 10|
005] SW    R5,0(R1)  1  2  3  5  6 13 14 ,P0(P1)<-P8  ---- SW -   P8 P1  0  -  3  -  ---- 005 -   -  1  0  1  |---- LW P14 3004 11|
006] SW    R5,0(R3)  1  2  3  6  7 13 14 ,P0(P3)<-P8  ---- SW -   P8 P3  0  -  3  -  ---- 006 -   -  1  0  1  |---- LW P21 1008 13|
007] ADDI  R1,R1,4    1  2  3  4  4  5 14 P9,P1,4  ---- ADDI P9 P1 -   4  3  -  -  ---- 007 R1 P1  0  0  1  |---- LW P22 3008 14|
008] ADDI  R3,R3,4    2  3  4  5  5  6 15 P10,P3,4  ---- ADDI P10 P3 -   4  4  -  -  ---- 008 R3 P3  0  0  1  +-----+
009] ADDI  R7,R7,-1  2  3  4  5  5  6 15 P12,P11,-1  ---- ADDI P12 P11 -  -1  4  -  -  ---- 009 R7 P11 0  0  1  |
010] BNE   R7,R0,-11 2  3  4  6  6  7 15 ,P12,P0,-11  ---- BNE -   P12 P0 -11  6  4  -  -  ---- 010 -   -  0  0  1  +-----+
011] LW    R2,0(R1)  3  4  5  7  8 10 15 P13,0(P9)  ---- LW P13 P9 -   0  5  -  -  ---- 000 R2 P2  0  0  1  |SQ(3 )|
012] LW    R4,0(R3)  3  4  5  8  9 11 16 P14,0(P10)  ---- LW P14 P10 -   0  6  -  -  ---- 001 R4 P4  0  0  1  |PC  OP Pi  EFAD C1|
013] ADD   R5,R5,R2  3  4  5 13 13 14 16 P15,P8,P13  ---- ADD P15 P8 P13 - 13 10 -  ---- 002 R5 P8  0  0  1  |---- SW P0 1000 13|
014] ADD   R5,R5,R4  3  4  5 14 14 15 16 P16,P15,P14  ---- ADD P16 P15 P14 - 14 11 -  ---- 003 R5 P15 0  0  1  |---- SW P0 3000 13|
015] MUL   R5,R5,R5  4  5  6 15 15  P17,P16,P16  ---- MUL P17 P16 P16 - 15 15 -  ---- 015) 004 R5 P16 0  0  0  |016] SW P0 1004 .|
016] SW    R5,0(R1)  4  5  6  9 10  ,P0(P9)<-P17  ---- SW -   P17 P9  0  -  6  -  ---- 016) 005 -   -  1  0  0  |017] SW P0 3004 .|
017] SW    R5,0(R3)  4  5  6 13 14  ,P0(P10)<-P17  ---- SW -   P17 P10  0  -  6  -  ---- 017) 006 -   -  1  0  0  |027] SW P0 1008 .|
```

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```
018] ADDI R1,R1,4      4 5 6 7 7 8      P18,P9,4      ---- ADDI P18 P9 - 4 6 - - 018) 007 R1 P9 0 0 1 +-----+
019] ADDI R3,R3,4      5 6 7 8 8 9      P19,P10,4     ---- ADDI P19 P10 - 4 7 - - 019) 008 R3 P10 0 0 1
020] ADDI R7,R7,-1     5 6 7 9 9 10     P20,P12,-1     ---- ADDI P20 P12 - -1 7 - - 020) 009 R7 P12 0 0 1
021] BNE R7,R0,-11     5 6 7 9 9 10     ,P20,P0,-11    ---- BNE - P20 P0 -11 - 7 - - 021) 010 - - 0 0 1
022] LW R2,0(R1)       6 7 8 10 11 13    P21,0(P18)     ---- LW P21 P18 - 0 8 - - 022) 000 R2 P13 0 0 1
023] LW R4,0(R3)       6 7 8 11 12 14    P22,0(P19)     ---- LW P22 P19 - 0 9 - - 023) 001 R4 P14 0 0 1
024] ADD R5,R5,R2      6 7 8          P23,P17,P21    004) ADD P23 P17 P21 - . 13 - - 024) 002 R5 P17 0 0 0
025] ADD R5,R5,R4      6 7 8          P24,P23,P22    010) ADD P24 P23 P22 - . 14 - - 025) 003 R5 P23 0 0 0
026] MUL R5,R5,R5      7 8 9          P5,P24,P24    003) MUL P5 P24 P24 - . . - 026) 004 R5 P24 0 0 0
027] SW R5,0(R1)       7 8 9 14 15      ,P0(P18)<-P5    ---- SW - P5 P18 0 - 9 - - 027) 005 - - 1 0 0
028] SW R5,0(R3)       7 8 9          ,P0(P19)<-P5    009) SW - P5 P19 0 - 9 - - 028) 006 - - 1 0 0
029] ADDI R1,R1,4      7 9 10 11 11 12    P6,P18,4      ---- ADDI P6 P18 - 4 10 - - 029) 007 R1 P18 0 0 1
030] ADDI R3,R3,4      8 14 15 16 16      P7,P19,4      000> ADDI P7 P19 - 4 15 - - 030) 008 R3 P19 0 0 0
031] ADDI R7,R7,-1     8 14 15 16 16      P1,P20,-1     001> ADDI P1 P20 - -1 15 - - 031) 009 R7 P20 0 0 0
032] BNE R7,R0,-11     8 14 15 16 16      ,P1,P0,-11    002> BNE - P1 P0 -11 - 15 - - 032) 010 - - 0 0 0
```

Press ENTER to continue (PC=12,IC=33,CK=16,CTOT=17,IPC=1.94)...

```
@016 stall due to NO SLOTS when trying to move instnction ADD/024 from stage P to stage I.
@016 stall due to NO SLOTS when trying to move instnction ADD/025 from stage P to stage I.
@016 stall due to NO SLOTS when trying to move instnction MUL/026 from stage P to stage I.
@016 stall due to SQ full
@016 stall due to no S-unit available
@016 stall due to NO SLOTS when trying to move instnction SW/028 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 1 1 1 1 0 0 1 0 0 1 0 0 0 1 0 1 0 0 0 0 0 1 1
vi: 00 00 00 00 00 0C 0C 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00
=====
REG.FILE: Ri: 1 2 3 4 5 6 7 8
Pi: 6 21 7 22 5 - 1 -
Qi: 0 0 0 0 1 0 0 0
Vi: 00001000 00000000 0000300C 00000000 00000000 00000000 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 16 4 12 4 4 24 16 99 4 1 1 0 1 4 1
BUSY SLOTS: 0 0 4 0 1 1 0 18 4 18 0 0 0 0 0 0 0
STALLS: 0 6 0 93 0 0 6 6 0 0 0 0 0 0 0 0 0 0 0 0 3 23 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 Ri oPi x s c +-----+
000] LW R2,0(R1) 0 1 2 3 4 6 7 P2,0(P1) ---- LW P2 P1 - 0 2 - - ---- 000 R2 - 0 0 1 |LQ(0 )|
001] LW R4,0(R3) 0 1 2 4 5 7 8 P4,0(P3) ---- LW P4 P3 - 0 2 - - ---- 001 R4 - 0 0 1 |PC OP Pi EFAD Ci|
002] ADD R5,R5,R2 0 1 2 6 6 7 8 P6,P5,P2 ---- ADD P6 P5 P2 - 2 6 - - ---- 002 R5 P5 0 0 1 |---- LW P2 1000 6|
003] ADD R5,R5,R4 0 1 2 7 7 8 9 P7,P6,P4 ---- ADD P7 P6 P4 - 7 7 - - ---- 003 R5 P6 0 0 1 |---- LW P4 3000 7|
004] MUL R5,R5,R5 1 2 3 8 8 13 14 P8,P7,P7 ---- MUL P8 P7 P7 - 8 8 - - ---- 004 R5 P7 0 0 1 |---- LW P13 1004 10|
005] SW R5,0(R1) 1 2 3 5 6 13 14 ,P0(P1)<-P8 ---- SW - P8 P1 0 - 3 - - ---- 005 - - 1 0 1 |---- LW P14 3004 11|
006] SW R5,0(R3) 1 2 3 6 7 13 14 ,P0(P3)<-P8 ---- SW - P8 P3 0 - 3 - - ---- 006 - - 1 0 1 |---- LW P21 1008 13|
007] ADDI R1,R1,4 1 2 3 4 4 5 14 P9,P1,4 ---- ADDI P9 P1 - 4 3 - - ---- 007 R1 P1 0 0 1 |---- LW P22 3008 14|
008] ADDI R3,R3,4 2 3 4 5 5 6 15 P10,P3,4 ---- ADDI P10 P3 - 4 4 - - ---- 008 R3 P3 0 0 1 +-----+
009] ADDI R7,R7,-1 2 3 4 5 5 6 15 P12,P11,-1 ---- ADDI P12 P11 - -1 4 - - ---- 009 R7 P11 0 0 1
010] BNE R7,R0,-11 2 3 4 6 6 7 15 ,P12,P0,-11 ---- BNE - P12 P0 -11 6 4 - - ---- 010 - - 0 0 1 +-----+
011] LW R2,0(R1) 3 4 5 7 8 10 15 P13,0(P9) ---- LW P13 P9 - 0 5 - - ---- 000 R2 P2 0 0 1 |SQ(3 )|
012] LW R4,0(R3) 3 4 5 8 9 11 16 P14,0(P10) ---- LW P14 P10 - 0 6 - - ---- 001 R4 P4 0 0 1 |PC OP Pi EFAD C1|
013] ADD R5,R5,R2 3 4 5 13 13 14 16 P15,P8,P13 ---- ADD P15 P8 P13 - 13 10 - - ---- 002 R5 P8 0 0 1 |---- SW P0 1000 13|
014] ADD R5,R5,R4 3 4 5 14 14 15 16 P16,P15,P14 ---- ADD P16 P15 P14 - 14 11 - - ---- 003 R5 P15 0 0 1 |---- SW P0 3000 13|
015] MUL R5,R5,R5 4 5 6 15 15 P17,P16,P16 ---- MUL P17 P16 P16 - 15 15 - - (015) 004 R5 P16 0 0 0 |016] SW P0 1004 .|
016] SW R5,0(R1) 4 5 6 9 10 ,P0(P9)<-P17 ---- SW - P17 P9 0 - 6 - (016) 005 - - 1 0 0 |017] SW P0 3004 .|
017] SW R5,0(R3) 4 5 6 13 14 ,P0(P10)<-P17 ---- SW - P17 P10 0 - 6 - (017) 006 - - 1 0 0 |027] SW P0 1008 .|
018] ADDI R1,R1,4 4 5 6 7 7 8 P18,P9,4 ---- ADDI P18 P9 - 4 6 - - (018) 007 R1 P9 0 0 1 +-----+
019] ADDI R3,R3,4 5 6 7 8 8 9 P19,P10,4 ---- ADDI P19 P10 - 4 7 - - (019) 008 R3 P10 0 0 1
020] ADDI R7,R7,-1 5 6 7 9 9 10 P20,P12,-1 ---- ADDI P20 P12 - -1 7 - - (020) 009 R7 P12 0 0 1
021] BNE R7,R0,-11 5 6 7 9 9 10 ,P20,P0,-11 ---- BNE - P20 P0 -11 - 7 - - (021) 010 - - 0 0 1
022] LW R2,0(R1) 6 7 8 10 11 13 P21,0(P18) ---- LW P21 P18 - 0 8 - - (022) 000 R2 P13 0 0 1
023] LW R4,0(R3) 6 7 8 11 12 14 P22,0(P19) ---- LW P22 P19 - 0 9 - - (023) 001 R4 P14 0 0 1
024] ADD R5,R5,R2 6 7 8 P23,P17,P21 004) ADD P23 P17 P21 - . 13 - - (024) 002 R5 P17 0 0 0
025] ADD R5,R5,R4 6 7 8 P24,P23,P22 010) ADD P24 P23 P22 - . 14 - - (025) 003 R5 P23 0 0 0
026] MUL R5,R5,R5 7 8 9 P5,P24,P24 003) MUL P5 P24 P24 - . . - (026) 004 R5 P24 0 0 0
027] SW R5,0(R1) 7 8 9 14 15 ,P0(P18)<-P5 ---- SW - P5 P18 0 - 9 - - (027) 005 - - 1 0 0
028] SW R5,0(R3) 7 8 9 ,P0(P19)<-P5 009) SW - P5 P19 0 - 9 - - (028) 006 - - 1 0 0
029] ADDI R1,R1,4 7 9 10 11 11 12 P6,P18,4 ---- ADDI P6 P18 - 4 10 - - (029) 007 R1 P18 0 0 1
030] ADDI R3,R3,4 8 14 15 16 16 17 P7,P19,4 ---- ADDI P7 P19 - 4 15 - - (030) 008 R3 P19 0 0 1
=====
```

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```
031] ADDI R7,R7,-1      8 14 15 16 16 17      P1,P20,-1      ---- ADDI P1 P20 - -1 15 - - 031) 009 R7 P20 0 0 1
032] BNE R7,R0,-11      8 14 15 16 16 17      ,P1,P0,-11      ---- BNE - P1 P0 -11 - 15 - 032) 010 - - 0 0 1
```

----- Press ENTER to continue (PC=12,IC=33,CK=17,CTOT=18,IPC=1.83)...

