

out_ex1.txt

Fri Oct 26 16:36:01 2018

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```
./run_ex1.sh
TEST: ex1
./freess -exe prog_ex1 -iw 4 -wins 16 -pregs 24 -robs 99 -lqs 3 -sqs 3 -llat 2 -afu 1 -int no
```

LIST OF INITIALIZATION PARAMETERS

-----[General]

Program Name = prog_ex1
Silent = no
Interactive = no
Batch File = no

-----[Architecture]

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

-----[Program Defaults]

Log File Name = def.log

* Input program: 'prog_ex1'

R1 <-- 00001000
R4 <-- 00004000
R5 <-- 00005000
R6 <-- 00006000
000) 36 3 4 2 --> LW R3,R2(R4)
001) 36 7 5 2 --> LW R7,R2(R5)
002) 24 7 7 3 --> MUL R7,R7,R3
003) 8 1 1 -1 --> ADDI R1,R1,-1
004) 44 7 6 2 --> SW R7,R2(R6)
005) 8 2 2 8 --> ADDI R2,R2,8
006) 5 1 0 -7 --> BNE R1,R0,-7

* TOTAL_INSTRUCTIONS=7

* 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 = 9 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, R4=0x4000, R5=0x5000, R6=0x6000 and the other registers contain zero.

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```
lab1:  LW  R3,R2(R4)
      LW  R7,R2(R5)
      MUL R7,R7,R3
      ADDI R1,R1,-1
      SW   R7,R2(R6)
      ADDI R2,R2,8
      BNE R1,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 1 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
      vi:  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 00000000 00004000 00005000 00006000 00000000 00000000

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

=====
PC  INSTRUCTION  F  D  P  I  X  W  C  Pi,Pj Pk Pl  IW#  OPCODE Pi  Pj  Pk I/P1  Cj  Ck  Cl  ROB# PC  Ri  oPi x s c  +-----+
000] LW   R3,R2(R4)  0                                P3,P2(P1)                                |LQ(0 )|
001] LW   R7,R2(R5)  0                                P5,P2(P4)                                |PC  OP Pi  EFAD Ci|
002] MUL  R7,R7,R3   0                                P6,P5,P3                                +-----+
003] ADDI R1,R1,-1   0                                P8,P7,-1                                +-----+
```

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  0  1  0  1  1  0  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

=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
      Pi:      8      2      3      1      4      -      6      -
      Qi:      1      0      1      0      0      0      1      0
      Vi:  00001000 00000000 00000000 00004000 00005000 00006000 00000000 00000000

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

=====
PC  INSTRUCTION  F  D  P  I  X  W  C  Pi,Pj Pk Pl  IW#  OPCODE Pi  Pj  Pk I/P1  Cj  Ck  Cl  ROB# PC  Ri  oPi x s c  +-----+
000] LW   R3,R2(R4)  0  1                                P3,P2(P1)                                |LQ(0 )|
001] LW   R7,R2(R5)  0  1                                P5,P2(P4)                                |PC  OP Pi  EFAD Ci|
002] MUL  R7,R7,R3   0  1                                P6,P5,P3                                +-----+
003] ADDI R1,R1,-1   0  1                                P8,P7,-1                                +-----+
```

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```
004] SW   R7,R2(R6)    1
005] ADDI R2,R2,8      1
006] BNE  R1,R0,-7     1
```

----- Press ENTER to continue (PC=0,IC=7,CK=1,CTOT=2,IPC=3.50)...

```
=====
PHYSICAL REGS:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *
qi:  0  0  1  0  1  1  0  1  0  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 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:      8     10      3      1      4      9      6      -
          Qi:      1      1      1      0      0      0      1      0
          Vi:  00001000 00000000 00000000 00004000 00005000 00006000 00000000 00000000
=====
```

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

```
=====
PC  INSTRUCTION      F  D  P  I  X  W  C  Pi,Pj Pk P1  IW#  OPCD Pi  Pj  Pk I/P1  Cj  Ck  Cl  ROB# PC  Ri  oPi x s c  +-----+
000] LW   R3,R2(R4)    0  1  2          P3,P2(P1)  000)  LW  P3  P1  P2  -  2  2  -  000) 000 R3  -  0  0  0  |LQ(0 )|
001] LW   R7,R2(R5)    0  1  2          P5,P2(P4)  001)  LW  P5  P4  P2  -  2  2  -  001) 001 R7  -  0  0  0  |PC  OP Pi  EFAD Ci|
002] MUL  R7,R7,R3      0  1  2          P6,P5,P3  002)  MUL  P6  P5  P3  -  .  .  -  002) 002 R7  P5  0  0  0  +-----+
003] ADDI R1,R1,-1      0  1  2          P8,P7,-1  003) ADDI P8  P7  -  -1  2  -  -  003) 003 R1  P7  0  0  0
004] SW   R7,R2(R6)      1  2          ,P6(P2)<-P9
005] ADDI R2,R2,8        1  2          P10,P2,8
006] BNE  R1,R0,-7      1  2          ,P8,P0,-7
007] LW   R3,R2(R4)      2
008] LW   R7,R2(R5)      2
009] MUL  R7,R7,R3        2
010] ADDI R1,R1,-1      2
=====
```

----- Press ENTER to continue (PC=4,IC=11,CK=2,CTOT=3,IPC=3.67)...

```
=====
PHYSICAL REGS:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *
qi:  0  0  1  0  1  1  0  1  0  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
vi:  00 00 00 00 00 00 00 FF 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:     14     10     11      1      4      9     13      -
          Qi:      1      1      1      0      0      0      1      0
          Vi:  00001000 00000000 00000000 00004000 00005000 00006000 00000000 00000000
=====
```

```
=====
STAGES:          F  D  P  I  X  W  C  RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A  M  L  S  B  F  X
TOTAL SLOTS:      4  4 16  4  9  4  4  24          16          99          1  1  1  0  1  4  1
BUSY SLOTS:        3  4  5  1  1  0  0  14          5           7           0  0  0  0  0  0  0
STALLS:            0  0  0  2  0  0  0  0          0           0           0  0  1  0  0  0  0
=====
```

```
=====
PC  INSTRUCTION      F  D  P  I  X  W  C  Pi,Pj Pk P1  IW#  OPCD Pi  Pj  Pk I/P1  Cj  Ck  Cl  ROB# PC  Ri  oPi x s c  +-----+
000] LW   R3,R2(R4)    0  1  2  3          P3,P2(P1)  000>  LW  P3  P1  P2  -  2  2  -  000) 000 R3  -  0  0  0  |LQ(1 )|
001] LW   R7,R2(R5)    0  1  2          P5,P2(P4)  001)  LW  P5  P4  P2  -  2  2  -  001) 001 R7  -  0  0  0  |PC  OP Pi  EFAD Ci|
002] MUL  R7,R7,R3      0  1  2          P6,P5,P3  002)  MUL  P6  P5  P3  -  .  .  -  002) 002 R7  P5  0  0  0  |000] LW P3 0000 .|
003] ADDI R1,R1,-1      0  1  2  3  3          P8,P7,-1  003> ADDI P8  P7  -  -1  2  -  -  003) 003 R1  P7  0  0  0  +-----+
004] SW   R7,R2(R6)      1  2  3          ,P6(P2)<-P9  000)  SW  -  P9  P2  P6  3  3  -  004) 004 -  -  1  0  0
005] ADDI R2,R2,8        1  2  3          P10,P2,8  003) ADDI P10 P2  -  8  3  -  -  005) 005 R2  P2  0  0  0  +-----+
006] BNE  R1,R0,-7      1  2  3          ,P8,P0,-7  004)  BNE -  P8  P0  -7  -  3  -  006) 006 -  -  0  0  0  |SQ(0 )|
007] LW   R3,R2(R4)      2  3          P11,P10(P1)
008] LW   R7,R2(R5)      2  3          P12,P10(P4)
009] MUL  R7,R7,R3        2  3          P13,P12,P11
010] ADDI R1,R1,-1      2  3          P14,P8,-1
011] SW   R7,R2(R6)      3
012] ADDI R2,R2,8        3
013] BNE  R1,R0,-7      3
=====
```