```
@017 stall due to NO SLOTS when trying to move instnction ADD/014 from stage W to stage C.
@017 stall due to NO SLOTS when trying to move instnction ADD/024 from stage P to stage I.
@017 stall due to NO SLOTS when trying to move instnction ADD/025 from stage P to stage I.
@017 stall due to NO SLOTS when trying to move instnction MUL/026 from stage P to stage I.
@017 stall due to SQ full
@017 stall due to no S-unit available
@017 stall due to NO SLOTS when trying to move instnction SW/028 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  1  1  1  1  0  0  1  0  0  1  0  0  0  1  0  1  0  0  0  0  0  1  1
vi:    00 00 00 00 00 0C 0C 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
          Pi:      6     21      7     22      5      -      1      -
          Qi:      0      0      0      0      1      0      0      0
          Vi: 00001000 00000000 0000300C 00000000 00000000 00000000 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 16  4 12  4  4 24          16          99          4  1  1  0  1  4  1
BUSY SLOTS:       0  0  4  0  1  1  0 18          4          18          0  0  0  0  0  0  0
STALLS:          0  6  0 97  0  0  7 6          0          0          0  0  3 24  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 Ri oPi x s c  +-----+
000] LW R2,0(R1)      0  1  2  3  4  6  7 P2,0(P1)  ---- LW P2 P1 - 0 2 - - ---- 000 R2 - 0 0 1 |LQ(0 )|
001] LW R4,0(R3)      0  1  2  4  5  7  8 P4,0(P3)  ---- LW P4 P3 - 0 2 - - ---- 001 R4 - 0 0 1 |PC OP Pi EFAD Ci|
002] ADD R5,R5,R2      0  1  2  6  6  7  8 P6,P5,P2  ---- ADD P6 P5 P2 - 2 6 - - ---- 002 R5 P5 0 0 1 |---- LW P2 1000 6|
003] ADD R5,R5,R4      0  1  2  7  7  8  9 P7,P6,P4  ---- ADD P7 P6 P4 - 7 7 - - ---- 003 R5 P6 0 0 1 |---- LW P4 3000 7|
004] MUL R5,R5,R5      1  2  3  8  8 13 14 P8,P7,P7  ---- MUL P8 P7 P7 - 8 8 - - ---- 004 R5 P7 0 0 1 |---- LW P13 1004 10|
005] SW R5,0(R1)      1  2  3  5  6 13 14 ,P0(P1)<-P8  ---- SW - P8 P1 0 - 3 - - ---- 005 - - 1 0 1 |---- LW P14 3004 11|
006] SW R5,0(R3)      1  2  3  6  7 13 14 ,P0(P3)<-P8  ---- SW - P8 P3 0 - 3 - - ---- 006 - - 1 0 1 |---- LW P21 1008 13|
007] ADDI R1,R1,4      1  2  3  4  4  5 14 P9,P1,4  ---- ADDI P9 P1 - 4 3 - - ---- 007 R1 P1 0 0 1 |---- LW P22 3008 14|
008] ADDI R3,R3,4      2  3  4  5  5  6 15 P10,P3,4  ---- ADDI P10 P3 - 4 4 - - ---- 008 R3 P3 0 0 1 +-----+
009] ADDI R7,R7,-1      2  3  4  5  5  6 15 P12,P11,-1  ---- ADDI P12 P11 - -1 4 - - ---- 009 R7 P11 0 0 1
010] BNE R7,R0,-11      2  3  4  6  6  7 15 ,P12,P0,-11  ---- BNE - P12 P0 -11 6 4 - - ---- 010 - - 0 0 1 +-----+
011] LW R2,0(R1)      3  4  5  7  8 10 15 P13,0(P9)  ---- LW P13 P9 - 0 5 - - ---- 000 R2 P2 0 0 1 |SQ(3 )|
012] LW R4,0(R3)      3  4  5  8  9 11 16 P14,0(P10)  ---- LW P14 P10 - 0 6 - - ---- 001 R4 P4 0 0 1 |PC OP Pi EFAD Cl|
013] ADD R5,R5,R2      3  4  5 13 13 14 16 P15,P8,P13  ---- ADD P15 P8 P13 - 13 10 - - ---- 002 R5 P8 0 0 1 |---- SW P0 1000 13|
014] ADD R5,R5,R4      3  4  5 14 14 15 16 P16,P15,P14  ---- ADD P16 P15 P14 - 14 11 - - ---- 003 R5 P15 0 0 1 |---- SW P0 3000 13|
015] MUL R5,R5,R5      4  5  6 15 15 P17,P16,P16  ---- MUL P17 P16 P16 - 15 15 - - (015) 004 R5 P16 0 0 0 |016] SW P0 1004 .|
016] SW R5,0(R1)      4  5  6  9 10 ,P0(P9)<-P17  ---- SW - P17 P9 0 - 6 - - (016) 005 - - 1 0 0 |017] SW P0 3004 .|
017] SW R5,0(R3)      4  5  6 13 14 ,P0(P10)<-P17  ---- SW - P17 P10 0 - 6 - - (017) 006 - - 1 0 0 |027] SW P0 1008 .|
018] ADDI R1,R1,4      4  5  6  7  7  8 P18,P9,4  ---- ADDI P18 P9 - 4 6 - - (018) 007 R1 P9 0 0 1 +-----+
019] ADDI R3,R3,4      5  6  7  8  8  9 P19,P10,4  ---- ADDI P19 P10 - 4 7 - - (019) 008 R3 P10 0 0 1
020] ADDI R7,R7,-1      5  6  7  9  9 10 P20,P12,-1  ---- ADDI P20 P12 - -1 7 - - (020) 009 R7 P12 0 0 1
021] BNE R7,R0,-11      5  6  7  9  9 10 ,P20,P0,-11  ---- BNE - P20 P0 -11 - 7 - - (021) 010 - - 0 0 1
022] LW R2,0(R1)      6  7  8 10 11 13 P21,0(P18)  ---- LW P21 P18 - 0 8 - - (022) 000 R2 P13 0 0 1
023] LW R4,0(R3)      6  7  8 11 12 14 P22,0(P19)  ---- LW P22 P19 - 0 9 - - (023) 001 R4 P14 0 0 1
024] ADD R5,R5,R2      6  7  8 P23,P17,P21 004) ADD P23 P17 P21 - . 13 - - (024) 002 R5 P17 0 0 0
025] ADD R5,R5,R4      6  7  8 P24,P23,P22 010) ADD P24 P23 P22 - . 14 - - (025) 003 R5 P23 0 0 0
026] MUL R5,R5,R5      7  8  9 P5,P24,P24 003) MUL P5 P24 P24 - . - - (026) 004 R5 P24 0 0 0
027] SW R5,0(R1)      7  8  9 14 15 ,P0(P18)<-P5  ---- SW - P5 P18 0 - 9 - - (027) 005 - - 1 0 0
028] SW R5,0(R3)      7  8  9 ,P0(P19)<-P5 009) SW - P5 P19 0 - 9 - - (028) 006 - - 1 0 0
029] ADDI R1,R1,4      7  9 10 11 11 12 P6,P18,4  ---- ADDI P6 P18 - 4 10 - - (029) 007 R1 P18 0 0 1
030] ADDI R3,R3,4      8 14 15 16 16 17 P7,P19,4  ---- ADDI P7 P19 - 4 15 - - (030) 008 R3 P19 0 0 1
031] ADDI R7,R7,-1      8 14 15 16 16 17 P1,P20,-1  ---- ADDI P1 P20 - -1 15 - - (031) 009 R7 P20 0 0 1
032] BNE R7,R0,-11      8 14 15 16 16 17 ,P1,P0,-11  ---- BNE - P1 P0 -11 - 15 - - (032) 010 - - 0 0 1
=====
```

----- Press ENTER to continue (PC=12,IC=33,CK=18,CTOT=19,IPC=1.74)...

```
@018 stall due to NO SLOTS when trying to move instnction BNE/032 from stage W to stage C.
@018 stall due to NO SLOTS when trying to move instnction ADD/024 from stage P to stage I.
@018 stall due to NO SLOTS when trying to move instnction ADD/025 from stage P to stage I.
@018 stall due to NO SLOTS when trying to move instnction MUL/026 from stage P to stage I.
@018 stall due to SQ full
@018 stall due to no S-unit available
@018 stall due to NO SLOTS when trying to move instnction SW/028 from stage P to stage I.
```

=====

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```
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  1  1  1  0  0  1  0  0  1  0  0  0  1  0  1  0  0  0  0  0  1  1
vi:    00 00 00 00 00 0C 0C 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00

=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
         Pi:      6      21     7      22     5      -      1      -
         Qi:      0      0      0      0      1      0      0      0
         Vi: 00001000 00000000 0000300C 00000000 00000000 00000000 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 16 4 12 4 4 24          16                      99              4 1 1 0 1 4 1
BUSY SLOTS:       0 0 4 0 1 1 0 18           4                      18              0 0 0 0 0 0 0
STALLS:          0 6 0101 0 0 8 6            0                      0              0 0 3 25 0 0 0

=====
PC  INSTRUCTION  F D P I X W C Pi,Pj Pk P1 IW# OPCD P1 Pj Pk I/P1 Cj Ck C1 ROB# PC Ri oPi x s c +-----+
000] LW  R2,0(R1)  0 1 2 3 4 6 7 P2,0(P1) ---- LW P2 P1 - 0 2 - - ---- 000 R2 - 0 0 1 |LQ(0 ) |
001] LW  R4,0(R3)  0 1 2 4 5 7 8 P4,0(P3) ---- LW P4 P3 - 0 2 - - ---- 001 R4 - 0 0 1 |PC  OP Pi EFAD Ci|
002] ADD  R5,R5,R2  0 1 2 6 6 7 8 P6,P5,P2 ---- ADD P6 P5 P2 - 2 6 - - ---- 002 R5 P5 0 0 1 |---- LW P2 1000 6|
003] ADD  R5,R5,R4  0 1 2 7 7 8 9 P7,P6,P4 ---- ADD P7 P6 P4 - 7 7 - - ---- 003 R5 P6 0 0 1 |---- LW P4 3000 7|
004] MUL  R5,R5,R5  1 2 3 8 8 13 14 P8,P7,P7 ---- MUL P8 P7 P7 - 8 8 - - ---- 004 R5 P7 0 0 1 |---- LW P13 1004 10|
005] SW  R5,0(R1)  1 2 3 5 6 13 14 ,P0(P1)<-P8 ---- SW - P8 P1 0 - 3 - - ---- 005 - - 1 0 1 |---- LW P14 3004 11|
006] SW  R5,0(R3)  1 2 3 6 7 13 14 ,P0(P3)<-P8 ---- SW - P8 P3 0 - 3 - - ---- 006 - - 1 0 1 |---- LW P21 1008 13|
007] ADDI R1,R1,4  1 2 3 4 4 5 14 P9,P1,4 ---- ADDI P9 P1 - 4 3 - - ---- 007 R1 P1 0 0 1 |---- LW P22 3008 14|
008] ADDI R3,R3,4  2 3 4 5 5 6 15 P10,P3,4 ---- ADDI P10 P3 - 4 4 - - ---- 008 R3 P3 0 0 1 +-----+
009] ADDI R7,R7,-1 2 3 4 5 5 6 15 P12,P11,-1 ---- ADDI P12 P11 - -1 4 - - ---- 009 R7 P11 0 0 1
010] BNE  R7,R0,-11 2 3 4 6 6 7 15 ,P12,P0,-11 ---- BNE - P12 P0 -11 6 4 - - ---- 010 - - 0 0 1 +-----+
011] LW  R2,0(R1)  3 4 5 7 8 10 15 P13,0(P9) ---- LW P13 P9 - 0 5 - - ---- 000 R2 P2 0 0 1 |SQ(3 ) |
012] LW  R4,0(R3)  3 4 5 8 9 11 16 P14,0(P10) ---- LW P14 P10 - 0 6 - - ---- 001 R4 P4 0 0 1 |PC  OP Pi EFAD C1|
013] ADD  R5,R5,R2  3 4 5 13 13 14 16 P15,P8,P13 ---- ADD P15 P8 P13 - 13 10 - - ---- 002 R5 P8 0 0 1 |---- SW P0 1000 13|
014] ADD  R5,R5,R4  3 4 5 14 14 15 16 P16,P15,P14 ---- ADD P16 P15 P14 - 14 11 - - ---- 003 R5 P15 0 0 1 |---- SW P0 3000 13|
015] MUL  R5,R5,R5  4 5 6 15 15 P17,P16,P16 ---- MUL P17 P16 P16 - 15 15 - - (015) 004 R5 P16 0 0 0 |016] SW P0 1004 .|
016] SW  R5,0(R1)  4 5 6 9 10 ,P0(P9)<-P17 ---- SW - P17 P9 0 - 6 - - (016) 005 - - 1 0 0 |017] SW P0 3004 .|
017] SW  R5,0(R3)  4 5 6 13 14 ,P0(P10)<-P17 ---- SW - P17 P10 0 - 6 - - (017) 006 - - 1 0 0 |027] SW P0 1008 .|
018] ADDI R1,R1,4  4 5 6 7 7 8 P18,P9,4 ---- ADDI P18 P9 - 4 6 - - (018) 007 R1 P9 0 0 1 +-----+
019] ADDI R3,R3,4  5 6 7 8 8 9 P19,P10,4 ---- ADDI P19 P10 - 4 7 - - (019) 008 R3 P10 0 0 1
020] ADDI R7,R7,-1 5 6 7 9 9 10 P20,P12,-1 ---- ADDI P20 P12 - -1 7 - - (020) 009 R7 P12 0 0 1
021] BNE  R7,R0,-11 5 6 7 9 9 10 ,P20,P0,-11 ---- BNE - P20 P0 -11 - 7 - - (021) 010 - - 0 0 1
022] LW  R2,0(R1)  6 7 8 10 11 13 P21,0(P18) ---- LW P21 P18 - 0 8 - - (022) 000 R2 P13 0 0 1
023] LW  R4,0(R3)  6 7 8 11 12 14 P22,0(P19) ---- LW P22 P19 - 0 9 - - (023) 001 R4 P14 0 0 1
024] ADD  R5,R5,R2  6 7 8 P23,P17,P21 004) ADD P23 P17 P21 - . 13 - - (024) 002 R5 P17 0 0 0
025] ADD  R5,R5,R4  6 7 8 P24,P23,P22 010) ADD P24 P23 P22 - . 14 - - (025) 003 R5 P23 0 0 0
026] MUL  R5,R5,R5  7 8 9 P5,P24,P24 003) MUL P5 P24 P24 - . - - (026) 004 R5 P24 0 0 0
027] SW  R5,0(R1)  7 8 9 14 15 ,P0(P18)<-P5 ---- SW - P5 P18 0 - 9 - - (027) 005 - - 1 0 0
028] SW  R5,0(R3)  7 8 9 ,P0(P19)<-P5 009) SW - P5 P19 0 - 9 - - (028) 006 - - 1 0 0
029] ADDI R1,R1,4  7 9 10 11 11 12 P6,P18,4 ---- ADDI P6 P18 - 4 10 - - (029) 007 R1 P18 0 0 1
030] ADDI R3,R3,4  8 14 15 16 16 17 P7,P19,4 ---- ADDI P7 P19 - 4 15 - - (030) 008 R3 P19 0 0 1
031] ADDI R7,R7,-1 8 14 15 16 16 17 P1,P20,-1 ---- ADDI P1 P20 - -1 15 - - (031) 009 R7 P20 0 0 1
032] BNE  R7,R0,-11 8 14 15 16 16 17 ,P1,P0,-11 ---- BNE - P1 P0 -11 - 15 - - (032) 010 - - 0 0 1

=====
Press ENTER to continue (PC=12,IC=33,CK=19,CTOT=20,IPC=1.65)...

@019 stall due to NO SLOTS when trying to move instuction BNE/032 from stage W to stage C.
@019 stall due to NO SLOTS when trying to move instuction ADD/024 from stage P to stage I.
@019 stall due to NO SLOTS when trying to move instuction ADD/025 from stage P to stage I.
@019 stall due to NO SLOTS when trying to move instuction MUL/026 from stage P to stage I.
@019 stall due to SQ full
@019 stall due to no S-unit available
@019 stall due to NO SLOTS when trying to move instuction SW/028 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  1  1  1  1  0  0  1  0  0  1  0  0  0  1  0  0  0  0  0  0  0  1  1
vi:    00 00 00 00 00 0C 0C 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00

=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
         Pi:      6      21     7      22     5      -      1      -
         Qi:      0      0      0      0      1      0      0      0
         Vi: 00001000 00000000 0000300C 00000000 00000000 00000000 00000000 00000000

=====
```