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

@003 stall due to no L-unit available

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

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

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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  0  1  0  1  1  0  0  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1
                vi:  00 00 00 00 00 00 00 FF 00 08 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:     14     15     11      1      4      9     13      -
           Qi:      1      1      1      0      0      0      1      0
           Vi:  00000FFF 00000000 00000000 00004000 00005000 00006000 00000000 00000000
=====
STAGES:          F  D  P  I  X  W  C RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A  M  L  S  B  F  X
TOTAL SLOTS:      4  4 16  4  9  4  4 24          16          99          1  1  1  0  1  4  1
BUSY SLOTS:       4  3  6  1  3  1  0 15          6          11          0  0  0  0  0  0  0
STALLS:          0  0  0  4  0  0  0  0          0          0          0  0  1  1  0  0  0
=====
PC  INSTRUCTION  F  D  P  I  X  W  C  Pi,Pj Pk P1  IW#  OPCODE Pi  Pj  Pk I/P1  Cj  Ck  Cl  ROB# PC  Ri  oPi x s c  +-----+
000] LW   R3,R2(R4)  0  1  2  3  4          P3,P2(P1)  ----  LW P3 P1 P2 -  2  2  -  000) 000 R3 -  0  0  0  |LQ(2 )|
001] LW   R7,R2(R5)  0  1  2  4          P5,P2(P4)  001>  LW P5 P4 P2 -  2  2  -  001) 001 R7 -  0  0  0  |PC  OP Pi  EFAD Ci|
002] MUL  R7,R7,R3   0  1  2          P6,P5,P3   002)  MUL P6 P5 P3 -  .  .  -  002) 002 R7 P5  0  0  0  |000] LW P3 4000 .|
003] ADDI R1,R1,-1   0  1  2  3  3  4  P8,P7,-1   ----  ADDI P8 P7 - -1  2  -  003) 003 R1 P7  0  0  1  |001] LW P5 0000 .|
004] SW   R7,R2(R6)  1  2  3          ,P6(P2)<-P9 000)  SW -  P9 P2 P6 3  3  -  004) 004 -  -  1  0  0  +-----+
005] ADDI R2,R2,8     1  2  3  4  4  P10,P2,8   003>  ADDI P10 P2 -  8  3  -  005) 005 R2 P2  0  0  0
006] BNE  R1,R0,-7   1  2  3  4  4  ,P8,P0,-7   004>  BNE -  P8 P0 -7  4  3  -  006) 006 -  -  0  0  0  +-----+
007] LW   R3,R2(R4)  2  3  4  P11,P10(P1)  001)  LW P11 P1 P10 -  4  .  -  007) 000 R3 P3  0  0  0  |SQ(0 )|
008] LW   R7,R2(R5)  2  3  4  P12,P10(P4)  003)  LW P12 P4 P10 -  4  .  -  008) 001 R7 P6  0  0  0  |PC  OP Pi  EFAD Cl|
009] MUL  R7,R7,R3   2  3  4  P13,P12,P11 004)  MUL P13 P12 P11 -  .  .  -  009) 002 R7 P12 0  0  0  +-----+
010] ADDI R1,R1,-1   2  3  4  P14,P8,-1   005)  ADDI P14 P8 - -1  4  -  010) 003 R1 P8  0  0  0
011] SW   R7,R2(R6)  3  4  ,P13(P10)<-P9
012] ADDI R2,R2,8     3  4  P15,P10,8
013] BNE  R1,R0,-7   3  4  ,P14,P0,-7
014] LW   R3,R2(R4)  4
015] LW   R7,R2(R5)  4
016] MUL  R7,R7,R3   4
017] ADDI R1,R1,-1   4
=====
Press ENTER to continue (PC=4,IC=18,CK=4,CTOT=5,IPC=3.60)...
@004 stall due to NO SLOTS when trying to move instnuction MUL/002 from stage P to stage I.
@004 stall due to no S-unit available
@004 stall due to NO SLOTS when trying to move instnuction SW/004 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  1  0  1  1  0  0  0  0  1  1  1  1  1  1  1  1  1  1  1  1  1
                vi:  00 00 00 00 00 00 00 FF 00 08 00 00 00 FE 00 00 00 00 00 00 00 00 00 00
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
           Pi:     19     15     16      1      4      9     18      -
           Qi:      1      1      1      0      0      0      1      0
           Vi:  00000FFF 00000008 00000000 00004000 00005000 00006000 00000000 00000000
=====
STAGES:          F  D  P  I  X  W  C RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A  M  L  S  B  F  X
TOTAL SLOTS:      4  4 16  4  9  4  4 24          16          99          1  1  1  0  1  4  1
BUSY SLOTS:       3  4  7  1  3  1  0 19          7          14          0  0  0  0  0  0  0
STALLS:          0  0  0  8  0  0  1  0          0          0          0  0  3  1  0  0  0
=====
PC  INSTRUCTION  F  D  P  I  X  W  C  Pi,Pj Pk P1  IW#  OPCODE Pi  Pj  Pk I/P1  Cj  Ck  Cl  ROB# PC  Ri  oPi x s c  +-----+
000] LW   R3,R2(R4)  0  1  2  3  4          P3,P2(P1)  ----  LW P3 P1 P2 -  2  2  -  000) 000 R3 -  0  0  0  |LQ(2 )|
001] LW   R7,R2(R5)  0  1  2  4  5          P5,P2(P4)  ----  LW P5 P4 P2 -  2  2  -  001) 001 R7 -  0  0  0  |PC  OP Pi  EFAD Ci|
002] MUL  R7,R7,R3   0  1  2          P6,P5,P3   002)  MUL P6 P5 P3 -  .  .  -  002) 002 R7 P5  0  0  0  |000] LW P3 4000 .|
003] ADDI R1,R1,-1   0  1  2  3  3  4  P8,P7,-1   ----  ADDI P8 P7 - -1  2  -  003) 003 R1 P7  0  0  1  |001] LW P5 5000 .|
004] SW   R7,R2(R6)  1  2  3  5          ,P6(P2)<-P9 000>  SW -  P9 P2 P6 3  3  -  004) 004 -  -  1  0  0  +-----+
005] ADDI R2,R2,8     1  2  3  4  4  5  P10,P2,8   ----  ADDI P10 P2 -  8  3  -  005) 005 R2 P2  0  0  1
006] BNE  R1,R0,-7   1  2  3  4  4  5  ,P8,P0,-7   ----  BNE -  P8 P0 -7  4  3  -  006) 006 -  -  0  0  1  +-----+
007] LW   R3,R2(R4)  2  3  4  P11,P10(P1)  001)  LW P11 P1 P10 -  4  5  -  007) 000 R3 P3  0  0  0  |SQ(1 )|
008] LW   R7,R2(R5)  2  3  4  P12,P10(P4)  003)  LW P12 P4 P10 -  4  5  -  008) 001 R7 P6  0  0  0  |PC  OP Pi  EFAD Cl|
009] MUL  R7,R7,R3   2  3  4  P13,P12,P11 004)  MUL P13 P12 P11 -  .  .  -  009) 002 R7 P12 0  0  0  |004] SW P6 0000 .|
010] ADDI R1,R1,-1   2  3  4  5  5  P14,P8,-1   005>  ADDI P14 P8 - -1  4  -  010) 003 R1 P8  0  0  0  +-----+
```

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```
011] SW   R7,R2(R6)      3  4  5      ,P13(P10)<-P9 000) SW   -   P9  P10 P13  5  5  -   011) 004 -   -   1  0  0
012] ADDI R2,R2,8        3  4  5      ,P15,P10,8  005) ADDI P15 P10 -   8  5  -   -   012) 005 R2 P10 0 0 0
013] BNE  R1,R0,-7       3  4  5      ,P14,P0,-7  006) BNE  -   P14 P0  -7  -   5  -   -   013) 006 -   -   0  0  0
014] LW   R3,R2(R4)      4  5          P16,P15(P1)
015] LW   R7,R2(R5)      4  5          P17,P15(P4)
016] MUL  R7,R7,R3       4  5          P18,P17,P16
017] ADDI R1,R1,-1       4  5          P19,P14,-1
018] SW   R7,R2(R6)      5
019] ADDI R2,R2,8        5
020] BNE  R1,R0,-7       5
```

----- Press ENTER to continue (PC=8,IC=21,CK=5,CTOT=6,IPC=3.50)...

```
@005 stall due to NO SLOTS when trying to move instnction ADDI/003 from stage W to stage C.
@005 stall due to NO SLOTS when trying to move instnction MUL/002 from stage P to stage I.
@005 stall due to no L-unit available
@005 stall due to NO SLOTS when trying to move instnction LW/007 from stage P to stage I.
@005 stall due to no L-unit available
@005 stall due to NO SLOTS when trying to move instnction LW/008 from stage P to stage I.
@005 stall due to NO SLOTS when trying to move instnction MUL/009 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  1  1  0  0  0  0  1  1  1  0  1  1  1  1  1  1  1  1  1
vi:  00 00 00 00 00 00 00 FF 00 08 00 00 00 FE 10 00 00 00 00 00 00 00 00 00
```

```
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
          Pi:     19     20     16      1      4      9     18      -
          Qi:      1      1      1      0      0      0      1      0
          Vi:  0000FFFE 00000008 00000000 00004000 00005000 00006000 00000000 00000000
```

```
=====
STAGES:          F  D  P  I  X  W  C  RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A  M  L  S  B  F  X
TOTAL SLOTS:     4  4 16  4  9  4  4 24          16          99          1  1  1  0  1  4  1
BUSY SLOTS:      0  3  8  1  3  1  0 20          8          18          0  0  0  0  0  0  0
STALLS:          0  0  0 12  0  0  2  0          0          0          0  0  4  2  0  0  0
```

```
=====
PC  INSTRUCTION      F  D  P  I  X  W  C  P1,Pj Pk P1  IW#  OPCD P1  Pj  Pk I/P1  Cj  Ck  Cl  ROB#  PC  R1  oPi x s c  +-----+
000] LW   R3,R2(R4)    0  1  2  3  4  6      P3,P2(P1)  ----  LW  P3  P1  P2  -   2  2  -   000) 000 R3 -   0  0  1  |LQ(2 )
001] LW   R7,R2(R5)    0  1  2  4  5          P5,P2(P4)  ----  LW  P5  P4  P2  -   2  2  -   001) 001 R7 -   0  0  0  |PC  OP Pi  EFAD Ci|
002] MUL  R7,R7,R3     0  1  2          P6,P5,P3  002) MUL  P6  P5  P3  -   .  6  -   002) 002 R7 P5  0  0  0  |---- LW P3 4000 6|
003] ADDI R1,R1,-1     0  1  2  3  3  4      P8,P7,-1  ----  ADDI P8  P7  -   -1  2  -   003) 003 R1 P7  0  0  1  |[001] LW P5 5000 .|
004] SW   R7,R2(R6)    1  2  3  5  6      ,P6(P2)<-P9  ----  SW   -   P9  P2  P6  3  3  -   004) 004 -   -   1  0  0  |[007] LW P11 0000 .|
005] ADDI R2,R2,8      1  2  3  4  4  5      P10,P2,8  ----  ADDI P10 P2  -   8  3  -   005) 005 R2 P2  0  0  1  +-----+
006] BNE  R1,R0,-7     1  2  3  4  4  5      ,P8,P0,-7  ----  BNE  -   P8  P0  -7  4  3  -   006) 006 -   -   0  0  1
007] LW   R3,R2(R4)    2  3  4  6          P11,P10(P1) 001>  LW  P11 P1  P10  -   4  5  -   007) 000 R3 P3  0  0  0  +-----+
008] LW   R7,R2(R5)    2  3  4          P12,P10(P1) 003)  LW  P12 P4  P10  -   4  5  -   008) 001 R7 P6  0  0  0  |SQ(1 )
009] MUL  R7,R7,R3     2  3  4          P13,P12,P11 004)  MUL  P13 P12 P11  -   .  .  -   009) 002 R7 P12 0  0  0  |PC  OP Pi  EFAD Cl|
010] ADDI R1,R1,-1     2  3  4  5  5  6      P14,P8,-1  ----  ADDI P14 P8  -   -1  4  -   010) 003 R1 P8  0  0  1  |[004] SW P6 6000 .|
011] SW   R7,R2(R6)    3  4  5          ,P13(P10)<-P9 000)  SW   -   P9  P10 P13  5  5  -   011) 004 -   -   1  0  0  +-----+
012] ADDI R2,R2,8      3  4  5  6  6          P15,P10,8  005>  ADDI P15 P10  -   8  5  -   012) 005 R2 P10 0  0  0
013] BNE  R1,R0,-7     3  4  5  6  6          ,P14,P0,-7  006>  BNE  -   P14 P0  -7  6  5  -   013) 006 -   -   0  0  0
014] LW   R3,R2(R4)    4  5  6          P16,P15(P1) 001)  LW  P16 P1  P15  -   6  .  -   014) 000 R3 P11 0  0  0
015] LW   R7,R2(R5)    4  5  6          P17,P15(P4) 005)  LW  P17 P4  P15  -   6  .  -   015) 001 R7 P13 0  0  0
016] MUL  R7,R7,R3     4  5  6          P18,P17,P16 006)  MUL  P18 P17 P16  -   .  .  -   016) 002 R7 P17 0  0  0
017] ADDI R1,R1,-1     4  5  6          P19,P14,-1 007)  ADDI P19 P14  -   -1  6  -   017) 003 R1 P14 0  0  0
018] SW   R7,R2(R6)    5  6          ,P18(P15)<-P9
019] ADDI R2,R2,8      5  6          P20,P15,8
020] BNE  R1,R0,-7     5  6          ,P19,P0,-7
```