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```
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 16 4 12 4 4 24        16                    99                    4 1 1 0 1 4 1
BUSY SLOTS:      0 0 2 1 1 1 0 18          2                    18                    0 0 0 0 0 0 0
STALLS:          0 6 0103 0 0 9 6          0                    0                    0 0 3 25 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 Ri oPi x s c  +-----+
000] LW  R2,0(R1)    0 1 2 3 4 6 7 P2,0(P1)  ----  LW P2 P1 - 0 2 - -  ---- 000 R2 - 0 0 1  |LQ(0 ) |
001] LW  R4,0(R3)    0 1 2 4 5 7 8 P4,0(P3)  ----  LW P4 P3 - 0 2 - -  ---- 001 R4 - 0 0 1  |PC  OP Pi EFAD Ci|
002] ADD  R5,R5,R2   0 1 2 6 6 7 8 P6,P5,P2  ----  ADD P6 P5 P2 - 2 6 - -  ---- 002 R5 P5 0 0 1  |---- LW P2 1000 6|
003] ADD  R5,R5,R4   0 1 2 7 7 8 9 P7,P6,P4  ----  ADD P7 P6 P4 - 7 7 - -  ---- 003 R5 P6 0 0 1  |---- LW P4 3000 7|
004] MUL  R5,R5,R5   1 2 3 8 8 13 14 P8,P7,P7  ----  MUL P8 P7 P7 - 8 8 - -  ---- 004 R5 P7 0 0 1  |---- LW P13 1004 10|
005] SW   R5,0(R1)   1 2 3 5 6 13 14 ,P0(P1)<-P8  ----  SW - P8 P1 0 - 3 - -  ---- 005 - - 1 0 1  |---- LW P14 3004 11|
006] SW   R5,0(R3)   1 2 3 6 7 13 14 ,P0(P3)<-P8  ----  SW - P8 P3 0 - 3 - -  ---- 006 - - 1 0 1  |---- LW P21 1008 13|
007] ADDI R1,R1,4    1 2 3 4 4 5 14 P9,P1,4    ----  ADDI P9 P1 - 4 3 - -  ---- 007 R1 P1 0 0 1  |---- LW P22 3008 14|
008] ADDI R3,R3,4    2 3 4 5 5 6 15 P10,P3,4    ----  ADDI P10 P3 - 4 4 - -  ---- 008 R3 P3 0 0 1  +-----+
009] ADDI R7,R7,-1   2 3 4 5 5 6 15 P12,P11,-1    ----  ADDI P12 P11 - -1 4 - -  ---- 009 R7 P11 0 0 1  +-----+
010] BNE  R7,R0,-11  2 3 4 6 6 7 15 ,P12,P0,-11    ----  BNE - P12 P0 -11 6 4 - -  ---- 010 - - 0 0 1  +-----+
011] LW  R2,0(R1)    3 4 5 7 8 10 15 P13,0(P9)  ----  LW P13 P9 - 0 5 - -  ---- 000 R2 P2 0 0 1  |SQ(3 ) |
012] LW  R4,0(R3)    3 4 5 8 9 11 16 P14,0(P10)  ----  LW P14 P10 - 0 6 - -  ---- 001 R4 P4 0 0 1  |PC  OP Pi EFAD Cl|
013] ADD  R5,R5,R2   3 4 5 13 13 14 16 P15,P8,P13  ----  ADD P15 P8 P13 - 13 10 - -  ---- 002 R5 P8 0 0 1  |---- SW P0 1000 13|
014] ADD  R5,R5,R4   3 4 5 14 14 15 16 P16,P15,P14  ----  ADD P16 P15 P14 - 14 11 - -  ---- 003 R5 P15 0 0 1  |---- SW P0 3000 13|
015] MUL  R5,R5,R5   4 5 6 15 15 20 P17,P16,P16  ----  MUL P17 P16 P16 - 15 15 - 015) 004 R5 P16 0 0 1  |---- SW P0 1004 20|
016] SW   R5,0(R1)   4 5 6 9 10 20 ,P0(P9)<-P17  ----  SW - P17 P9 0 - 6 - 016) 005 - - 1 0 1  |017] SW P0 3004 20|
017] SW   R5,0(R3)   4 5 6 13 14 20 ,P0(P10)<-P17  ----  SW - P17 P10 0 - 6 - 017) 006 - - 1 0 1  |027] SW P0 1008 .|
018] ADDI R1,R1,4    4 5 6 7 7 8 P18,P9,4    ----  ADDI P18 P9 - 4 6 - - 018) 007 R1 P9 0 0 1  |028] SW P0 0000 .|
019] ADDI R3,R3,4    5 6 7 8 8 9 P19,P10,4    ----  ADDI P19 P10 - 4 7 - - 019) 008 R3 P10 0 0 1  +-----+
020] ADDI R7,R7,-1   5 6 7 9 9 10 P20,P12,-1    ----  ADDI P20 P12 - -1 7 - - 020) 009 R7 P12 0 0 1  +-----+
021] BNE  R7,R0,-11  5 6 7 9 9 10 ,P20,P0,-11    ----  BNE - P20 P0 -11 - 7 - 021) 010 - - 0 0 1  +-----+
022] LW  R2,0(R1)    6 7 8 10 11 13 P21,0(P18)  ----  LW P21 P18 - 0 8 - - 022) 000 R2 P13 0 0 1  +-----+
023] LW  R4,0(R3)    6 7 8 11 12 14 P22,0(P19)  ----  LW P22 P19 - 0 9 - - 023) 001 R4 P14 0 0 1  +-----+
024] ADD  R5,R5,R2   6 7 8 20 20 P23,P17,P21 004>  ADD P23 P17 P21 - 20 13 - 024) 002 R5 P17 0 0 0  +-----+
025] ADD  R5,R5,R4   6 7 8 P24,P23,P22 010)  ADD P24 P23 P22 - . 14 - 025) 003 R5 P23 0 0 0  +-----+
026] MUL  R5,R5,R5   7 8 9 P5,P24,P24 003)  MUL P5 P24 P24 - . . - 026) 004 R5 P24 0 0 0  +-----+
027] SW   R5,0(R1)   7 8 9 14 15 ,P0(P18)<-P5  ----  SW - P5 P18 0 - 9 - 027) 005 - - 1 0 0  +-----+
028] SW   R5,0(R3)   7 8 9 20 ,P0(P19)<-P5 009>  SW - P5 P19 0 - 9 - 028) 006 - - 1 0 0  +-----+
029] ADDI R1,R1,4    7 9 10 11 11 12 P6,P18,4  ----  ADDI P6 P18 - 4 10 - - 029) 007 R1 P18 0 0 1  +-----+
030] ADDI R3,R3,4    8 14 15 16 16 17 P7,P19,4  ----  ADDI P7 P19 - 4 15 - - 030) 008 R3 P19 0 0 1  +-----+
031] ADDI R7,R7,-1   8 14 15 16 16 17 P1,P20,-1  ----  ADDI P1 P20 - -1 15 - - 031) 009 R7 P20 0 0 1  +-----+
032] BNE  R7,R0,-11  8 14 15 16 16 17 ,P1,P0,-11  ----  BNE - P1 P0 -11 - 15 - 032) 010 - - 0 0 1  +-----+

Press ENTER to continue (PC=12,IC=33,CK=20,CTOT=21,IPC=1.57)...

@020 stall due to NO SLOTS when trying to move instnction BNE/032 from stage W to stage C.
@020 stall due to NO SLOTS when trying to move instnction ADD/025 from stage P to stage I.
@020 stall due to NO SLOTS when trying to move instnction MUL/026 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 1 1 1 1 0 0 1 1 0 1 0 0 0 1 1 0 0 0 0 0 0 0 1
vi:  00 00 00 00 00 0C 0C 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00

=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
Pi:      6      21     7     22     5      -      1      -
Qi:      0      0      0      0      1      0      0      0
Vi:  00001004 00000000 0000300C 00000000 00000000 00000000 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 16 4 12 4 4 24        16                    99                    4 1 1 0 1 4 1
BUSY SLOTS:      0 0 1 0 1 1 0 16          1                    14                    0 0 0 0 0 0 0
STALLS:          0 6 0104 0 0 9 6          0                    0                    0 0 3 25 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 Ri oPi x s c  +-----+
000] LW  R2,0(R1)    0 1 2 3 4 6 7 P2,0(P1)  ----  LW P2 P1 - 0 2 - -  ---- 000 R2 - 0 0 1  |LQ(0 ) |
001] LW  R4,0(R3)    0 1 2 4 5 7 8 P4,0(P3)  ----  LW P4 P3 - 0 2 - -  ---- 001 R4 - 0 0 1  |PC  OP Pi EFAD Ci|
002] ADD  R5,R5,R2   0 1 2 6 6 7 8 P6,P5,P2  ----  ADD P6 P5 P2 - 2 6 - -  ---- 002 R5 P5 0 0 1  |---- LW P2 1000 6|
003] ADD  R5,R5,R4   0 1 2 7 7 8 9 P7,P6,P4  ----  ADD P7 P6 P4 - 7 7 - -  ---- 003 R5 P6 0 0 1  |---- LW P4 3000 7|
004] MUL  R5,R5,R5   1 2 3 8 8 13 14 P8,P7,P7  ----  MUL P8 P7 P7 - 8 8 - -  ---- 004 R5 P7 0 0 1  |---- LW P13 1004 10|
005] SW   R5,0(R1)   1 2 3 5 6 13 14 ,P0(P1)<-P8  ----  SW - P8 P1 0 - 3 - -  ---- 005 - - 1 0 1  |---- LW P14 3004 11|
006] SW   R5,0(R3)   1 2 3 6 7 13 14 ,P0(P3)<-P8  ----  SW - P8 P3 0 - 3 - -  ---- 006 - - 1 0 1  |---- LW P21 1008 13|
007] ADDI R1,R1,4    1 2 3 4 4 5 14 P9,P1,4    ----  ADDI P9 P1 - 4 3 - -  ---- 007 R1 P1 0 0 1  |---- LW P22 3008 14|
008] ADDI R3,R3,4    2 3 4 5 5 6 15 P10,P3,4    ----  ADDI P10 P3 - 4 4 - -  ---- 008 R3 P3 0 0 1  +-----+
```

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009] ADDI R7,R7,-1      2 3 4 5 6 15 P12,P11,-1      ---- ADDI P12 P11 - -1 4 - - ---- 009 R7 P11 0 0 1
010] BNE R7,R0,-11      2 3 4 6 6 7 15 ,P12,P0,-11      ---- BNE - P12 P0 -11 6 4 - ---- 010 - - 0 0 1
011] LW R2,0(R1)        3 4 5 7 8 10 15 P13,0(P9)      ---- LW P13 P9 - 0 5 - - ---- 000 R2 P2 0 0 1
012] LW R4,0(R3)        3 4 5 8 9 11 16 P14,0(P10)      ---- LW P14 P10 - 0 6 - - ---- 001 R4 P4 0 0 1
013] ADD R5,R5,R2       3 4 5 13 13 14 16 P15,P8,P13      ---- ADD P15 P8 P13 - 13 10 - ---- 002 R5 P8 0 0 1
014] ADD R5,R5,R4       3 4 5 14 14 15 16 P16,P15,P14      ---- ADD P16 P15 P14 - 14 11 - ---- 003 R5 P15 0 0 1
015] MUL R5,R5,R5       4 5 6 15 15 20 21 P17,P16,P16      ---- MUL P17 P16 P16 - 15 15 - ---- 004 R5 P16 0 0 1
016] SW R5,0(R1)        4 5 6 9 10 20 21 ,P0(P9)<-P17    ---- SW - P17 P9 0 - 6 - - ---- 005 - - 1 0 1
017] SW R5,0(R3)        4 5 6 13 14 20 21 ,P0(P10)<-P17   ---- SW - P17 P10 0 - 6 - - ---- 006 - - 1 0 1
018] ADDI R1,R1,4       4 5 6 7 7 8 21 P18,P9,4          ---- ADDI P18 P9 - 4 6 - - ---- 007 R1 P9 0 0 1
019] ADDI R3,R3,4       5 6 7 8 8 9 P19,P10,4          ---- ADDI P19 P10 - 4 7 - - ---- 019) 008 R3 P10 0 0 1
020] ADDI R7,R7,-1      5 6 7 9 9 10 P20,P12,-1        ---- ADDI P20 P12 - -1 7 - - ---- 020) 009 R7 P12 0 0 1
021] BNE R7,R0,-11      5 6 7 9 9 10 ,P20,P0,-11      ---- BNE - P20 P0 -11 - 7 - ---- 021) 010 - - 0 0 1
022] LW R2,0(R1)        6 7 8 10 11 13 P21,0(P18)        ---- LW P21 P18 - 0 8 - - ---- 022) 000 R2 P13 0 0 1
023] LW R4,0(R3)        6 7 8 11 12 14 P22,0(P19)        ---- LW P22 P19 - 0 9 - - ---- 023) 001 R4 P14 0 0 1
024] ADD R5,R5,R2       6 7 8 20 20 21 P23,P17,P21      ---- ADD P23 P17 P21 - 20 13 - ---- 024) 002 R5 P17 0 0 1
025] ADD R5,R5,R4       6 7 8 21 21 P24,P23,P22      010> ADD P24 P23 P22 - 21 14 - ---- 025) 003 R5 P23 0 0 0
026] MUL R5,R5,R5       7 8 9 P5,P24,P24      003) MUL P5 P24 P24 - . . - ---- 026) 004 R5 P24 0 0 0
027] SW R5,0(R1)        7 8 9 14 15 ,P0(P18)<-P5        ---- SW - P5 P18 0 - 9 - ---- 027) 005 - - 1 0 0
028] SW R5,0(R3)        7 8 9 20 21 ,P0(P19)<-P5        ---- SW - P5 P19 0 - 9 - ---- 028) 006 - - 1 0 0
029] ADDI R1,R1,4       7 9 10 11 11 12 P6,P18,4        ---- ADDI P6 P18 - 4 10 - - ---- 029) 007 R1 P18 0 0 1
030] ADDI R3,R3,4       8 14 15 16 16 17 P7,P19,4        ---- ADDI P7 P19 - 4 15 - - ---- 030) 008 R3 P19 0 0 1
031] ADDI R7,R7,-1      8 14 15 16 16 17 P1,P20,-1      ---- ADDI P1 P20 - -1 15 - - ---- 031) 009 R7 P20 0 0 1
032] BNE R7,R0,-11      8 14 15 16 16 17 ,P1,P0,-11    ---- BNE - P1 P0 -11 - 15 - ---- 032) 010 - - 0 0 1
```

----- Press ENTER to continue (PC=12,IC=33,CK=21,CTOT=22,IPC=1.50)...

@021 stall due to NO SLOTS when trying to move instuction MUL/026 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 1 1 1 1 1 0 0 1 1 1 1 1 1 0 1 1 0 0 0 0 0 0 0 0
vi:  00 00 00 00 00 0C 0C 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
          Pi:      6     21      7     22      5      -      1      -
          Qi:      0      0      0      0      1      0      0      0
          Vi:  00001004 00000000 00003004 00000000 00000000 00000000 00000002 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 16 4 12 4 4 24          16          99          4 1 1 0 1 4 1
BUSY SLOTS:      0 0 0 0 1 1 0 13            0          10          0 0 0 0 0 0 0
STALLS:          0 6 0104 0 0 9 6            0          0          0 0 3 25 0 0 0
=====
```

```
PC INSTRUCTION      F D P I X W C P1,Pj Pk P1 IW# OPCODE P1 Pj Pk I/P1 Cj Ck C1 ROB# PC Ri oPi x s c +-----+
000] LW R2,0(R1)     0 1 2 3 4 6 7 P2,0(P1)      ---- LW P2 P1 - 0 2 - - ---- 000 R2 - 0 0 1 |LQ(0 )|
001] LW R4,0(R3)     0 1 2 4 5 7 8 P4,0(P3)      ---- LW P4 P3 - 0 2 - - ---- 001 R4 - 0 0 1 |PC OP Pi EFAD Ci|
002] ADD R5,R5,R2     0 1 2 6 6 7 8 P6,P5,P2      ---- ADD P6 P5 P2 - 2 6 - ---- 002 R5 P5 0 0 1 |---- LW P2 1000 6|
003] ADD R5,R5,R4     0 1 2 7 7 8 9 P7,P6,P4      ---- ADD P7 P6 P4 - 7 7 - ---- 003 R5 P6 0 0 1 |---- LW P4 3000 7|
004] MUL R5,R5,R5     1 2 3 8 8 13 14 P8,P7,P7      ---- MUL P8 P7 P7 - 8 8 - ---- 004 R5 P7 0 0 1 |---- LW P13 1004 10|
005] SW R5,0(R1)     1 2 3 5 6 13 14 ,P0(P1)<-P8    ---- SW - P8 P1 0 - 3 - ---- 005 - - 1 0 1 |---- LW P14 3004 11|
006] SW R5,0(R3)     1 2 3 6 7 13 14 ,P0(P3)<-P8    ---- SW - P8 P3 0 - 3 - ---- 006 - - 1 0 1 |---- LW P21 1008 13|
007] ADDI R1,R1,4     1 2 3 4 4 5 14 P9,P1,4        ---- ADDI P9 P1 - 4 3 - - ---- 007 R1 P1 0 0 1 |---- LW P22 3008 14|
008] ADDI R3,R3,4     2 3 4 5 5 6 15 P10,P3,4      ---- ADDI P10 P3 - 4 4 - - ---- 008 R3 P3 0 0 1 +-----+
009] ADDI R7,R7,-1    2 3 4 5 5 6 15 P12,P11,-1      ---- ADDI P12 P11 - -1 4 - - ---- 009 R7 P11 0 0 1
010] BNE R7,R0,-11    2 3 4 6 6 7 15 ,P12,P0,-11      ---- BNE - P12 P0 -11 6 4 - ---- 010 - - 0 0 1 +-----+
011] LW R2,0(R1)     3 4 5 7 8 10 15 P13,0(P9)      ---- LW P13 P9 - 0 5 - - ---- 000 R2 P2 0 0 1 |SQ(2 )|
012] LW R4,0(R3)     3 4 5 8 9 11 16 P14,0(P10)      ---- LW P14 P10 - 0 6 - - ---- 001 R4 P4 0 0 1 |PC OP Pi EFAD C1|
013] ADD R5,R5,R2     3 4 5 13 13 14 16 P15,P8,P13      ---- ADD P15 P8 P13 - 13 10 - ---- 002 R5 P8 0 0 1 |---- SW P0 1000 13|
014] ADD R5,R5,R4     3 4 5 14 14 15 16 P16,P15,P14      ---- ADD P16 P15 P14 - 14 11 - ---- 003 R5 P15 0 0 1 |---- SW P0 3000 13|
015] MUL R5,R5,R5     4 5 6 15 15 20 21 P17,P16,P16      ---- MUL P17 P16 P16 - 15 15 - ---- 004 R5 P16 0 0 1 |---- SW P0 1004 20|
016] SW R5,0(R1)     4 5 6 9 10 20 21 ,P0(P9)<-P17    ---- SW - P17 P9 0 - 6 - ---- 005 - - 1 0 1 |---- SW P0 3004 20|
017] SW R5,0(R3)     4 5 6 13 14 20 21 ,P0(P10)<-P17   ---- SW - P17 P10 0 - 6 - ---- 006 - - 1 0 1 |027] SW P0 1008 .|
018] ADDI R1,R1,4     4 5 6 7 7 8 21 P18,P9,4          ---- ADDI P18 P9 - 4 6 - - ---- 007 R1 P9 0 0 1 |028] SW P0 3008 .|
019] ADDI R3,R3,4     5 6 7 8 8 9 22 P19,P10,4          ---- ADDI P19 P10 - 4 7 - - ---- 008 R3 P10 0 0 1 +-----+
020] ADDI R7,R7,-1    5 6 7 9 9 10 22 P20,P12,-1      ---- ADDI P20 P12 - -1 7 - - ---- 009 R7 P12 0 0 1
021] BNE R7,R0,-11    5 6 7 9 9 10 22 ,P20,P0,-11      ---- BNE - P20 P0 -11 - 7 - ---- 010 - - 0 0 1
022] LW R2,0(R1)     6 7 8 10 11 13 22 P21,0(P18)        ---- LW P21 P18 - 0 8 - - ---- 000 R2 P13 0 0 1
023] LW R4,0(R3)     6 7 8 11 12 14 P22,0(P19)        ---- LW P22 P19 - 0 9 - - ---- 023) 001 R4 P14 0 0 1
024] ADD R5,R5,R2     6 7 8 20 20 21 P23,P17,P21      ---- ADD P23 P17 P21 - 20 13 - ---- 024) 002 R5 P17 0 0 1
025] ADD R5,R5,R4     6 7 8 21 21 22 P24,P23,P22      ---- ADD P24 P23 P22 - 21 14 - ---- 025) 003 R5 P23 0 0 1
026] MUL R5,R5,R5     7 8 9 22 22 P5,P24,P24      003> MUL P5 P24 P24 - 22 22 - ---- 026) 004 R5 P24 0 0 0
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027] SW R5,0(R1) 7 8 9 14 15 ,P0(P18)<-P5 ---- SW - P5 P18 0 - 9 - 027) 005 - - 1 0 0
028] SW R5,0(R3) 7 8 9 20 21 ,P0(P19)<-P5 ---- SW - P5 P19 0 - 9 - 028) 006 - - 1 0 0
029] ADDI R1,R1,4 7 9 10 11 11 12 P6,P18,4 ---- ADDI P6 P18 - 4 10 - - 029) 007 R1 P18 0 0 1
030] ADDI R3,R3,4 8 14 15 16 16 17 P7,P19,4 ---- ADDI P7 P19 - 4 15 - - 030) 008 R3 P19 0 0 1
031] ADDI R7,R7,-1 8 14 15 16 16 17 P1,P20,-1 ---- ADDI P1 P20 - -1 15 - - 031) 009 R7 P20 0 0 1
032] BNE R7,R0,-11 8 14 15 16 16 17 ,P1,P0,-11 ---- BNE - P1 P0 -11 - 15 - 032) 010 - - 0 0 1
```

Press ENTER to continue (PC=12,IC=33,CK=22,CTOT=23,IPC=1.43)...