----- Press ENTER to continue (PC=8,IC=21,CK=6,CTOT=7,IPC=3.00)...

```
@006 stall due to NO SLOTS when trying to move instnction BNE/006 from stage W to stage C.
@006 stall due to NO SLOTS when trying to move instnction MUL/002 from stage P to stage I.
@006 stall due to no L-unit available
@006 stall due to NO SLOTS when trying to move instnction LW/008 from stage P to stage I.
@006 stall due to NO SLOTS when trying to move instnction MUL/009 from stage P to stage I.
@006 stall due to no S-unit available
@006 stall due to NO SLOTS when trying to move instnction SW/011 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  0  0  0  0  0  1  0  0  0  0  1  1  1  0  0  1  1  1  1  1  1  1  1
vi:    00 00 00 00 00 00 00 00 FF 00 08 00 00 00 FE 10 00 00 00 FD 00 00 00 00 00

=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
          Pi:     19     20     16      1      4      9     18      -
          Qi:      1      1      1      0      0      0      1      0
          Vi:  00000FFE 00000010 00000000 00004000 00005000 00006000 00000000 00000000

=====
STAGES:          F  D  P  I  X  W  C RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A  M  L  S  B  F  X
TOTAL SLOTS:      4  4 16  4  9  4  4 24         16                      99                      1  1  1  0  1  4  1
BUSY SLOTS:       0  0  8  1  3  1  0 20         8                       20                      0  0  0  0  0  0  0
STALLS:          0  0  0 17  0  0  2  0         0                       0                      0  0  6  3  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   R3,R2(R4)  0  1  2  3  4  6  7 P3,P2(P1)  ----  LW  P3  P1  P2  -    2  2  -    ----  000 R3  -    0  0  1  |LQ(2 )|
001] LW   R7,R2(R5)  0  1  2  4  5  7  P5,P2(P4)  ----  LW  P5  P4  P2  -    2  2  -    001) 001 R7  -    0  0  1  |PC  OP Pi  EFAD Ci|
002] MUL  R7,R7,R3   0  1  2  7  7  P6,P5,P3   002>  MUL  P6  P5  P3  -    7  6  -    002) 002 R7  P5  0  0  0  |----  LW P3  4000 6|
003] ADDI R1,R1,-1   0  1  2  3  3  4  P8,P7,-1   ----  ADDI P8  P7  -    -1  2  -    003) 003 R1  P7  0  0  1  |----  LW P5  5000 7|
004] SW   R7,R2(R6)  1  2  3  5  6  P6(P2)<-P9  ----  SW   -   P9  P2  P6  3  3  -    004) 004 -    -    1  0  0  |007] LW P11 4008 .|
005] ADDI R2,R2,8    1  2  3  4  4  5  P10,P2,8   ----  ADDI P10 P2  -    8  3  -    005) 005 R2  P2  0  0  1  |008] LW P12 0000 .|
006] BNE  R1,R0,-7   1  2  3  4  4  5  P8,P0,-7   ----  BNE  -   P8  P0  -7  4  3  -    006) 006 -    -    0  0  1  +-----+
007] LW   R3,R2(R4)  2  3  4  6  7  P11,P10(P1)  ----  LW  P11 P1  P10  -    4  5  -    007) 000 R3  P3  0  0  0
008] LW   R7,R2(R5)  2  3  4  7  P12,P10(P4)  003>  LW  P12 P4  P10  -    4  5  -    008) 001 R7  P6  0  0  0  +-----+
009] MUL  R7,R7,R3   2  3  4  P13,P12,P11  004)  MUL  P13 P12 P11  -    .  .  -    009) 002 R7  P12 0  0  0  |SQ(1 )|
010] ADDI R1,R1,-1   2  3  4  5  5  6  P14,P8,-1   ----  ADDI P14 P8  -    -1  4  -    010) 003 R1  P8  0  0  1  |PC  OP Pi  EFAD Cl|
011] SW   R7,R2(R6)  3  4  5  P13(P10)<-P9  000)  SW   -   P9  P10 P13  5  5  -    011) 004 -    -    1  0  0  |004] SW P6  6000 .|
012] ADDI R2,R2,8    3  4  5  6  6  7  P15,P10,8   ----  ADDI P15 P10  -    8  5  -    012) 005 R2  P10 0  0  1  +-----+
013] BNE  R1,R0,-7   3  4  5  6  6  7  P14,P0,-7   ----  BNE  -   P14 P0  -7  6  5  -    013) 006 -    -    0  0  1
014] LW   R3,R2(R4)  4  5  6  P16,P15(P1)  001)  LW  P16 P1  P15  -    6  7  -    014) 000 R3  P11 0  0  0
015] LW   R7,R2(R5)  4  5  6  P17,P15(P4)  005)  LW  P17 P4  P15  -    6  7  -    015) 001 R7  P13 0  0  0
016] MUL  R7,R7,R3   4  5  6  P18,P17,P16  006)  MUL  P18 P17 P16  -    .  .  -    016) 002 R7  P17 0  0  0
017] ADDI R1,R1,-1   4  5  6  7  7  P19,P14,-1  007>  ADDI P19 P14  -    -1  6  -    017) 003 R1  P14 0  0  0
018] SW   R7,R2(R6)  5  6  7  P18(P15)<-P9  002)  SW   -   P9  P15 P18  7  7  -    018) 004 -    -    1  0  0
019] ADDI R2,R2,8    5  6  7  P20,P15,8   003)  ADDI P20 P15  -    8  7  -    019) 005 R2  P15 0  0  0
020] BNE  R1,R0,-7   5  6  7  P19,P0,-7   007)  BNE  -   P19 P0  -7  -    7  -    020) 006 -    -    0  0  0

----- Press ENTER to continue (PC=8,IC=21,CK=7,CTOT=8,IPC=2.62)...

@007 stall due to NO SLOTS when trying to move instnuction MUL/009 from stage P to stage I.
@007 stall due to no S-unit available
@007 stall due to NO SLOTS when trying to move instnuction SW/011 from stage P to stage I.
@007 stall due to no L-unit available
@007 stall due to NO SLOTS when trying to move instnuction LW/014 from stage P to stage I.
@007 stall due to no L-unit available
@007 stall due to NO SLOTS when trying to move instnuction LW/015 from stage P to stage I.
@007 stall due to NO SLOTS when trying to move instnuction MUL/016 from stage P to stage I.
```

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

=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
          Pi:     19     20     16      1      4      9     18      -
          Qi:      0      1      1      0      0      0      1      0
          Vi:  00000FFD 00000010 00000000 00004000 00005000 00006000 00000000 00000000

=====
STAGES:          F  D  P  I  X  W  C RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A  M  L  S  B  F  X
TOTAL SLOTS:      4  4 16  4  9  4  4 24         16                      99                      1  1  1  0  1  4  1
BUSY SLOTS:       0  0  5  1  5  1  0 20         5                       19                      0  0  0  0  0  0  0
STALLS:          0  0  0 22  0  0  2  0         0                       0                      0  0  8  4  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   R3,R2(R4)  0  1  2  3  4  6  7 P3,P2(P1)  ----  LW  P3  P1  P2  -    2  2  -    ----  000 R3  -    0  0  1  |LQ(2 )|
001] LW   R7,R2(R5)  0  1  2  4  5  7  P5,P2(P4)  ----  LW  P5  P4  P2  -    2  2  -    ----  001 R7  -    0  0  1  |PC  OP Pi  EFAD Ci|
002] MUL  R7,R7,R3   0  1  2  7  7  P6,P5,P3   ----  MUL  P6  P5  P3  -    7  6  -    002) 002 R7  P5  0  0  0  |----  LW P3  4000 6|
003] ADDI R1,R1,-1   0  1  2  3  3  4  P8,P7,-1   ----  ADDI P8  P7  -    -1  2  -    003) 003 R1  P7  0  0  1  |----  LW P5  5000 7|
004] SW   R7,R2(R6)  1  2  3  5  6  P6(P2)<-P9  ----  SW   -   P9  P2  P6  3  3  -    004) 004 -    -    1  0  0  |007] LW P11 4008 .|
005] ADDI R2,R2,8    1  2  3  4  4  5  P10,P2,8   ----  ADDI P10 P2  -    8  3  -    005) 005 R2  P2  0  0  1  |008] LW P12 5008 .|
```

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```
006] BNE R1,R0,-7      1 2 3 4 4 5      ,P8,P0,-7      ---- BNE - P8 P0 -7 4 3 - 006) 006 - - 0 0 1 +-----+
007] LW R3,R2(R4)      2 3 4 6 7      P11,P10(P1) ---- LW P11 P1 P10 - 4 5 - 007) 000 R3 P3 0 0 0 |
008] LW R7,R2(R5)      2 3 4 7 8      P12,P10(P4) ---- LW P12 P4 P10 - 4 5 - 008) 001 R7 P6 0 0 0 +-----+
009] MUL R7,R7,R3      2 3 4      P13,P12,P11 004) MUL P13 P12 P11 - . . - 009) 002 R7 P12 0 0 0 |SQ(2 )|
010] ADDI R1,R1,-1      2 3 4 5 5 6      P14,P8,-1 ---- ADDI P14 P8 - -1 4 - 010) 003 R1 P8 0 0 1 |PC OP Pi EFAD C1|
011] SW R7,R2(R6)      3 4 5 8      ,P13(P10)<-P9 000> SW - P9 P10 P13 5 5 - 011) 004 - - 1 0 0 |004] SW P6 6000 .|
012] ADDI R2,R2,8      3 4 5 6 6 7      P15,P10,8 ---- ADDI P15 P10 - 8 5 - 012) 005 R2 P10 0 0 1 |011] SW P13 0000 .|
013] BNE R1,R0,-7      3 4 5 6 6 7      ,P14,P0,-7 ---- BNE - P14 P0 -7 6 5 - 013) 006 - - 0 0 1 +-----+
014] LW R3,R2(R4)      4 5 6      P16,P15(P1) 001) LW P16 P1 P15 - 6 7 - 014) 000 R3 P11 0 0 0
015] LW R7,R2(R5)      4 5 6      P17,P15(P4) 005) LW P17 P4 P15 - 6 7 - 015) 001 R7 P13 0 0 0
016] MUL R7,R7,R3      4 5 6      P18,P17,P16 006) MUL P18 P17 P16 - . . - 016) 002 R7 P17 0 0 0
017] ADDI R1,R1,-1      4 5 6 7 7 8      P19,P14,-1 ---- ADDI P19 P14 - -1 6 - 017) 003 R1 P14 0 0 1
018] SW R7,R2(R6)      5 6 7      ,P18(P15)<-P9 002) SW - P9 P15 P18 7 7 - 018) 004 - - 1 0 0
019] ADDI R2,R2,8      5 6 7 8 8      P20,P15,8 003> ADDI P20 P15 - 8 7 - 019) 005 R2 P15 0 0 0
020] BNE R1,R0,-7      5 6 7 8 8      ,P19,P0,-7 007> BNE - P19 P0 -7 8 7 - 020) 006 - - 0 0 0
```