```
=====
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 1 1 1 0 0 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 1 0
vi: 00 00 00 00 00 0C 0C 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00
```

```
=====
REG.FILE: Ri: 1 2 3 4 5 6 7 8
          Pi: 6 21 7 22 5 - 1 -
          Qi: 0 0 0 0 0 0 0 0
          Vi: 00001004 00000000 00003004 00000000 00000000 00000000 00000002 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 16 4 12 4 4 24 16 99 4 1 1 0 1 4 1
BUSY SLOTS: 0 0 0 0 1 0 0 10 0 7 0 0 0 0 0 0 0
STALLS: 0 6 0104 0 0 9 6 0 0 0 0 0 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 C1 ROB# PC Ri oPi x s c +-----+
000] LW R2,0(R1) 0 1 2 3 4 6 7 P2,0(P1) ---- LW P2 P1 - 0 2 - - ---- 000 R2 - 0 0 1 |LQ(0 )|
001] LW R4,0(R3) 0 1 2 4 5 7 8 P4,0(P3) ---- LW P4 P3 - 0 2 - - ---- 001 R4 - 0 0 1 |PC OP Pi EFAD Ci|
002] ADD R5,R5,R2 0 1 2 6 6 7 8 P6,P5,P2 ---- ADD P6 P5 P2 - 2 6 - - ---- 002 R5 P5 0 0 1 |---- LW P2 1000 6|
003] ADD R5,R5,R4 0 1 2 7 7 8 9 P7,P6,P4 ---- ADD P7 P6 P4 - 7 7 - - ---- 003 R5 P6 0 0 1 |---- LW P4 3000 7|
004] MUL R5,R5,R5 1 2 3 8 8 13 14 P8,P7,P7 ---- MUL P8 P7 P7 - 8 8 - - ---- 004 R5 P7 0 0 1 |---- LW P13 1004 10|
005] SW R5,0(R1) 1 2 3 5 6 13 14 ,P0(P1)<-P8 ---- SW - P8 P1 0 - 3 - - ---- 005 - - 1 0 1 |---- LW P14 3004 11|
006] SW R5,0(R3) 1 2 3 6 7 13 14 ,P0(P3)<-P8 ---- SW - P8 P3 0 - 3 - - ---- 006 - - 1 0 1 |---- LW P21 1008 13|
007] ADDI R1,R1,4 1 2 3 4 4 5 14 P9,P1,4 ---- ADDI P9 P1 - 4 3 - - ---- 007 R1 P1 0 0 1 |---- LW P22 3008 14|
008] ADDI R3,R3,4 2 3 4 5 5 6 15 P10,P3,4 ---- ADDI P10 P3 - 4 4 - - ---- 008 R3 P3 0 0 1 +-----+
009] ADDI R7,R7,-1 2 3 4 5 5 6 15 P12,P11,-1 ---- ADDI P12 P11 - -1 4 - - ---- 009 R7 P11 0 0 1
010] BNE R7,R0,-11 2 3 4 6 6 7 15 ,P12,P0,-11 ---- BNE - P12 P0 -11 6 4 - - ---- 010 - - 0 0 1 +-----+
011] LW R2,0(R1) 3 4 5 7 8 10 15 P13,0(P9) ---- LW P13 P9 - 0 5 - - ---- 000 R2 P2 0 0 1 |SQ(2 )|
012] LW R4,0(R3) 3 4 5 8 9 11 16 P14,0(P10) ---- LW P14 P10 - 0 6 - - ---- 001 R4 P4 0 0 1 |PC OP Pi EFAD C1|
013] ADD R5,R5,R2 3 4 5 13 13 14 16 P15,P8,P13 ---- ADD P15 P8 P13 - 13 10 - - ---- 002 R5 P8 0 0 1 |---- SW P0 1000 13|
014] ADD R5,R5,R4 3 4 5 14 14 15 16 P16,P15,P14 ---- ADD P16 P15 P14 - 14 11 - - ---- 003 R5 P15 0 0 1 |---- SW P0 3000 13|
015] MUL R5,R5,R5 4 5 6 15 15 20 21 P17,P16,P16 ---- MUL P17 P16 P16 - 15 15 - - ---- 004 R5 P16 0 0 1 |---- SW P0 1004 20|
016] SW R5,0(R1) 4 5 6 9 10 20 21 ,P0(P9)<-P17 ---- SW - P17 P9 0 - 6 - - ---- 005 - - 1 0 1 |---- SW P0 3004 20|
017] SW R5,0(R3) 4 5 6 13 14 20 21 ,P0(P10)<-P17 ---- SW - P17 P10 0 - 6 - - ---- 006 - - 1 0 1 |027] SW P0 1008 .|
018] ADDI R1,R1,4 4 5 6 7 7 8 21 P18,P9,4 ---- ADDI P18 P9 - 4 6 - - ---- 007 R1 P9 0 0 1 |028] SW P0 3008 .|
019] ADDI R3,R3,4 5 6 7 8 8 9 22 P19,P10,4 ---- ADDI P19 P10 - 4 7 - - ---- 008 R3 P10 0 0 1 +-----+
020] ADDI R7,R7,-1 5 6 7 9 9 10 22 P20,P12,-1 ---- ADDI P20 P12 - -1 7 - - ---- 009 R7 P12 0 0 1
021] BNE R7,R0,-11 5 6 7 9 9 10 22 ,P20,P0,-11 ---- BNE - P20 P0 -11 - 7 - - ---- 010 - - 0 0 1
022] LW R2,0(R1) 6 7 8 10 11 13 22 P21,0(P18) ---- LW P21 P18 - 0 8 - - ---- 000 R2 P13 0 0 1
023] LW R4,0(R3) 6 7 8 11 12 14 23 P22,0(P19) ---- LW P22 P19 - 0 9 - - ---- 001 R4 P14 0 0 1
024] ADD R5,R5,R2 6 7 8 20 20 21 23 P23,P17,P21 ---- ADD P23 P17 P21 - 20 13 - - ---- 002 R5 P17 0 0 1
025] ADD R5,R5,R4 6 7 8 21 21 22 23 P24,P23,P22 ---- ADD P24 P23 P22 - 21 14 - - ---- 003 R5 P23 0 0 1
026] MUL R5,R5,R5 7 8 9 22 22 P5,P24,P24 ---- MUL P5 P24 P24 - 22 22 - 026) 004 R5 P24 0 0 0
027] SW R5,0(R1) 7 8 9 14 15 ,P0(P18)<-P5 ---- SW - P5 P18 0 - 9 - 027) 005 - - 1 0 0
028] SW R5,0(R3) 7 8 9 20 21 ,P0(P19)<-P5 ---- SW - P5 P19 0 - 9 - 028) 006 - - 1 0 0
029] ADDI R1,R1,4 7 9 10 11 11 12 P6,P18,4 ---- ADDI P6 P18 - 4 10 - - 029) 007 R1 P18 0 0 1
030] ADDI R3,R3,4 8 14 15 16 16 17 P7,P19,4 ---- ADDI P7 P19 - 4 15 - - 030) 008 R3 P19 0 0 1
031] ADDI R7,R7,-1 8 14 15 16 16 17 P1,P20,-1 ---- ADDI P1 P20 - -1 15 - - 031) 009 R7 P20 0 0 1
032] BNE R7,R0,-11 8 14 15 16 16 17 ,P1,P0,-11 ---- BNE - P1 P0 -11 - 15 - 032) 010 - - 0 0 1
```

Press ENTER to continue (PC=12,IC=33,CK=23,CTOT=24,IPC=1.38)...

```
=====
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 1 1 1 0 0 1 1 1 1 1 1 1 1 1 0 0 0 0 0 1 0
vi: 00 00 00 00 00 0C 0C 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00
```

```
=====
REG.FILE: Ri: 1 2 3 4 5 6 7 8
          Pi: 6 21 7 22 5 - 1 -
          Qi: 0 0 0 0 0 0 0 0
          Vi: 00001004 00000000 00003004 00000000 00000000 00000000 00000002 00000000
```

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```
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 16 4 12 4 4 24      16      99      4 1 1 0 1 4 1
BUSY SLOTS:      0 0 0 0 1 0 0 10        0       7      0 0 0 0 0 0 0
STALLS:          0 6 0104 0 0 10 6        0       0      0 0 3 25 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 C1  ROB# PC Ri  oPi x s c  +-----+
000] LW  R2,0(R1)    0 1 2 3 4 6 7 P2,0(P1)  ----  LW P2 P1 - 0 2 - -  ---- 000 R2 - 0 0 1  |LQ(0 ) |
001] LW  R4,0(R3)    0 1 2 4 5 7 8 P4,0(P3)  ----  LW P4 P3 - 0 2 - -  ---- 001 R4 - 0 0 1  |PC  OP Pi EFAD Ci|
002] ADD  R5,R5,R2    0 1 2 6 6 7 8 P6,P5,P2  ----  ADD P6 P5 P2 - 2 6 - -  ---- 002 R5 P5 0 0 1  |---- LW P2 1000 6|
003] ADD  R5,R5,R4    0 1 2 7 7 8 9 P7,P6,P4  ----  ADD P7 P6 P4 - 7 7 - -  ---- 003 R5 P6 0 0 1  |---- LW P4 3000 7|
004] MUL  R5,R5,R5    1 2 3 8 8 13 14 P8,P7,P7  ----  MUL P8 P7 P7 - 8 8 - -  ---- 004 R5 P7 0 0 1  |---- LW P13 1004 10|
005] SW  R5,0(R1)    1 2 3 5 6 13 14 ,P0(P1)<--P8  ----  SW - P8 P1 0 - 3 - - -  ---- 005 - - 1 0 1  |---- LW P14 3004 11|
006] SW  R5,0(R3)    1 2 3 6 7 13 14 ,P0(P3)<--P8  ----  SW - P8 P3 0 - 3 - - -  ---- 006 - - 1 0 1  |---- LW P21 1008 13|
007] ADDI R1,R1,4    1 2 3 4 4 5 14 P9,P1,4  ----  ADDI P9 P1 - 4 3 - -  ---- 007 R1 P1 0 0 1  |---- LW P22 3008 14|
008] ADDI R3,R3,4    2 3 4 5 5 6 15 P10,P3,4  ----  ADDI P10 P3 - 4 4 - -  ---- 008 R3 P3 0 0 1  +-----+
009] ADDI R7,R7,-1   2 3 4 5 5 6 15 P12,P11,-1  ----  ADDI P12 P11 - -1 4 - -  ---- 009 R7 P11 0 0 1  +-----+
010] BNE  R7,R0,-11  2 3 4 6 6 7 15 ,P12,P0,-11  ----  BNE - P12 P0 -11 6 4 - -  ---- 010 - - 0 0 1  +-----+
011] LW  R2,0(R1)    3 4 5 7 8 10 15 P13,0(P9)  ----  LW P13 P9 - 0 5 - -  ---- 000 R2 P2 0 0 1  |SQ(2 ) |
012] LW  R4,0(R3)    3 4 5 8 9 11 16 P14,0(P10)  ----  LW P14 P10 - 0 6 - -  ---- 001 R4 P4 0 0 1  |PC  OP Pi EFAD C1|
013] ADD  R5,R5,R2    3 4 5 13 13 14 16 P15,P8,P13  ----  ADD P15 P8 P13 - 13 10 - -  ---- 002 R5 P8 0 0 1  |---- SW P0 1000 13|
014] ADD  R5,R5,R4    3 4 5 14 14 15 16 P16,P15,P14  ----  ADD P16 P15 P14 - 14 11 - -  ---- 003 R5 P15 0 0 1  |---- SW P0 3000 13|
015] MUL  R5,R5,R5    4 5 6 15 15 20 21 P17,P16,P16  ----  MUL P17 P16 P16 - 15 15 - -  ---- 004 R5 P16 0 0 1  |---- SW P0 1004 20|
016] SW  R5,0(R1)    4 5 6 9 10 20 21 ,P0(P9)<--P17  ----  SW - P17 P9 0 - 6 - - -  ---- 005 - - 1 0 1  |---- SW P0 3004 20|
017] SW  R5,0(R3)    4 5 6 13 14 20 21 ,P0(P10)<--P17  ----  SW - P17 P10 0 - 6 - - -  ---- 006 - - 1 0 1  |027] SW P0 1008 .|
018] ADDI R1,R1,4    4 5 6 7 7 8 21 P18,P9,4  ----  ADDI P18 P9 - 4 6 - -  ---- 007 R1 P9 0 0 1  |028] SW P0 3008 .|
019] ADDI R3,R3,4    5 6 7 8 8 9 22 P19,P10,4  ----  ADDI P19 P10 - 4 7 - -  ---- 008 R3 P10 0 0 1  +-----+
020] ADDI R7,R7,-1   5 6 7 9 9 10 22 P20,P12,-1  ----  ADDI P20 P12 - -1 7 - -  ---- 009 R7 P12 0 0 1  +-----+
021] BNE  R7,R0,-11  5 6 7 9 9 10 22 ,P20,P0,-11  ----  BNE - P20 P0 -11 - 7 - -  ---- 010 - - 0 0 1  +-----+
022] LW  R2,0(R1)    6 7 8 10 11 13 22 P21,0(P18)  ----  LW P21 P18 - 0 8 - -  ---- 000 R2 P13 0 0 1  |---- 000 R2 P13 0 0 1|
023] LW  R4,0(R3)    6 7 8 11 12 14 23 P22,0(P19)  ----  LW P22 P19 - 0 9 - -  ---- 001 R4 P14 0 0 1  |---- 001 R4 P14 0 0 1|
024] ADD  R5,R5,R2    6 7 8 20 20 21 23 P23,P17,P21  ----  ADD P23 P17 P21 - 20 13 - -  ---- 002 R5 P17 0 0 1  |---- 002 R5 P17 0 0 1|
025] ADD  R5,R5,R4    6 7 8 21 21 22 23 P24,P23,P22  ----  ADD P24 P23 P22 - 21 14 - -  ---- 003 R5 P23 0 0 1  |---- 003 R5 P23 0 0 1|
026] MUL  R5,R5,R5    7 8 9 22 22 ,P5,P24,P24  ----  MUL P5 P24 P24 - 22 22 - 026) 004 R5 P24 0 0 0  |---- 026) 004 R5 P24 0 0 0|
027] SW  R5,0(R1)    7 8 9 14 15 ,P0(P18)<--P5  ----  SW - P5 P18 0 - 9 - 027) 005 - - 1 0 0  |---- 027) 005 - - 1 0 0|
028] SW  R5,0(R3)    7 8 9 20 21 ,P0(P19)<--P5  ----  SW - P5 P19 0 - 9 - 028) 006 - - 1 0 0  |---- 028) 006 - - 1 0 0|
029] ADDI R1,R1,4    7 9 10 11 11 12 P6,P18,4  ----  ADDI P6 P18 - 4 10 - - 029) 007 R1 P18 0 0 1  |---- 029) 007 R1 P18 0 0 1|
030] ADDI R3,R3,4    8 14 15 16 16 17 P7,P19,4  ----  ADDI P7 P19 - 4 15 - - 030) 008 R3 P19 0 0 1  |---- 030) 008 R3 P19 0 0 1|
031] ADDI R7,R7,-1   8 14 15 16 16 17 P1,P20,-1  ----  ADDI P1 P20 - -1 15 - - 031) 009 R7 P20 0 0 1  |---- 031) 009 R7 P20 0 0 1|
032] BNE  R7,R0,-11  8 14 15 16 16 17 P1,P0,-11  ----  BNE - P1 P0 -11 - 15 - 032) 010 - - 0 0 1  |---- 032) 010 - - 0 0 1|

=====
Press ENTER to continue (PC=12,IC=33,CK=24,CTOT=25,IPC=1.32)...
#024 stall due to NO SLOTS when trying to move instuction ADD/025 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 1 1 1 0 0 0 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 1 0
vi:  00 00 00 00 00 0C 0C 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00
=====
REG. FILE: Ri:      1      2      3      4      5      6      7      8
Pi:      6      21      7      22      5      -      1      -
Qi:      0      0      0      0      1      0      0      0
Vi:  00001004 00000000 00003004 00000000 00000000 00000000 00000002 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 16 4 12 4 4 24      16      99      4 1 1 0 1 4 1
BUSY SLOTS:      0 0 0 0 1 0 0 10        0       7      0 0 0 0 0 0 0
STALLS:          0 6 0104 0 0 11 6        0       0      0 0 3 25 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 C1  ROB# PC Ri  oPi x s c  +-----+
000] LW  R2,0(R1)    0 1 2 3 4 6 7 P2,0(P1)  ----  LW P2 P1 - 0 2 - -  ---- 000 R2 - 0 0 1  |LQ(0 ) |
001] LW  R4,0(R3)    0 1 2 4 5 7 8 P4,0(P3)  ----  LW P4 P3 - 0 2 - -  ---- 001 R4 - 0 0 1  |PC  OP Pi EFAD Ci|
002] ADD  R5,R5,R2    0 1 2 6 6 7 8 P6,P5,P2  ----  ADD P6 P5 P2 - 2 6 - -  ---- 002 R5 P5 0 0 1  |---- LW P2 1000 6|
003] ADD  R5,R5,R4    0 1 2 7 7 8 9 P7,P6,P4  ----  ADD P7 P6 P4 - 7 7 - -  ---- 003 R5 P6 0 0 1  |---- LW P4 3000 7|
004] MUL  R5,R5,R5    1 2 3 8 8 13 14 P8,P7,P7  ----  MUL P8 P7 P7 - 8 8 - -  ---- 004 R5 P7 0 0 1  |---- LW P13 1004 10|
005] SW  R5,0(R1)    1 2 3 5 6 13 14 ,P0(P1)<--P8  ----  SW - P8 P1 0 - 3 - - -  ---- 005 - - 1 0 1  |---- LW P14 3004 11|
006] SW  R5,0(R3)    1 2 3 6 7 13 14 ,P0(P3)<--P8  ----  SW - P8 P3 0 - 3 - - -  ---- 006 - - 1 0 1  |---- LW P21 1008 13|
007] ADDI R1,R1,4    1 2 3 4 4 5 14 P9,P1,4  ----  ADDI P9 P1 - 4 3 - -  ---- 007 R1 P1 0 0 1  |---- LW P22 3008 14|
008] ADDI R3,R3,4    2 3 4 5 5 6 15 P10,P3,4  ----  ADDI P10 P3 - 4 4 - -  ---- 008 R3 P3 0 0 1  +-----+
009] ADDI R7,R7,-1   2 3 4 5 5 6 15 P12,P11,-1  ----  ADDI P12 P11 - -1 4 - -  ---- 009 R7 P11 0 0 1  +-----+
010] BNE  R7,R0,-11  2 3 4 6 6 7 15 ,P12,P0,-11  ----  BNE - P12 P0 -11 6 4 - -  ---- 010 - - 0 0 1  +-----+
011] LW  R2,0(R1)    3 4 5 7 8 10 15 P13,0(P9)  ----  LW P13 P9 - 0 5 - -  ---- 000 R2 P2 0 0 1  |SQ(2 ) |
=====
```