Press ENTER to continue (PC=8,IC=21,CK=8,CTOT=9,IPC=2.33)...

```
@008 stall due to NO SLOTS when trying to move instnction MUL/009 from stage P to stage I.
@008 stall due to no L-unit available
@008 stall due to NO SLOTS when trying to move instnction LW/014 from stage P to stage I.
@008 stall due to no L-unit available
@008 stall due to NO SLOTS when trying to move instnction LW/015 from stage P to stage I.
@008 stall due to NO SLOTS when trying to move instnction MUL/016 from stage P to stage I.
@008 stall due to no S-unit available
@008 stall due to NO SLOTS when trying to move instnction SW/018 from stage P to stage I.
```

```
=====
PHYSICAL REGS:  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                * * * * * * * * * * * * * * * * * * * *
qi:  0 0 0 0 0 0 1 0 0 0 0 0 1 1 0 0 1 1 1 0 0 1 1 1
vi:  00 00 00 00 00 00 00 FF 00 08 00 00 00 FE 10 00 00 00 FD 18 00 00 00 00
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
Pi:      19     20     16      1      4      9     18      -
Qi:      0      0      1      0      0      0      1      0
Vi:  00000FFD 00000018 00000000 00004000 00005000 00006000 00000000 00000000
=====
```

```
=====
STAGES:          F D P I X W C RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER          A M L S B F X
TOTAL SLOTS:      4 4 16 4 9 4 4 24      16      99          1 1 1 0 1 4 1
BUSY SLOTS:       0 0 4 1 2 1 0 20      4      19          0 0 0 0 0 0 0
STALLS:          0 0 0 26 0 0 3 0      0      0          0 0 9 5 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 R3,R2(R4)    0 1 2 3 4 6 7 P3,P2(P1) ---- LW P3 P1 P2 - 2 2 - ---- 000 R3 - 0 0 1 |LQ(2 )|
001] LW R7,R2(R5)    0 1 2 4 5 7 8 P5,P2(P4) ---- LW P5 P4 P2 - 2 2 - ---- 001 R7 - 0 0 1 |PC OP Pi EFAD Ci|
002] MUL R7,R7,R3    0 1 2 7 7      P6,P5,P3 ---- MUL P6 P5 P3 - 7 6 - 002) 002 R7 P5 0 0 0 |---- LW P3 4000 6|
003] ADDI R1,R1,-1    0 1 2 3 3 4      P8,P7,-1 ---- ADDI P8 P7 - -1 2 - 003) 003 R1 P7 0 0 1 |---- LW P5 5000 7|
004] SW R7,R2(R6)    1 2 3 5 6      ,P6(P2)<-P9 ---- SW - P9 P2 P6 3 3 - 004) 004 - - 1 0 0 |---- LW P11 4008 9|
005] ADDI R2,R2,8    1 2 3 4 4 5      P10,P2,8 ---- ADDI P10 P2 - 8 3 - 005) 005 R2 P2 0 0 1 |008] LW P12 5008 .|
006] BNE R1,R0,-7    1 2 3 4 4 5      ,P8,P0,-7 ---- BNE - P8 P0 -7 4 3 - 006) 006 - - 0 0 1 |014] LW P16 0000 .|
007] LW R3,R2(R4)    2 3 4 6 7 9      P11,P10(P1) ---- LW P11 P1 P10 - 4 5 - 007) 000 R3 P3 0 0 1 +-----+
008] LW R7,R2(R5)    2 3 4 7 8      P12,P10(P4) ---- LW P12 P4 P10 - 4 5 - 008) 001 R7 P6 0 0 0
009] MUL R7,R7,R3    2 3 4      P13,P12,P11 004) MUL P13 P12 P11 - . 9 - 009) 002 R7 P12 0 0 0 +-----+
010] ADDI R1,R1,-1    2 3 4 5 5 6      P14,P8,-1 ---- ADDI P14 P8 - -1 4 - 010) 003 R1 P8 0 0 1 |SQ(2 )|
011] SW R7,R2(R6)    3 4 5 8 9      ,P13(P10)<-P9 ---- SW - P9 P10 P13 5 5 - 011) 004 - - 1 0 0 |PC OP Pi EFAD C1|
012] ADDI R2,R2,8    3 4 5 6 6 7      P15,P10,8 ---- ADDI P15 P10 - 8 5 - 012) 005 R2 P10 0 0 1 |004] SW P6 6000 .|
013] BNE R1,R0,-7    3 4 5 6 6 7      ,P14,P0,-7 ---- BNE - P14 P0 -7 6 5 - 013) 006 - - 0 0 1 |011] SW P13 6008 .|
014] LW R3,R2(R4)    4 5 6 9      P16,P15(P1) 001> LW P16 P1 P15 - 6 7 - 014) 000 R3 P11 0 0 0 +-----+
015] LW R7,R2(R5)    4 5 6      P17,P15(P4) 005) LW P17 P4 P15 - 6 7 - 015) 001 R7 P13 0 0 0
016] MUL R7,R7,R3    4 5 6      P18,P17,P16 006) MUL P18 P17 P16 - . . - 016) 002 R7 P17 0 0 0
017] ADDI R1,R1,-1    4 5 6 7 7 8      P19,P14,-1 ---- ADDI P19 P14 - -1 6 - 017) 003 R1 P14 0 0 1
018] SW R7,R2(R6)    5 6 7      ,P18(P15)<-P9 002) SW - P9 P15 P18 7 7 - 018) 004 - - 1 0 0
019] ADDI R2,R2,8    5 6 7 8 8 9      P20,P15,8 ---- ADDI P20 P15 - 8 7 - 019) 005 R2 P15 0 0 1
020] BNE R1,R0,-7    5 6 7 8 8 9      ,P19,P0,-7 ---- BNE - P19 P0 -7 8 7 - 020) 006 - - 0 0 1
```

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

```
@009 stall due to NO SLOTS when trying to move instnction ADDI/017 from stage W to stage C.
@009 stall due to NO SLOTS when trying to move instnction MUL/009 from stage P to stage I.
@009 stall due to no L-unit available
@009 stall due to NO SLOTS when trying to move instnction LW/015 from stage P to stage I.
@009 stall due to NO SLOTS when trying to move instnction MUL/016 from stage P to stage I.
```

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@009 stall due to no S-unit available

@009 stall due to NO SLOTS when trying to move instnuction SW/018 from stage P to stage I.

```
=====
PHYSICAL REGS:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *
qi:  0  0  0  0  0  0  1  0  0  0  0  0  1  0  0  1  1  1  0  0  1  1  1  1
vi:  00 00 00 00 00 00 00 00 FF 00 08 00 00 00 00 FE 10 00 00 00 FD 18 00 00 00 00
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
         Pi:     19     20     16      1      4      9     18      -
         Qi:      0      0      1      0      0      0      1      0
         Vi:  00000FFD 00000018 00000000 00004000 00005000 00006000 00000000 00000000
=====
STAGES:          F  D  P  I  X  W  C RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A  M  L  S  B  F  X
TOTAL SLOTS:     4  4 16  4  9  4  4 24          16          99          1  1  1  0  1  4  1
BUSY SLOTS:      0  0  2  1  3  1  0 20          2          19          0  0  0  0  0  0  0
STALLS:          0  0  0 28  0  0  4  0          0          0          0  0  9  6  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  R3,R2(R4) 0  1  2  3  4  6  7 P3,P2(P1)  ----  LW  P3  P1  P2  -  2  2  -  ---- 000 R3  -  0  0  1  |LQ(2 )|
001] LW  R7,R2(R5) 0  1  2  4  5  7  8 P5,P2(P4)  ----  LW  P5  P4  P2  -  2  2  -  ---- 001 R7  -  0  0  1  |PC  OP Pi  EFAD Ci|
002] MUL R7,R7,R3  0  1  2  7  7      P6,P5,P3  ----  MUL  P6  P5  P3  -  7  6  -  002] 002 R7  P5  0  0  0  |---- LW P3 4000 6|
003] ADDI R1,R1,-1 0  1  2  3  3  4      P8,P7,-1  ----  ADDI  P8  P7  -  -1  2  -  -  003] 003 R1  P7  0  0  1  |---- LW P5 5000 7|
004] SW  R7,R2(R6)  1  2  3  5  6      ,P6(P2)<-P9  ----  SW  -  P9  P2  P6  3  3  -  004] 004 -  -  1  0  0  |---- LW P11 4008 9|
005] ADDI R2,R2,8   1  2  3  4  4  5      P10,P2,8  ----  ADDI  P10 P2  -  8  3  -  005] 005 R2  P2  0  0  1  |---- LW P12 5008 10|
006] BNE R1,R0,-7  1  2  3  4  4  5      ,P8,P0,-7  ----  BNE  -  P8  P0  -7  4  3  -  006] 006 -  -  0  0  1  |014] LW P16 4010 .|
007] LW  R3,R2(R4) 2  3  4  6  7  9      P11,P10(P1) ----  LW  P11 P1  P10 -  4  5  -  007] 000 R3  P3  0  0  1  |015] LW P17 0000 .|
008] LW  R7,R2(R5) 2  3  4  7  8 10      P12,P10(P4) ----  LW  P12 P4  P10 -  4  5  -  008] 001 R7  P6  0  0  1  +-----+
009] MUL R7,R7,R3  2  3  4 10 10      P13,P12,P11 004> MUL  P13 P12 P11 - 10 9  -  009] 002 R7  P12 0  0  0
010] ADDI R1,R1,-1 2  3  4  5  5  6      P14,P8,-1  ----  ADDI  P14 P8  -  -1  4  -  010] 003 R1  P8  0  0  1  +-----+
011] SW  R7,R2(R6) 3  4  5  8  9      ,P13(P10)<-P9  ----  SW  -  P9  P10 P13 5  5  -  011] 004 -  -  1  0  0  |SQ(2 )|
012] ADDI R2,R2,8   3  4  5  6  6  7      P15,P10,8  ----  ADDI  P15 P10 -  8  5  -  012] 005 R2  P10 0  0  1  |PC  OP Pi  EFAD Cl|
013] BNE R1,R0,-7  3  4  5  6  6  7      ,P14,P0,-7  ----  BNE  -  P14 P0  -7  6  5  -  013] 006 -  -  0  0  1  |004] SW P6 6000 .|
014] LW  R3,R2(R4) 4  5  6  9 10      P16,P15(P1) ----  LW  P16 P1  P15 -  6  7  -  014] 000 R3  P11 0  0  0  |011] SW P13 6008 .|
015] LW  R7,R2(R5) 4  5  6 10      P17,P15(P4) 005> LW  P17 P4  P15 -  6  7  -  015] 001 R7  P13 0  0  0  +-----+
016] MUL R7,R7,R3  4  5  6      P18,P17,P16 006] MUL  P18 P17 P16 -  .  .  -  016] 002 R7  P17 0  0  0
017] ADDI R1,R1,-1 4  5  6  7  7  8      P19,P14,-1  ----  ADDI  P19 P14 -  -1  6  -  017] 003 R1  P14 0  0  1
018] SW  R7,R2(R6) 4  5  6  7      ,P18(P15)<-P9 002] SW  -  P9  P15 P18 7  7  -  018] 004 -  -  1  0  0
019] ADDI R2,R2,8   5  6  7  8  8  9      P20,P15,8  ----  ADDI  P20 P15 -  8  7  -  019] 005 R2  P15 0  0  1
020] BNE R1,R0,-7  5  6  7  8  8  9      ,P19,P0,-7  ----  BNE  -  P19 P0  -7  8  7  -  020] 006 -  -  0  0  1
=====
                                Press ENTER to continue (PC=8,IC=21,CK=10,CTOT=11,IPC=1.91)...
@010 stall due to NO SLOTS when trying to move instnuction BNE/020 from stage W to stage C.
@010 stall due to NO SLOTS when trying to move instnuction MUL/016 from stage P to stage I.
@010 stall due to no S-unit available
@010 stall due to NO SLOTS when trying to move instnuction SW/018 from stage P to stage I.
```

```
=====
PHYSICAL REGS:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *  *
qi:  0  0  0  0  0  0  1  0  0  0  0  0  0  1  0  0  1  1  1  0  0  1  1  1  1
vi:  00 00 00 00 00 00 00 00 FF 00 08 00 00 00 00 FE 10 00 00 00 FD 18 00 00 00 00
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
         Pi:     19     20     16      1      4      9     18      -
         Qi:      0      0      1      0      0      0      1      0
         Vi:  00000FFD 00000018 00000000 00004000 00005000 00006000 00000000 00000000
=====
STAGES:          F  D  P  I  X  W  C RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A  M  L  S  B  F  X
TOTAL SLOTS:     4  4 16  4  9  4  4 24          16          99          1  1  1  0  1  4  1
BUSY SLOTS:      0  0  1  1  4  1  0 20          1          19          0  0  0  0  0  0  0
STALLS:          0  0  0 29  0  0  5  0          0          0          0  0  9  6  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  R3,R2(R4) 0  1  2  3  4  6  7 P3,P2(P1)  ----  LW  P3  P1  P2  -  2  2  -  ---- 000 R3  -  0  0  1  |LQ(2 )|
001] LW  R7,R2(R5) 0  1  2  4  5  7  8 P5,P2(P4)  ----  LW  P5  P4  P2  -  2  2  -  ---- 001 R7  -  0  0  1  |PC  OP Pi  EFAD Ci|
002] MUL R7,R7,R3  0  1  2  7  7      P6,P5,P3  ----  MUL  P6  P5  P3  -  7  6  -  002] 002 R7  P5  0  0  0  |---- LW P3 4000 6|
003] ADDI R1,R1,-1 0  1  2  3  3  4      P8,P7,-1  ----  ADDI  P8  P7  -  -1  2  -  -  003] 003 R1  P7  0  0  1  |---- LW P5 5000 7|
```


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```
004] SW   R7,R2(R6)      1 2 3 5 6      ,P6(P2)<--P9      ---- SW   -   P9  P2  P6  3 3 -   004) 004 -   -   1 0 0 |---- LW P11 4008 9|
005] ADDI R2,R2,8        1 2 3 4 4 5      P10,P2,8        ---- ADDI P10 P2 -   8 3 -   005) 005 R2 P2 0 0 1 |---- LW P12 5008 10|
006] BNE  R1,R0,-7       1 2 3 4 4 5      ,P8,P0,-7       ---- BNE  -   P8  P0 -7  4 3 -   006) 006 -   -   0 0 1 |014] LW P16 4010 .|
007] LW   R3,R2(R4)      2 3 4 6 7 9      P11,P10(P1)     ---- LW   P11 P1 P10 -  4 5 -   007) 000 R3 P3 0 0 1 |015] LW P17 5010 .|
008] LW   R7,R2(R5)      2 3 4 7 8 10     P12,P10(P4)     ---- LW   P12 P4 P10 -  4 5 -   008) 001 R7 P6 0 0 1 +-----+
009] MUL  R7,R7,R3       2 3 4 10 10     P13,P12,P11     ---- MUL  P13 P12 P11 - 10 9 -   009) 002 R7 P12 0 0 0
010] ADDI R1,R1,-1       2 3 4 5 5 6      P14,P8,-1       ---- ADDI P14 P8 -   -1 4 -   010) 003 R1 P8 0 0 1 +-----+
011] SW   R7,R2(R6)      3 4 5 8 9        ,P13(P10)<--P9   ---- SW   -   P9  P10 P13 5 5 -   011) 004 -   -   1 0 0 |SQ(3 )|
012] ADDI R2,R2,8        3 4 5 6 6 7      P15,P10,8       ---- ADDI P15 P10 -   8 5 -   012) 005 R2 P10 0 0 1 |PC  OP Pi EFAD C1|
013] BNE  R1,R0,-7       3 4 5 6 6 7      ,P14,P0,-7       ---- BNE  -   P14 P0 -7  6 5 -   013) 006 -   -   0 0 1 |004] SW P6 6000 .|
014] LW   R3,R2(R4)      4 5 6 9 10     P16,P15(P1)     ---- LW   P16 P1 P15 -  6 7 -   014) 000 R3 P11 0 0 0 |011] SW P13 6008 .|
015] LW   R7,R2(R5)      4 5 6 10 11     P17,P15(P4)     ---- LW   P17 P4 P15 -  6 7 -   015) 001 R7 P13 0 0 0 |018] SW P18 0000 .|
016] MUL  R7,R7,R3       4 5 6          P18,P17,P16    006) MUL  P18 P17 P16 -   . -   016) 002 R7 P17 0 0 0 +-----+
017] ADDI R1,R1,-1       4 5 6 7 7 8      P19,P14,-1      ---- ADDI P19 P14 -   -1 6 -   017) 003 R1 P14 0 0 1
018] SW   R7,R2(R6)      5 6 7 11       ,P18(P15)<--P9   002> SW   -   P9  P15 P18 7 7 -   018) 004 -   -   1 0 0
019] ADDI R2,R2,8        5 6 7 8 8 9      P20,P15,8       ---- ADDI P20 P15 -   8 7 -   019) 005 R2 P15 0 0 1
020] BNE  R1,R0,-7       5 6 7 8 8 9      ,P19,P0,-7      ---- BNE  -   P19 P0 -7  8 7 -   020) 006 -   -   0 0 1
```

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

@011 stall due to NO SLOTS when trying to move instnction LW/008 from stage W to stage C.

@011 stall due to NO SLOTS when trying to move instnction MUL/016 from stage P to stage I.

```
=====
PHYSICAL REGS:  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                * * * * *
qi:  0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 1 1 0 0 1 1 1 1
vi:  00 00 00 00 00 00 00 FF 00 08 00 00 00 FE 10 00 00 00 FD 18 00 00 00 00 00
=====
REG.FILE:  Ri:      1      2      3      4      5      6      7      8
          Pi:     19     20     16      1      4      9     18      -
          Qi:      0      0      0      0      0      0      1      0
          Vi:  00000FFD 00000018 00000000 00004000 00005000 00006000 00000000 00000000
=====
```