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```
012] LW R4,0(R3) 3 4 5 8 9 11 16 P14,0(P10) ---- LW P14 P10 - 0 6 - - ---- 001 R4 P4 0 0 1 |PC OP Pi EFAD C1|
013] ADD R5,R5,R2 3 4 5 13 13 14 16 P15,P8,P13 ---- ADD P15 P8 P13 - 13 10 - ---- 002 R5 P8 0 0 1 |---- SW P0 1000 13|
014] ADD R5,R5,R4 3 4 5 14 14 15 16 P16,P15,P14 ---- ADD P16 P15 P14 - 14 11 - ---- 003 R5 P15 0 0 1 |---- SW P0 3000 13|
015] MUL R5,R5,R5 4 5 6 15 15 20 21 P17,P16,P16 ---- MUL P17 P16 P16 - 15 15 - ---- 004 R5 P16 0 0 1 |---- SW P0 1004 20|
016] SW R5,0(R1) 4 5 6 9 10 20 21 ,P0(P9)<-P17 ---- SW - P17 P9 0 - 6 - ---- 005 - - 1 0 1 |---- SW P0 3004 20|
017] SW R5,0(R3) 4 5 6 13 14 20 21 ,P0(P10)<-P17 ---- SW - P17 P10 0 - 6 - ---- 006 - - 1 0 1 |027] SW P0 1008 .|
018] ADDI R1,R1,4 4 5 6 7 7 8 21 P18,P9,4 ---- ADDI P18 P9 - 4 6 - - ---- 007 R1 P9 0 0 1 |028] SW P0 3008 .|
019] ADDI R3,R3,4 5 6 7 8 8 9 22 P19,P10,4 ---- ADDI P19 P10 - 4 7 - - ---- 008 R3 P10 0 0 1 +-----+
020] ADDI R7,R7,-1 5 6 7 9 9 10 22 P20,P12,-1 ---- ADDI P20 P12 - -1 7 - - ---- 009 R7 P12 0 0 1
021] BNE R7,R0,-11 5 6 7 9 9 10 22 ,P20,P0,-11 ---- BNE - P20 P0 -11 - 7 - - ---- 010 - - 0 0 1
022] LW R2,0(R1) 6 7 8 10 11 13 22 P21,0(P18) ---- LW P21 P18 - 0 8 - - ---- 000 R2 P13 0 0 1
023] LW R4,0(R3) 6 7 8 11 12 14 23 P22,0(P19) ---- LW P22 P19 - 0 9 - - ---- 001 R4 P14 0 0 1
024] ADD R5,R5,R2 6 7 8 20 20 21 23 P23,P17,P21 ---- ADD P23 P17 P21 - 20 13 - ---- 002 R5 P17 0 0 1
025] ADD R5,R5,R4 6 7 8 21 21 22 23 P24,P23,P22 ---- ADD P24 P23 P22 - 21 14 - ---- 003 R5 P23 0 0 1
026] MUL R5,R5,R5 7 8 9 22 22 P5,P24,P24 ---- MUL P5 P24 P24 - 22 22 - 026) 004 R5 P24 0 0 0
027] SW R5,0(R1) 7 8 9 14 15 ,P0(P18)<-P5 ---- SW - P5 P18 0 - 9 - 027) 005 - - 1 0 0
028] SW R5,0(R3) 7 8 9 20 21 ,P0(P19)<-P5 ---- SW - P5 P19 0 - 9 - 028) 006 - - 1 0 0
029] ADDI R1,R1,4 7 9 10 11 11 12 P6,P18,4 ---- ADDI P6 P18 - 4 10 - - 029) 007 R1 P18 0 0 1
030] ADDI R3,R3,4 8 14 15 16 16 17 P7,P19,4 ---- ADDI P7 P19 - 4 15 - - 030) 008 R3 P19 0 0 1
031] ADDI R7,R7,-1 8 14 15 16 16 17 P1,P20,-1 ---- ADDI P1 P20 - -1 15 - - 031) 009 R7 P20 0 0 1
032] BNE R7,R0,-11 8 14 15 16 16 17 ,P1,P0,-11 ---- BNE - P1 P0 -11 - 15 - 032) 010 - - 0 0 1
```

Press ENTER to continue (PC=12,IC=33,CK=25,CTOT=26,IPC=1.27)...

@025 stall due to NO SLOTS when trying to move instuction ADD/025 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 1 1 1 1 0 0 0 1 1 1 1 1 1 1 1 0 0 0 0 0 0 1 0
vi: 00 00 00 00 00 0C 0C 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00
=====
REG.FILE: Ri: 1 2 3 4 5 6 7 8
          Pi: 6 21 7 22 5 - 1 -
          Qi: 0 0 0 0 1 0 0 0
          Vi: 00001004 00000000 00003004 00000000 00000000 00000000 00000002 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 16 4 12 4 4 24 16 99 4 1 1 0 1 4 1
BUSY SLOTS: 0 0 0 0 1 0 0 10 0 7 0 0 0 0 0 0 0
STALLS: 0 6 0104 0 0 12 6 0 0 0 0 0 0 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 C1 ROB# PC Ri oPi x s c +-----+
000] LW R2,0(R1) 0 1 2 3 4 6 7 P2,0(P1) ---- LW P2 P1 - 0 2 - - ---- 000 R2 - 0 0 1 |LQ(0 )|
001] LW R4,0(R3) 0 1 2 4 5 7 8 P4,0(P3) ---- LW P4 P3 - 0 2 - - ---- 001 R4 - 0 0 1 |PC OP Pi EFAD Ci|
002] ADD R5,R5,R2 0 1 2 6 6 7 8 P6,P5,P2 ---- ADD P6 P5 P2 - 2 6 - - ---- 002 R5 P5 0 0 1 |---- LW P2 1000 6|
003] ADD R5,R5,R4 0 1 2 7 7 8 9 P7,P6,P4 ---- ADD P7 P6 P4 - 7 7 - - ---- 003 R5 P6 0 0 1 |---- LW P4 3000 7|
004] MUL R5,R5,R5 1 2 3 8 8 13 14 P8,P7,P7 ---- MUL P8 P7 P7 - 8 8 - - ---- 004 R5 P7 0 0 1 |---- LW P13 1004 10|
005] SW R5,0(R1) 1 2 3 5 6 13 14 ,P0(P1)<-P8 ---- SW - P8 P1 0 - 3 - ---- 005 - - 1 0 1 |---- LW P14 3004 11|
006] SW R5,0(R3) 1 2 3 6 7 13 14 ,P0(P3)<-P8 ---- SW - P8 P3 0 - 3 - ---- 006 - - 1 0 1 |---- LW P21 1008 13|
007] ADDI R1,R1,4 1 2 3 4 4 5 14 P9,P1,4 ---- ADDI P9 P1 - 4 3 - - ---- 007 R1 P1 0 0 1 |---- LW P22 3008 14|
008] ADDI R3,R3,4 2 3 4 5 5 6 15 P10,P3,4 ---- ADDI P10 P3 - 4 4 - - ---- 008 R3 P3 0 0 1 +-----+
009] ADDI R7,R7,-1 2 3 4 5 5 6 15 P12,P11,-1 ---- ADDI P12 P11 - -1 4 - - ---- 009 R7 P11 0 0 1
010] BNE R7,R0,-11 2 3 4 6 6 7 15 ,P12,P0,-11 ---- BNE - P12 P0 -11 6 4 - - ---- 010 - - 0 0 1 +-----+
011] LW R2,0(R1) 3 4 5 7 8 10 15 P13,0(P9) ---- LW P13 P9 - 0 5 - - ---- 000 R2 P2 0 0 1 |SQ(2 )|
012] LW R4,0(R3) 3 4 5 8 9 11 16 P14,0(P10) ---- LW P14 P10 - 0 6 - - ---- 001 R4 P4 0 0 1 |PC OP Pi EFAD C1|
013] ADD R5,R5,R2 3 4 5 13 13 14 16 P15,P8,P13 ---- ADD P15 P8 P13 - 13 10 - ---- 002 R5 P8 0 0 1 |---- SW P0 1000 13|
014] ADD R5,R5,R4 3 4 5 14 14 15 16 P16,P15,P14 ---- ADD P16 P15 P14 - 14 11 - ---- 003 R5 P15 0 0 1 |---- SW P0 3000 13|
015] MUL R5,R5,R5 4 5 6 15 15 20 21 P17,P16,P16 ---- MUL P17 P16 P16 - 15 15 - ---- 004 R5 P16 0 0 1 |---- SW P0 1004 20|
016] SW R5,0(R1) 4 5 6 9 10 20 21 ,P0(P9)<-P17 ---- SW - P17 P9 0 - 6 - ---- 005 - - 1 0 1 |---- SW P0 3004 20|
017] SW R5,0(R3) 4 5 6 13 14 20 21 ,P0(P10)<-P17 ---- SW - P17 P10 0 - 6 - ---- 006 - - 1 0 1 |027] SW P0 1008 .|
018] ADDI R1,R1,4 4 5 6 7 7 8 21 P18,P9,4 ---- ADDI P18 P9 - 4 6 - - ---- 007 R1 P9 0 0 1 |028] SW P0 3008 .|
019] ADDI R3,R3,4 5 6 7 8 8 9 22 P19,P10,4 ---- ADDI P19 P10 - 4 7 - - ---- 008 R3 P10 0 0 1 +-----+
020] ADDI R7,R7,-1 5 6 7 9 9 10 22 P20,P12,-1 ---- ADDI P20 P12 - -1 7 - - ---- 009 R7 P12 0 0 1
021] BNE R7,R0,-11 5 6 7 9 9 10 22 ,P20,P0,-11 ---- BNE - P20 P0 -11 - 7 - - ---- 010 - - 0 0 1
022] LW R2,0(R1) 6 7 8 10 11 13 22 P21,0(P18) ---- LW P21 P18 - 0 8 - - ---- 000 R2 P13 0 0 1
023] LW R4,0(R3) 6 7 8 11 12 14 23 P22,0(P19) ---- LW P22 P19 - 0 9 - - ---- 001 R4 P14 0 0 1
024] ADD R5,R5,R2 6 7 8 20 20 21 23 P23,P17,P21 ---- ADD P23 P17 P21 - 20 13 - ---- 002 R5 P17 0 0 1
025] ADD R5,R5,R4 6 7 8 21 21 22 23 P24,P23,P22 ---- ADD P24 P23 P22 - 21 14 - ---- 003 R5 P23 0 0 1
026] MUL R5,R5,R5 7 8 9 22 22 P5,P24,P24 ---- MUL P5 P24 P24 - 22 22 - 026) 004 R5 P24 0 0 0
027] SW R5,0(R1) 7 8 9 14 15 ,P0(P18)<-P5 ---- SW - P5 P18 0 - 9 - 027) 005 - - 1 0 0
028] SW R5,0(R3) 7 8 9 20 21 ,P0(P19)<-P5 ---- SW - P5 P19 0 - 9 - 028) 006 - - 1 0 0
029] ADDI R1,R1,4 7 9 10 11 11 12 P6,P18,4 ---- ADDI P6 P18 - 4 10 - - 029) 007 R1 P18 0 0 1
```

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```
030] ADDI R3,R3,4      8 14 15 16 16 17    P7,P19,4      ---- ADDI P7 P19 - 4 15 - - 030) 008 R3 P19 0 0 1
031] ADDI R7,R7,-1     8 14 15 16 16 17    P1,P20,-1     ---- ADDI P1 P20 - -1 15 - - 031) 009 R7 P20 0 0 1
032] BNE R7,R0,-11     8 14 15 16 16 17    ,P1,P0,-11    ---- BNE - P1 P0 -11 - 15 - 032) 010 - - 0 0 1
```

Press ENTER to continue (PC=12,IC=33,CK=26,CTOT=27,IPC=1.22)...

@026 stall due to NO SLOTS when trying to move instnuction ADD/025 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  1  1  0  0  0  1  1  1  1  1  1  1  1  1  0  0  0  0  0  1  0
vi:   00 00 00 00 00 0C 0C 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
          Pi:      6      21     7      22     5      -      1      -
          Qi:      0      0      0      0      0      0      0      0
          Vi: 00001004 00000000 00003004 00000000 00000000 00000000 00000002 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 16 4 12 4 4 24         16                99          4 1 1 0 1 4 1
BUSY SLOTS:      0 0 0 0 0 1 0 10          0                 7          0 0 0 0 0 0 0
STALLS:          0 6 0104 0 0 13 6          0                 0          0 0 3 25 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 C1  ROB# PC Ri oPi x s c  +-----+
000] LW R2,0(R1)     0 1 2 3 4 6 7 P2,0(P1)  ---- LW P2 P1 - 0 2 - - ---- 000 R2 - 0 0 1 |LQ(0 )|
001] LW R4,0(R3)     0 1 2 4 5 7 8 P4,0(P3)  ---- LW P4 P3 - 0 2 - - ---- 001 R4 - 0 0 1 |PC OP Pi EFAD Ci|
002] ADD R5,R5,R2     0 1 2 6 6 7 8 P6,P5,P2  ---- ADD P6 P5 P2 - 2 6 - - ---- 002 R5 P5 0 0 1 |---- LW P2 1000 6|
003] ADD R5,R5,R4     0 1 2 7 7 8 9 P7,P6,P4  ---- ADD P7 P6 P4 - 7 7 - - ---- 003 R5 P6 0 0 1 |---- LW P4 3000 7|
004] MUL R5,R5,R5     1 2 3 8 8 13 14 P8,P7,P7  ---- MUL P8 P7 P7 - 8 8 - - ---- 004 R5 P7 0 0 1 |---- LW P13 1004 10|
005] SW R5,0(R1)     1 2 3 5 6 13 14 ,P0(P1)<-P8  ---- SW - P8 P1 0 - 3 - - ---- 005 - - 1 0 1 |---- LW P14 3004 11|
006] SW R5,0(R3)     1 2 3 6 7 13 14 ,P0(P3)<-P8  ---- SW - P8 P3 0 - 3 - - ---- 006 - - 1 0 1 |---- LW P21 1008 13|
007] ADDI R1,R1,4     1 2 3 4 4 5 14 P9,P1,4  ---- ADDI P9 P1 - 4 3 - - ---- 007 R1 P1 0 0 1 |---- LW P22 3008 14|
008] ADDI R3,R3,4     2 3 4 5 5 6 15 P10,P3,4  ---- ADDI P10 P3 - 4 4 - - ---- 008 R3 P3 0 0 1 +-----+
009] ADDI R7,R7,-1    2 3 4 5 5 6 15 P12,P11,-1  ---- ADDI P12 P11 - -1 4 - - ---- 009 R7 P11 0 0 1
010] BNE R7,R0,-11    2 3 4 6 6 7 15 ,P12,P0,-11  ---- BNE - P12 P0 -11 6 4 - - ---- 010 - - 0 0 1 +-----+
011] LW R2,0(R1)     3 4 5 7 8 10 15 P13,0(P9)  ---- LW P13 P9 - 0 5 - - ---- 000 R2 P2 0 0 1 |SQ(1 )|
012] LW R4,0(R3)     3 4 5 8 9 11 16 P14,0(P10)  ---- LW P14 P10 - 0 6 - - ---- 001 R4 P4 0 0 1 |PC OP Pi EFAD C1|
013] ADD R5,R5,R2     3 4 5 13 13 14 16 P15,P8,P13  ---- ADD P15 P8 P13 - 13 10 - - ---- 002 R5 P8 0 0 1 |---- SW P0 1000 13|
014] ADD R5,R5,R4     3 4 5 14 14 15 16 P16,P15,P14  ---- ADD P16 P15 P14 - 14 11 - - ---- 003 R5 P15 0 0 1 |---- SW P0 3000 13|
015] MUL R5,R5,R5     4 5 6 15 15 20 21 P17,P16,P16  ---- MUL P17 P16 P16 - 15 15 - - ---- 004 R5 P16 0 0 1 |---- SW P0 1004 20|
016] SW R5,0(R1)     4 5 6 9 10 20 21 ,P0(P9)<-P17  ---- SW - P17 P9 0 - 6 - - ---- 005 - - 1 0 1 |---- SW P0 3004 20|
017] SW R5,0(R3)     4 5 6 13 14 20 21 ,P0(P10)<-P17  ---- SW - P17 P10 0 - 6 - - ---- 006 - - 1 0 1 |---- SW P0 1008 27|
018] ADDI R1,R1,4     4 5 6 7 7 8 21 P18,P9,4  ---- ADDI P18 P9 - 4 6 - - ---- 007 R1 P9 0 0 1 |028] SW P0 3008 27|
019] ADDI R3,R3,4     5 6 7 8 8 9 22 P19,P10,4  ---- ADDI P19 P10 - 4 7 - - ---- 008 R3 P10 0 0 1 +-----+
020] ADDI R7,R7,-1    5 6 7 9 9 10 22 P20,P12,-1  ---- ADDI P20 P12 - -1 7 - - ---- 009 R7 P12 0 0 1
021] BNE R7,R0,-11    5 6 7 9 9 10 22 ,P20,P0,-11  ---- BNE - P20 P0 -11 - 7 - - ---- 010 - - 0 0 1
022] LW R2,0(R1)     6 7 8 10 11 13 22 P21,0(P18)  ---- LW P21 P18 - 0 8 - - ---- 000 R2 P13 0 0 1
023] LW R4,0(R3)     6 7 8 11 12 14 23 P22,0(P19)  ---- LW P22 P19 - 0 9 - - ---- 001 R4 P14 0 0 1
024] ADD R5,R5,R2     6 7 8 20 20 21 23 P23,P17,P21  ---- ADD P23 P17 P21 - 20 13 - - ---- 002 R5 P17 0 0 1
025] ADD R5,R5,R4     6 7 8 21 21 22 23 P24,P23,P22  ---- ADD P24 P23 P22 - 21 14 - - ---- 003 R5 P23 0 0 1
026] MUL R5,R5,R5     7 8 9 22 22 27 P5,P24,P24  ---- MUL P5 P24 P24 - 22 22 - - (026) 004 R5 P24 0 0 1
027] SW R5,0(R1)     7 8 9 14 15 27 ,P0(P18)<-P5  ---- SW - P5 P18 0 - 9 - - (027) 005 - - 1 0 1
028] SW R5,0(R3)     7 8 9 20 21 27 ,P0(P19)<-P5  ---- SW - P5 P19 0 - 9 - - (028) 006 - - 1 0 1
029] ADDI R1,R1,4     7 9 10 11 11 12 P6,P18,4  ---- ADDI P6 P18 - 4 10 - - (029) 007 R1 P18 0 0 1
030] ADDI R3,R3,4     8 14 15 16 16 17 P7,P19,4  ---- ADDI P7 P19 - 4 15 - - (030) 008 R3 P19 0 0 1
031] ADDI R7,R7,-1    8 14 15 16 16 17 P1,P20,-1  ---- ADDI P1 P20 - -1 15 - - (031) 009 R7 P20 0 0 1
032] BNE R7,R0,-11    8 14 15 16 16 17 ,P1,P0,-11  ---- BNE - P1 P0 -11 - 15 - (032) 010 - - 0 0 1
=====
```

Press ENTER to continue (PC=12,IC=33,CK=27,CTOT=28,IPC=1.18)...