```
=====
STAGES:          F D P I X W C RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A M L S B F X
TOTAL SLOTS:     4 4 16 4 9 4 4 24         16                    99                    1 1 1 0 1 4 1
BUSY SLOTS:      0 0 1 0 2 1 0 20          1                      19                    0 0 0 0 0 0 0
STALLS:          0 0 0 30 0 0 6 0           0                      0                    0 0 9 6 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   R3,R2(R4)    0 1 2 3 4 6 7 P3,P2(P1)  ---- LW P3 P1 P2 -   2 2 -   ---- 000 R3 -   0 0 1 |LQ(1 )|
001] LW   R7,R2(R5)    0 1 2 4 5 7 8 P5,P2(P4)  ---- LW P5 P4 P2 -   2 2 -   ---- 001 R7 -   0 0 1 |PC  OP Pi EFAD Ci|
002] MUL  R7,R7,R3     0 1 2 7 7 12   P6,P5,P3  ---- MUL P6 P5 P3 -   7 6 -   002) 002 R7 P5 0 0 1 |---- LW P3 4000 6|
003] ADDI R1,R1,-1     0 1 2 3 3 4      P8,P7,-1     ---- ADDI P8 P7 -   -1 2 -   003) 003 R1 P7 0 0 1 |---- LW P5 5000 7|
004] SW   R7,R2(R6)    1 2 3 5 6 12   ,P6(P2)<--P9  ---- SW   -   P9  P2  P6  3 3 -   004) 004 -   -   1 0 1 |---- LW P11 4008 9|
005] ADDI R2,R2,8      1 2 3 4 4 5      P10,P2,8     ---- ADDI P10 P2 -   8 3 -   005) 005 R2 P2 0 0 1 |---- LW P12 5008 10|
006] BNE  R1,R0,-7     1 2 3 4 4 5      ,P8,P0,-7     ---- BNE  -   P8  P0 -7  4 3 -   006) 006 -   -   0 0 1 |---- LW P16 4010 12|
007] LW   R3,R2(R4)    2 3 4 6 7 9      P11,P10(P1)   ---- LW P11 P1 P10 -  4 5 -   007) 000 R3 P3 0 0 1 |015] LW P17 5010 .|
008] LW   R7,R2(R5)    2 3 4 7 8 10     P12,P10(P4)   ---- LW P12 P4 P10 -  4 5 -   008) 001 R7 P6 0 0 1 +-----+
009] MUL  R7,R7,R3     2 3 4 10 10     P13,P12,P11   ---- MUL  P13 P12 P11 - 10 9 -   009) 002 R7 P12 0 0 0
010] ADDI R1,R1,-1     2 3 4 5 5 6      P14,P8,-1     ---- ADDI P14 P8 -   -1 4 -   010) 003 R1 P8 0 0 1 +-----+
011] SW   R7,R2(R6)    3 4 5 8 9        ,P13(P10)<--P9  ---- SW   -   P9  P10 P13 5 5 -   011) 004 -   -   1 0 0 |SQ(2 )|
012] ADDI R2,R2,8      3 4 5 6 6 7      P15,P10,8     ---- ADDI P15 P10 -   8 5 -   012) 005 R2 P10 0 0 1 |PC  OP Pi EFAD C1|
013] BNE  R1,R0,-7     3 4 5 6 6 7      ,P14,P0,-7     ---- BNE  -   P14 P0 -7  6 5 -   013) 006 -   -   0 0 1 |---- SW P6 6000 12|
014] LW   R3,R2(R4)    4 5 6 9 10 12   P16,P15(P1)   ---- LW   P16 P1 P15 -  6 7 -   014) 000 R3 P11 0 0 1 |011] SW P13 6008 .|
015] LW   R7,R2(R5)    4 5 6 10 11     P17,P15(P4)   ---- LW   P17 P4 P15 -  6 7 -   015) 001 R7 P13 0 0 0 |018] SW P18 6010 .|
016] MUL  R7,R7,R3     4 5 6          P18,P17,P16    006) MUL  P18 P17 P16 -   . 12 -   016) 002 R7 P17 0 0 0 +-----+
017] ADDI R1,R1,-1     4 5 6 7 7 8      P19,P14,-1    ---- ADDI P19 P14 -   -1 6 -   017) 003 R1 P14 0 0 1
018] SW   R7,R2(R6)    5 6 7 11 12     ,P18(P15)<--P9  ---- SW   -   P9  P15 P18 7 7 -   018) 004 -   -   1 0 0
019] ADDI R2,R2,8      5 6 7 8 8 9      P20,P15,8     ---- ADDI P20 P15 -   8 7 -   019) 005 R2 P15 0 0 1
020] BNE  R1,R0,-7     5 6 7 8 8 9      ,P19,P0,-7     ---- BNE  -   P19 P0 -7  8 7 -   020) 006 -   -   0 0 1
```

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

@012 stall due to NO SLOTS when trying to move instnction LW/008 from stage W to stage C.

@012 stall due to NO SLOTS when trying to move instnction MUL/016 from stage P to stage I.

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

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```
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
           Pi:     19     20     16      1      4      9     18      -
           Qi:      0      0      0      0      0      0      1      0
           Vi: 00001000 00000000 00000000 00004000 00005000 00006000 00000000 00000000
=====
STAGES:      F D P I X W C RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A M L S B F X
TOTAL SLOTS: 4 4 16 4 9 4 4 24          16                    99          1 1 1 0 1 4 1
BUSY SLOTS:  0 0 0 0 2 1 0 17          0                    15          0 0 0 0 0 0 0
STALLS:      0 0 0 30 0 0 6 0          0                    0          0 0 9 6 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  R3,R2(R4) 0 1 2 3 4 6 7 P3,P2(P1)  ----  LW P3 P1 P2 -  2 2 -  ---- 000 R3 -  0 0 1  |LQ(0 )|
001] LW  R7,R2(R5) 0 1 2 4 5 7 8 P5,P2(P4)  ----  LW P5 P4 P2 -  2 2 -  ---- 001 R7 -  0 0 1  |PC  OP Pi EFAD Ci|
002] MUL R7,R7,R3  0 1 2 7 7 12 13 P6,P5,P3  ----  MUL P6 P5 P3 -  7 6 -  ---- 002 R7 P5 0 0 1  |---- LW P3 4000 6|
003] ADDI R1,R1,-1  0 1 2 3 3 4 13 P8,P7,-1  ----  ADDI P8 P7 -  -1 2 -  ---- 003 R1 P7 0 0 1  |---- LW P5 5000 7|
004] SW  R7,R2(R6)  1 2 3 5 6 12 13 ,P6(P2)<-P9  ----  SW - P9 P2 P6 3 3 -  ---- 004 - - 1 0 1  |---- LW P11 4008 9|
005] ADDI R2,R2,8   1 2 3 4 4 5 13 P10,P2,8  ----  ADDI P10 P2 -  8 3 -  ---- 005 R2 P2 0 0 1  |---- LW P12 5008 10|
006] BNE R1,R0,-7  1 2 3 4 4 5 ,P8,P0,-7  ----  BNE - P8 P0 -7 4 3 -  ---- 006 006 - - 0 0 1  |---- LW P16 4010 12|
007] LW  R3,R2(R4)  2 3 4 6 7 9 P11,P10(P1)  ----  LW P11 P1 P10 - 4 5 - 007) 000 R3 P3 0 0 1  |---- LW P17 5010 13|
008] LW  R7,R2(R5)  2 3 4 7 8 10 P12,P10(P4)  ----  LW P12 P4 P10 - 4 5 - 008) 001 R7 P6 0 0 1  +-----+
009] MUL R7,R7,R3  2 3 4 10 10 P13,P12,P11  ----  MUL P13 P12 P11 - 10 9 - 009) 002 R7 P12 0 0 0
010] ADDI R1,R1,-1  2 3 4 5 5 6 P14,P8,-1  ----  ADDI P14 P8 -  -1 4 - 010) 003 R1 P8 0 0 1  +-----+
011] SW  R7,R2(R6)  3 4 5 8 9 ,P13(P10)<-P9  ----  SW - P9 P10 P13 5 5 - 011) 004 - - 1 0 0  |SQ(2 )|
012] ADDI R2,R2,8   3 4 5 6 6 7 P15,P10,8  ----  ADDI P15 P10 - 8 5 - 012) 005 R2 P10 0 0 1  |PC  OP Pi EFAD C1|
013] BNE R1,R0,-7  3 4 5 6 6 7 ,P14,P0,-7  ----  BNE - P14 P0 -7 6 5 - 013) 006 - - 0 0 1  |---- SW P6 6000 12|
014] LW  R3,R2(R4)  4 5 6 9 10 12 P16,P15(P1)  ----  LW P16 P1 P15 - 6 7 - 014) 000 R3 P11 0 0 1  |011] SW P13 6008 .|
015] LW  R7,R2(R5)  4 5 6 10 11 13 P17,P15(P4)  ----  LW P17 P4 P15 - 6 7 - 015) 001 R7 P13 0 0 1  |018] SW P18 6010 .|
016] MUL R7,R7,R3  4 5 6 13 13 P18,P17,P16 006> MUL P18 P17 P16 - 13 12 - 016) 002 R7 P17 0 0 0  +-----+
017] ADDI R1,R1,-1  4 5 6 7 7 8 P19,P14,-1  ----  ADDI P19 P14 -  -1 6 - 017) 003 R1 P14 0 0 1
018] SW  R7,R2(R6)  5 6 7 11 12 ,P18(P15)<-P9  ----  SW - P9 P15 P18 7 7 - 018) 004 - - 1 0 0
019] ADDI R2,R2,8   5 6 7 8 8 9 P20,P15,8  ----  ADDI P20 P15 - 8 7 - 019) 005 R2 P15 0 0 1
020] BNE R1,R0,-7  5 6 7 8 8 9 ,P19,P0,-7  ----  BNE - P19 P0 -7 8 7 - 020) 006 - - 0 0 1
=====
Press ENTER to continue (PC=8,IC=21,CK=13,CTOT=14,IPC=1.50)...
```

```
=====
PHYSICAL REGS: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                * * * * *
qi:  0 1 1 0 1 1 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1 1 1 1
vi:  00 00 00 00 00 00 00 FF 00 08 00 00 00 FE 10 00 00 00 FD 18 00 00 00 00
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
           Pi:     19     20     16      1      4      9     18      -
           Qi:      0      0      0      0      0      0      1      0
           Vi: 00001000 00000000 00000000 00004000 00005000 00006000 00000000 00000000
=====
STAGES:      F D P I X W C RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A M L S B F X
TOTAL SLOTS: 4 4 16 4 9 4 4 24          16                    99          1 1 1 0 1 4 1
BUSY SLOTS:  0 0 0 0 2 1 0 15          0                    12          0 0 0 0 0 0 0
STALLS:      0 0 0 30 0 0 6 0          0                    0          0 0 9 6 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  R3,R2(R4) 0 1 2 3 4 6 7 P3,P2(P1)  ----  LW P3 P1 P2 -  2 2 -  ---- 000 R3 -  0 0 1  |LQ(0 )|
001] LW  R7,R2(R5) 0 1 2 4 5 7 8 P5,P2(P4)  ----  LW P5 P4 P2 -  2 2 -  ---- 001 R7 -  0 0 1  |PC  OP Pi EFAD Ci|
002] MUL R7,R7,R3  0 1 2 7 7 12 13 P6,P5,P3  ----  MUL P6 P5 P3 -  7 6 -  ---- 002 R7 P5 0 0 1  |---- LW P3 4000 6|
003] ADDI R1,R1,-1  0 1 2 3 3 4 13 P8,P7,-1  ----  ADDI P8 P7 -  -1 2 -  ---- 003 R1 P7 0 0 1  |---- LW P5 5000 7|
004] SW  R7,R2(R6)  1 2 3 5 6 12 13 ,P6(P2)<-P9  ----  SW - P9 P2 P6 3 3 -  ---- 004 - - 1 0 1  |---- LW P11 4008 9|
005] ADDI R2,R2,8   1 2 3 4 4 5 13 P10,P2,8  ----  ADDI P10 P2 -  8 3 -  ---- 005 R2 P2 0 0 1  |---- LW P12 5008 10|
006] BNE R1,R0,-7  1 2 3 4 4 5 14 ,P8,P0,-7  ----  BNE - P8 P0 -7 4 3 -  ---- 006 - - 0 0 1  |---- LW P16 4010 12|
007] LW  R3,R2(R4)  2 3 4 6 7 9 14 P11,P10(P1)  ----  LW P11 P1 P10 - 4 5 -  ---- 000 R3 P3 0 0 1  |---- LW P17 5010 13|
008] LW  R7,R2(R5)  2 3 4 7 8 10 14 P12,P10(P4)  ----  LW P12 P4 P10 - 4 5 -  ---- 001 R7 P6 0 0 1  +-----+
009] MUL R7,R7,R3  2 3 4 10 10 P13,P12,P11  ----  MUL P13 P12 P11 - 10 9 - 009) 002 R7 P12 0 0 0
010] ADDI R1,R1,-1  2 3 4 5 5 6 P14,P8,-1  ----  ADDI P14 P8 -  -1 4 - 010) 003 R1 P8 0 0 1  +-----+
011] SW  R7,R2(R6)  3 4 5 8 9 ,P13(P10)<-P9  ----  SW - P9 P10 P13 5 5 - 011) 004 - - 1 0 0  |SQ(2 )|
012] ADDI R2,R2,8   3 4 5 6 6 7 P15,P10,8  ----  ADDI P15 P10 - 8 5 - 012) 005 R2 P10 0 0 1  |PC  OP Pi EFAD C1|
013] BNE R1,R0,-7  3 4 5 6 6 7 ,P14,P0,-7  ----  BNE - P14 P0 -7 6 5 - 013) 006 - - 0 0 1  |---- SW P6 6000 12|
014] LW  R3,R2(R4)  4 5 6 9 10 12 P16,P15(P1)  ----  LW P16 P1 P15 - 6 7 - 014) 000 R3 P11 0 0 1  |011] SW P13 6008 .|
015] LW  R7,R2(R5)  4 5 6 10 11 13 P17,P15(P4)  ----  LW P17 P4 P15 - 6 7 - 015) 001 R7 P13 0 0 1  |018] SW P18 6010 .|
016] MUL R7,R7,R3  4 5 6 13 13 P18,P17,P16  ----  MUL P18 P17 P16 - 13 12 - 016) 002 R7 P17 0 0 0  +-----+
017] ADDI R1,R1,-1  4 5 6 7 7 8 P19,P14,-1  ----  ADDI P19 P14 -  -1 6 - 017) 003 R1 P14 0 0 1
018] SW  R7,R2(R6)  5 6 7 11 12 ,P18(P15)<-P9  ----  SW - P9 P15 P18 7 7 - 018) 004 - - 1 0 0
```

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```
019] ADDI R2,R2,8      5 6 7 8 8 9      P20,P15,8      ---- ADDI P20 P15 - 8 7 - - 019) 005 R2 P15 0 0 1
020] BNE R1,R0,-7      5 6 7 8 8 9      ,P19,P0,-7      ---- BNE - P19 P0 -7 8 7 - 020) 006 - - 0 0 1
----- Press ENTER to continue (PC=8,IC=21,CK=14,CTOT=15,IPC=1.40)...
```

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

=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
          Pi:     19     20     16      1      4      9     18      -
          Qi:      0      0      0      0      0      0      1      0
          Vi:  00001000 00000000 00000000 00004000 00005000 00006000 00000000 00000000

=====
STAGES:          F D P I X W C RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A M L S B F X
TOTAL SLOTS:      4 4 16 4 9 4 4 24      16      99      1 1 1 0 1 4 1
BUSY SLOTS:       0 0 0 0 1 1 0 15      0      12      0 0 0 0 0 0 0
STALLS:          0 0 0 30 0 0 7 0      0      0      0 0 9 6 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  R3,R2(R4)    0 1 2 3 4 6 7 P3,P2(P1)  ----  LW P3 P1 P2 - 2 2 -  ---- 000 R3 - 0 0 1  |LQ(0 )|
001] LW  R7,R2(R5)    0 1 2 4 5 7 8 P5,P2(P4)  ----  LW P5 P4 P2 - 2 2 -  ---- 001 R7 - 0 0 1  |PC  OP Pi  EFAD Ci|
002] MUL  R7,R7,R3     0 1 2 7 7 12 13 P6,P5,P3  ----  MUL P6 P5 P3 - 7 6 -  ---- 002 R7 P5 0 0 1  |---- LW P3 4000 6|
003] ADDI R1,R1,-1     0 1 2 3 3 4 13 P8,P7,-1  ----  ADDI P8 P7 - -1 2 -  ---- 003 R1 P7 0 0 1  |---- LW P5 5000 7|
004] SW  R7,R2(R6)     1 2 3 5 6 12 13 ,P6(P2)<-P9  ----  SW - P9 P2 P6 3 3 -  ---- 004 - - 1 0 1  |---- LW P11 4008 9|
005] ADDI R2,R2,8      1 2 3 4 4 5 13 P10,P2,8  ----  ADDI P10 P2 - 8 3 -  ---- 005 R2 P2 0 0 1  |---- LW P12 5008 10|
006] BNE R1,R0,-7      1 2 3 4 4 5 14 ,P8,P0,-7  ----  BNE - P8 P0 -7 4 3 -  ---- 006 - - 0 0 1  |---- LW P16 4010 12|
007] LW  R3,R2(R4)     2 3 4 6 7 9 14 P11,P10(P1)  ----  LW P11 P1 P10 - 4 5 -  ---- 000 R3 P3 0 0 1  |---- LW P17 5010 13|
008] LW  R7,R2(R5)     2 3 4 7 8 10 14 P12,P10(P4)  ----  LW P12 P4 P10 - 4 5 -  ---- 001 R7 P6 0 0 1  +-----+
009] MUL  R7,R7,R3     2 3 4 10 10 15 P13,P12,P11  ----  MUL P13 P12 P11 - 10 9 - 009) 002 R7 P12 0 0 1
010] ADDI R1,R1,-1     2 3 4 5 5 6 P14,P8,-1  ----  ADDI P14 P8 - -1 4 - 010) 003 R1 P8 0 0 1  +-----+
011] SW  R7,R2(R6)     3 4 5 8 9 15 ,P13(P10)<-P9  ----  SW - P9 P10 P13 5 5 - 011) 004 - - 1 0 1  |SQ(1 )|
012] ADDI R2,R2,8      3 4 5 6 6 7 P15,P10,8  ----  ADDI P15 P10 - 8 5 - 012) 005 R2 P10 0 0 1  |PC  OP Pi  EFAD Cl|
013] BNE R1,R0,-7      3 4 5 6 6 7 P14,P0,-7  ----  BNE - P14 P0 -7 6 5 - 013) 006 - - 0 0 1  |---- SW P6 6000 12|
014] LW  R3,R2(R4)     4 5 6 9 10 12 P16,P15(P1)  ----  LW P16 P1 P15 - 6 7 - 014) 000 R3 P11 0 0 1  |---- SW P13 6008 15|
015] LW  R7,R2(R5)     4 5 6 10 11 13 P17,P15(P4)  ----  LW P17 P4 P15 - 6 7 - 015) 001 R7 P13 0 0 1  |018] SW P18 6010 .|
016] MUL  R7,R7,R3     4 5 6 13 13 P18,P17,P16  ----  MUL P18 P17 P16 - 13 12 - 016) 002 R7 P17 0 0 0  +-----+
017] ADDI R1,R1,-1     4 5 6 7 7 8 P19,P14,-1  ----  ADDI P19 P14 - -1 6 - 017) 003 R1 P14 0 0 1
018] SW  R7,R2(R6)     5 6 7 11 12 P18(P15)<-P9  ----  SW - P9 P15 P18 7 7 - 018) 004 - - 1 0 0
019] ADDI R2,R2,8      5 6 7 8 8 9 P20,P15,8  ----  ADDI P20 P15 - 8 7 - 019) 005 R2 P15 0 0 1
020] BNE R1,R0,-7      5 6 7 8 8 9 ,P19,P0,-7  ----  BNE - P19 P0 -7 8 7 - 020) 006 - - 0 0 1

----- Press ENTER to continue (PC=8,IC=21,CK=15,CTOT=16,IPC=1.31)...
@015 stall due to NO SLOTS when trying to move instuction LW/015 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 0 0 1 1 1 1 0 1 0 1 0 0 0 0 1 0 0 1 1 1 1 1
vi:  00 00 00 00 00 00 00 00 FF 00 08 00 00 00 00 FE 10 00 00 00 FD 18 00 00 00 00 00

=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
          Pi:     19     20     16      1      4      9     18      -
          Qi:      0      0      0      0      0      0      1      0
          Vi:  00000FFF 00000008 00000000 00004000 00005000 00006000 00000000 00000000

=====
STAGES:          F D P I X W C RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A M L S B F X
TOTAL SLOTS:      4 4 16 4 9 4 4 24      16      99      1 1 1 0 1 4 1
BUSY SLOTS:       0 0 0 0 1 1 0 12      0      8      0 0 0 0 0 0 0
STALLS:          0 0 0 30 0 0 7 0      0      0      0 0 9 6 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  R3,R2(R4)    0 1 2 3 4 6 7 P3,P2(P1)  ----  LW P3 P1 P2 - 2 2 -  ---- 000 R3 - 0 0 1  |LQ(0 )|
001] LW  R7,R2(R5)    0 1 2 4 5 7 8 P5,P2(P4)  ----  LW P5 P4 P2 - 2 2 -  ---- 001 R7 - 0 0 1  |PC  OP Pi  EFAD Ci|
002] MUL  R7,R7,R3     0 1 2 7 7 12 13 P6,P5,P3  ----  MUL P6 P5 P3 - 7 6 -  ---- 002 R7 P5 0 0 1  |---- LW P3 4000 6|
003] ADDI R1,R1,-1     0 1 2 3 3 4 13 P8,P7,-1  ----  ADDI P8 P7 - -1 2 -  ---- 003 R1 P7 0 0 1  |---- LW P5 5000 7|
004] SW  R7,R2(R6)     1 2 3 5 6 12 13 ,P6(P2)<-P9  ----  SW - P9 P2 P6 3 3 -  ---- 004 - - 1 0 1  |---- LW P11 4008 9|
005] ADDI R2,R2,8      1 2 3 4 4 5 13 P10,P2,8  ----  ADDI P10 P2 - 8 3 -  ---- 005 R2 P2 0 0 1  |---- LW P12 5008 10|
006] BNE R1,R0,-7      1 2 3 4 4 5 14 ,P8,P0,-7  ----  BNE - P8 P0 -7 4 3 -  ---- 006 - - 0 0 1  |---- LW P16 4010 12|
007] LW  R3,R2(R4)     2 3 4 6 7 9 14 P11,P10(P1)  ----  LW P11 P1 P10 - 4 5 -  ---- 000 R3 P3 0 0 1  |---- LW P17 5010 13|
```