@027 stall due to NO SLOTS when trying to move instnuction ADD/025 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  1  1  0  0  0  1  1  1  1  1  1  1  1  1  0  0  0  0  0  1  1
vi:   00 00 00 00 00 0C 0C 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
          Pi:      6      21     7      22     5      -      1      -
          Qi:      0      0      0      0      0      0      0      0
          Vi: 00001008 00000000 00003004 00000000 00000000 00000000 00000002 00000000
=====
```

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```
=====
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 16 4 12 4 4 24      16                      99                      4 1 1 0 1 4 1
BUSY SLOTS:      0 0 0 0 0 1 0 8          0                      3                      0 0 0 0 0 0 0
STALLS:          0 6 0104 0 0 13 6        0                      0                      0 0 3 25 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 C1  ROB# PC Ri oPi x s c  +-----+
000] LW  R2,0(R1)  0 1 2 3 4 6 7 P2,0(P1)  ----  LW P2 P1 - 0 2 - -  ---- 000 R2 - 0 0 1 |LQ(0 )|
001] LW  R4,0(R3)  0 1 2 4 5 7 8 P4,0(P3)  ----  LW P4 P3 - 0 2 - -  ---- 001 R4 - 0 0 1 |PC  OP Pi EFAD Ci|
002] ADD  R5,R5,R2  0 1 2 6 6 7 8 P6,P5,P2  ----  ADD P6 P5 P2 - 2 6 - -  ---- 002 R5 P5 0 0 1 |---- LW P2 1000 6|
003] ADD  R5,R5,R4  0 1 2 7 7 8 9 P7,P6,P4  ----  ADD P7 P6 P4 - 7 7 - -  ---- 003 R5 P6 0 0 1 |---- LW P4 3000 7|
004] MUL  R5,R5,R5  1 2 3 8 8 13 14 P8,P7,P7  ----  MUL P8 P7 P7 - 8 8 - -  ---- 004 R5 P7 0 0 1 |---- LW P13 1004 10|
005] SW  R5,0(R1)  1 2 3 5 6 13 14 ,P0(P1)<--P8  ----  SW - P8 P1 0 - 3 - -  ---- 005 - - 1 0 1 |---- LW P14 3004 11|
006] SW  R5,0(R3)  1 2 3 6 7 13 14 ,P0(P3)<--P8  ----  SW - P8 P3 0 - 3 - -  ---- 006 - - 1 0 1 |---- LW P21 1008 13|
007] ADDI R1,R1,4  1 2 3 4 4 5 14 P9,P1,4  ----  ADDI P9 P1 - 4 3 - -  ---- 007 R1 P1 0 0 1 |---- LW P22 3008 14|
008] ADDI R3,R3,4  2 3 4 5 5 6 15 P10,P3,4  ----  ADDI P10 P3 - 4 4 - -  ---- 008 R3 P3 0 0 1 +-----+
009] ADDI R7,R7,-1  2 3 4 5 5 6 15 P12,P11,-1  ----  ADDI P12 P11 - -1 4 - -  ---- 009 R7 P11 0 0 1
010] BNE  R7,R0,-11  2 3 4 6 6 7 15 ,P12,P0,-11  ----  BNE - P12 P0 -11 6 4 - -  ---- 010 - - 0 0 1 +-----+
011] LW  R2,0(R1)  3 4 5 7 8 10 15 P13,0(P9)  ----  LW P13 P9 - 0 5 - -  ---- 000 R2 P2 0 0 1 |SQ(0 )|
012] LW  R4,0(R3)  3 4 5 8 9 11 16 P14,0(P10)  ----  LW P14 P10 - 0 6 - -  ---- 001 R4 P4 0 0 1 |PC  OP Pi EFAD C1|
013] ADD  R5,R5,R2  3 4 5 13 13 14 16 P15,P8,P13  ----  ADD P15 P8 P13 - 13 10 - -  ---- 002 R5 P8 0 0 1 |---- SW P0 1000 13|
014] ADD  R5,R5,R4  3 4 5 14 14 15 16 P16,P15,P14  ----  ADD P16 P15 P14 - 14 11 - -  ---- 003 R5 P15 0 0 1 |---- SW P0 3000 13|
015] MUL  R5,R5,R5  4 5 6 15 15 20 21 P17,P16,P16  ----  MUL P17 P16 P16 - 15 15 - -  ---- 004 R5 P16 0 0 1 |---- SW P0 1004 20|
016] SW  R5,0(R1)  4 5 6 9 10 20 21 ,P0(P9)<--P17  ----  SW - P17 P9 0 - 6 - -  ---- 005 - - 1 0 1 |---- SW P0 3004 20|
017] SW  R5,0(R3)  4 5 6 13 14 20 21 ,P0(P10)<--P17  ----  SW - P17 P10 0 - 6 - -  ---- 006 - - 1 0 1 |---- SW P0 1008 27|
018] ADDI R1,R1,4  4 5 6 7 7 8 21 P18,P9,4  ----  ADDI P18 P9 - 4 6 - -  ---- 007 R1 P9 0 0 1 |---- SW P0 3008 27|
019] ADDI R3,R3,4  5 6 7 8 8 9 22 P19,P10,4  ----  ADDI P19 P10 - 4 7 - -  ---- 008 R3 P10 0 0 1 +-----+
020] ADDI R7,R7,-1  5 6 7 9 9 10 22 P20,P12,-1  ----  ADDI P20 P12 - -1 7 - -  ---- 009 R7 P12 0 0 1
021] BNE  R7,R0,-11  5 6 7 9 9 10 22 ,P20,P0,-11  ----  BNE - P20 P0 -11 7 - - -  ---- 010 - - 0 0 1
022] LW  R2,0(R1)  6 7 8 10 11 13 22 P21,0(P18)  ----  LW P21 P18 - 0 8 - -  ---- 000 R2 P13 0 0 1
023] LW  R4,0(R3)  6 7 8 11 12 14 23 P22,0(P19)  ----  LW P22 P19 - 0 9 - -  ---- 001 R4 P14 0 0 1
024] ADD  R5,R5,R2  6 7 8 20 20 21 23 P23,P17,P21  ----  ADD P23 P17 P21 - 20 13 - -  ---- 002 R5 P17 0 0 1
025] ADD  R5,R5,R4  6 7 8 21 21 22 23 P24,P23,P22  ----  ADD P24 P23 P22 - 21 14 - -  ---- 003 R5 P23 0 0 1
026] MUL  R5,R5,R5  7 8 9 22 22 27 28 P5,P24,P24  ----  MUL P5 P24 P24 - 22 22 - -  ---- 004 R5 P24 0 0 1
027] SW  R5,0(R1)  7 8 9 14 15 27 28 ,P0(P18)<--P5  ----  SW - P5 P18 0 - 9 - -  ---- 005 - - 1 0 1
028] SW  R5,0(R3)  7 8 9 20 21 27 28 ,P0(P19)<--P5  ----  SW - P5 P19 0 - 9 - -  ---- 006 - - 1 0 1
029] ADDI R1,R1,4  7 9 10 11 11 12 28 P6,P18,4  ----  ADDI P6 P18 - 4 10 - -  ---- 007 R1 P18 0 0 1
030] ADDI R3,R3,4  8 14 15 16 16 17 P7,P19,4  ----  ADDI P7 P19 - 4 15 - -  (030) 008 R3 P19 0 0 1
031] ADDI R7,R7,-1  8 14 15 16 16 17 P1,P20,-1  ----  ADDI P1 P20 - -1 15 - -  (031) 009 R7 P20 0 0 1
032] BNE  R7,R0,-11  8 14 15 16 16 17 P1,P0,-11  ----  BNE - P1 P0 -11 - 15 -  (032) 010 - - 0 0 1
=====
Press ENTER to continue (PC=12,IC=33,CK=28,CTOT=29,IPC=1.14)...
=====
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 1 1 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 1 1
vi:  00 00 00 00 00 0C 0C 00 04 04 03 02 00 00 00 00 00 08 08 01 00 00 00 00
=====
REG. FILE: Ri:      1      2      3      4      5      6      7      8
Pi:      6      21      7      22      5      -      1      -
Qi:      0      0      0      0      0      0      0      0
Vi:  00001008 00000000 00003008 00000000 00000000 00000000 00000001 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 16 4 12 4 4 24      16                      99                      4 1 1 0 1 4 1
BUSY SLOTS:      0 0 0 0 0 0 0 6          0                      0                      0 0 0 0 0 0 0
STALLS:          0 6 0104 0 0 13 6        0                      0                      0 0 3 25 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 C1  ROB# PC Ri oPi x s c  +-----+
000] LW  R2,0(R1)  0 1 2 3 4 6 7 P2,0(P1)  ----  LW P2 P1 - 0 2 - -  ---- 000 R2 - 0 0 1 |LQ(0 )|
001] LW  R4,0(R3)  0 1 2 4 5 7 8 P4,0(P3)  ----  LW P4 P3 - 0 2 - -  ---- 001 R4 - 0 0 1 |PC  OP Pi EFAD Ci|
002] ADD  R5,R5,R2  0 1 2 6 6 7 8 P6,P5,P2  ----  ADD P6 P5 P2 - 2 6 - -  ---- 002 R5 P5 0 0 1 |---- LW P2 1000 6|
003] ADD  R5,R5,R4  0 1 2 7 7 8 9 P7,P6,P4  ----  ADD P7 P6 P4 - 7 7 - -  ---- 003 R5 P6 0 0 1 |---- LW P4 3000 7|
004] MUL  R5,R5,R5  1 2 3 8 8 13 14 P8,P7,P7  ----  MUL P8 P7 P7 - 8 8 - -  ---- 004 R5 P7 0 0 1 |---- LW P13 1004 10|
005] SW  R5,0(R1)  1 2 3 5 6 13 14 ,P0(P1)<--P8  ----  SW - P8 P1 0 - 3 - -  ---- 005 - - 1 0 1 |---- LW P14 3004 11|
006] SW  R5,0(R3)  1 2 3 6 7 13 14 ,P0(P3)<--P8  ----  SW - P8 P3 0 - 3 - -  ---- 006 - - 1 0 1 |---- LW P21 1008 13|
007] ADDI R1,R1,4  1 2 3 4 4 5 14 P9,P1,4  ----  ADDI P9 P1 - 4 3 - -  ---- 007 R1 P1 0 0 1 |---- LW P22 3008 14|
008] ADDI R3,R3,4  2 3 4 5 5 6 15 P10,P3,4  ----  ADDI P10 P3 - 4 4 - -  ---- 008 R3 P3 0 0 1 +-----+
009] ADDI R7,R7,-1  2 3 4 5 5 6 15 P12,P11,-1  ----  ADDI P12 P11 - -1 4 - -  ---- 009 R7 P11 0 0 1
010] BNE  R7,R0,-11  2 3 4 6 6 7 15 ,P12,P0,-11  ----  BNE - P12 P0 -11 6 4 - -  ---- 010 - - 0 0 1 +-----+
011] LW  R2,0(R1)  3 4 5 7 8 10 15 P13,0(P9)  ----  LW P13 P9 - 0 5 - -  ---- 000 R2 P2 0 0 1 |SQ(0 )|
```


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012] LW R4,0(R3)345891116P14,0(P10)----LW P14 P10 - 06-- ---- 001 R4 P4 0 0 1|PC OP Pi EFAD C1|

013] ADD R5,R5,R234513131416P15,P8,P13----ADD P15 P8 P13 - 13 10 - ---- 002 R5 P8 0 0 1|---- SW P0 1000 13|

014] ADD R5,R5,R434514141516P16,P15,P14----ADD P16 P15 P14 - 14 11 - ---- 003 R5 P15 0 0 1|---- SW P0 3000 13|

015] MUL R5,R5,R545615152021P17,P16,P16----MUL P17 P16 P16 - 15 15 - ---- 004 R5 P16 0 0 1|---- SW P0 1004 20|

016] SW R5,0(R1)4569102021,P0(P9)<-P17----SW - P17 P9 0 - 6 - ---- 005 - - 1 0 1|---- SW P0 3004 20|

017] SW R5,0(R3)45613142021,P0(P10)<-P17----SW - P17 P10 0 - 6 - ---- 006 - - 1 0 1|---- SW P0 1008 27|

018] ADDI R1,R1,445677821P18,P9,4----ADDI P18 P9 - 4 6 - - ---- 007 R1 P9 0 0 1|---- SW P0 3008 27|

019] ADDI R3,R3,456788922P19,P10,4----ADDI P19 P10 - 4 7 - - ---- 008 R3 P10 0 0 1|-----+-----+|

020] ADDI R7,R7,-1567991022P20,P12,-1----ADDI P20 P12 - -1 7 - - ---- 009 R7 P12 0 0 1|-----+-----+|

021] BNE R7,R0,-11567991022,P20,P0,-11----BNE - P20 P0 -11 - 7 - ---- 010 - - 0 0 1|-----+-----+|

022] LW R2,0(R1)67810111322P21,0(P18)----LW P21 P18 - 0 8 - - ---- 000 R2 P13 0 0 1|-----+-----+|

023] LW R4,0(R3)67811121423P22,0(P19)----LW P22 P19 - 0 9 - - ---- 001 R4 P14 0 0 1|-----+-----+|

024] ADD R5,R5,R267820202123P23,P17,P21----ADD P23 P17 P21 - 20 13 - ---- 002 R5 P17 0 0 1|-----+-----+|

025] ADD R5,R5,R467821212223P24,P23,P22----ADD P24 P23 P22 - 21 14 - ---- 003 R5 P23 0 0 1|-----+-----+|

026] MUL R5,R5,R578922222728P5,P24,P24----MUL P5 P24 P24 - 22 22 - ---- 004 R5 P24 0 0 1|-----+-----+|

027] SW R5,0(R1)78914152728,P0(P18)<-P5----SW - P5 P18 0 - 9 - ---- 005 - - 1 0 1|-----+-----+|

028] SW R5,0(R3)78920212728,P0(P19)<-P5----SW - P5 P19 0 - 9 - ---- 006 - - 1 0 1|-----+-----+|

029] ADDI R1,R1,4791011111228P6,P18,4----ADDI P6 P18 - 4 10 - - ---- 007 R1 P18 0 0 1|-----+-----+|

030] ADDI R3,R3,48141516161729P7,P19,4----ADDI P7 P19 - 4 15 - - ---- 008 R3 P19 0 0 1|-----+-----+|

031] ADDI R7,R7,-18141516161729P1,P20,-1----ADDI P1 P20 - -1 15 - - ---- 009 R7 P20 0 0 1|-----+-----+|

032] BNE R7,R0,-118141516161729,P1,P0,-11----BNE - P1 P0 -11 - 15 - ---- 010 - - 0 0 1|-----+-----+|

----- Press ENTER to continue (PC=12,IC=33,CK=29,CTOT=30,IPC=1.10)...

Program 'prog070628' FINISHED

PC=12,IC=33,CK=30,IPC=1.10

Goodbye.