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```
008] LW R7,R2(R5) 2 3 4 7 8 10 14 P12,P10(P4) ---- LW P12 P4 P10 - 4 5 - ---- 001 R7 P6 0 0 1 +-----+
009] MUL R7,R7,R3 2 3 4 10 10 15 16 P13,P12,P11 ---- MUL P13 P12 P11 - 10 9 - ---- 002 R7 P12 0 0 1
010] ADDI R1,R1,-1 2 3 4 5 5 6 16 P14,P8,-1 ---- ADDI P14 P8 - -1 4 - - ---- 003 R1 P8 0 0 1 +-----+
011] SW R7,R2(R6) 3 4 5 8 9 15 16 ,P13(P10)<-P9 ---- SW - P9 P10 P13 5 5 - ---- 004 - - 1 0 1 |SQ(1 )|
012] ADDI R2,R2,8 3 4 5 6 6 7 16 P15,P10,8 ---- ADDI P15 P10 - 8 5 - - ---- 005 R2 P10 0 0 1 |PC OP Pi EFAD C1|
013] BNE R1,R0,-7 3 4 5 6 6 7 ,P14,P0,-7 ---- BNE - P14 P0 -7 6 5 - (013) 006 - - 0 0 1 |---- SW P6 6000 12|
014] LW R3,R2(R4) 4 5 6 9 10 12 P16,P15(P1) ---- LW P16 P1 P15 - 6 7 - (014) 000 R3 P11 0 0 1 |---- SW P13 6008 15|
015] LW R7,R2(R5) 4 5 6 10 11 13 P17,P15(P4) ---- LW P17 P4 P15 - 6 7 - (015) 001 R7 P13 0 0 1 |018] SW P18 6010 .|
016] MUL R7,R7,R3 4 5 6 13 13 P18,P17,P16 ---- MUL P18 P17 P16 - 13 12 - (016) 002 R7 P17 0 0 0 +-----+
017] ADDI R1,R1,-1 4 5 6 7 7 8 P19,P14,-1 ---- ADDI P19 P14 - -1 6 - - (017) 003 R1 P14 0 0 1
018] SW R7,R2(R6) 5 6 7 11 12 ,P18(P15)<-P9 ---- SW - P9 P15 P18 7 7 - (018) 004 - - 1 0 0
019] ADDI R2,R2,8 5 6 7 8 8 9 P20,P15,8 ---- ADDI P20 P15 - 8 7 - - (019) 005 R2 P15 0 0 1
020] BNE R1,R0,-7 5 6 7 8 8 9 ,P19,P0,-7 ---- BNE - P19 P0 -7 8 7 - (020) 006 - - 0 0 1
```

----- Press ENTER to continue (PC=8,IC=21,CK=16,CTOT=17,IPC=1.24)...

```
=====
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 0 0 1 1 1 1 0 1 1 1 0 0 0 0 0 1 0 0 1 1 1 1
vi: 00 00 00 00 00 00 00 FF 00 08 00 00 00 FE 10 00 00 00 FD 18 00 00 00 00
```

```
=====
REG.FILE: Ri: 1 2 3 4 5 6 7 8
Pi: 19 20 16 1 4 9 18 -
Qi: 0 0 0 0 0 0 0 0
Vi: 00000FFF 00000008 00000000 00004000 00005000 00006000 00000000 00000000
```

```
=====
STAGES: F D P I X W C RENAMED-STR INSTRUCTION-WINDOW REORDER-BUFFER A M L S B F X
TOTAL SLOTS: 4 4 16 4 9 4 4 24 16 99 1 1 1 0 1 4 1
BUSY SLOTS: 0 0 0 0 0 1 0 0 10 0 5 0 0 0 0 0 0 0
STALLS: 0 0 0 30 0 0 7 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# OPCODE Pi Pj Pk I/P1 Cj Ck Cl ROB# PC Ri oPi x s c +-----+
000] LW R3,R2(R4) 0 1 2 3 4 6 7 P3,P2(P1) ---- LW P3 P1 P2 - 2 2 - ---- 000 R3 - 0 0 1 |LQ(0 )|
001] LW R7,R2(R5) 0 1 2 4 5 7 8 P5,P2(P4) ---- LW P5 P4 P2 - 2 2 - ---- 001 R7 - 0 0 1 |PC OP Pi EFAD Ci|
002] MUL R7,R7,R3 0 1 2 7 12 13 P6,P5,P3 ---- MUL P6 P5 P3 - 7 6 - ---- 002 R7 P5 0 0 1 |---- LW P3 4000 6|
003] ADDI R1,R1,-1 0 1 2 3 4 13 P8,P7,-1 ---- ADDI P8 P7 - -1 2 - - ---- 003 R1 P7 0 0 1 |---- LW P5 5000 7|
004] SW R7,R2(R6) 1 2 3 5 6 12 13 ,P6(P2)<-P9 ---- SW - P9 P2 P6 3 3 - ---- 004 - - 1 0 1 |---- LW P11 4008 9|
005] ADDI R2,R2,8 1 2 3 4 4 5 13 P10,P2,8 ---- ADDI P10 P2 - 8 3 - - ---- 005 R2 P2 0 0 1 |---- LW P12 5008 10|
006] BNE R1,R0,-7 1 2 3 4 4 5 14 ,P8,P0,-7 ---- BNE - P8 P0 -7 4 3 - - ---- 006 - - 0 0 1 |---- LW P16 4010 12|
007] LW R3,R2(R4) 2 3 4 6 7 9 14 P11,P10(P1) ---- LW P11 P1 P10 - 4 5 - ---- 000 R3 P3 0 0 1 |---- LW P17 5010 13|
008] LW R7,R2(R5) 2 3 4 7 8 10 14 P12,P10(P4) ---- LW P12 P4 P10 - 4 5 - ---- 001 R7 P6 0 0 1 +-----+
009] MUL R7,R7,R3 2 3 4 10 10 15 16 P13,P12,P11 ---- MUL P13 P12 P11 - 10 9 - ---- 002 R7 P12 0 0 1
010] ADDI R1,R1,-1 2 3 4 5 5 6 16 P14,P8,-1 ---- ADDI P14 P8 - -1 4 - - ---- 003 R1 P8 0 0 1 +-----+
011] SW R7,R2(R6) 3 4 5 8 9 15 16 ,P13(P10)<-P9 ---- SW - P9 P10 P13 5 5 - ---- 004 - - 1 0 1 |SQ(1 )|
012] ADDI R2,R2,8 3 4 5 6 6 7 16 P15,P10,8 ---- ADDI P15 P10 - 8 5 - - ---- 005 R2 P10 0 0 1 |PC OP Pi EFAD C1|
013] BNE R1,R0,-7 3 4 5 6 6 7 17 ,P14,P0,-7 ---- BNE - P14 P0 -7 6 5 - - ---- 006 - - 0 0 1 |---- SW P6 6000 12|
014] LW R3,R2(R4) 4 5 6 9 10 12 17 P16,P15(P1) ---- LW P16 P1 P15 - 6 7 - ---- 000 R3 P11 0 0 1 |---- SW P13 6008 15|
015] LW R7,R2(R5) 4 5 6 10 11 13 17 P17,P15(P4) ---- LW P17 P4 P15 - 6 7 - ---- 001 R7 P13 0 0 1 |018] SW P18 6010 .|
016] MUL R7,R7,R3 4 5 6 13 13 P18,P17,P16 ---- MUL P18 P17 P16 - 13 12 - (016) 002 R7 P17 0 0 0 +-----+
017] ADDI R1,R1,-1 4 5 6 7 7 8 P19,P14,-1 ---- ADDI P19 P14 - -1 6 - - (017) 003 R1 P14 0 0 1
018] SW R7,R2(R6) 5 6 7 11 12 ,P18(P15)<-P9 ---- SW - P9 P15 P18 7 7 - (018) 004 - - 1 0 0
019] ADDI R2,R2,8 5 6 7 8 8 9 P20,P15,8 ---- ADDI P20 P15 - 8 7 - - (019) 005 R2 P15 0 0 1
020] BNE R1,R0,-7 5 6 7 8 8 9 ,P19,P0,-7 ---- BNE - P19 P0 -7 8 7 - (020) 006 - - 0 0 1
```

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

```
=====
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 0 0 1 1 1 1 0 0 1 1 1 0 0 0 0 0 0 0 1 1 1 1
vi: 00 00 00 00 00 00 00 FF 00 08 00 00 00 FE 10 00 00 00 FD 18 00 00 00 00
```

```
=====
REG.FILE: Ri: 1 2 3 4 5 6 7 8
Pi: 19 20 16 1 4 9 18 -
Qi: 0 0 0 0 0 0 0 0
Vi: 00000FFF 00000008 00000000 00004000 00005000 00006000 00000000 00000000
```

```
=====
STAGES: F D P I X W C RENAMED-STR INSTRUCTION-WINDOW REORDER-BUFFER A M L S B F X
TOTAL SLOTS: 4 4 16 4 9 4 4 24 16 99 1 1 1 0 1 4 1
BUSY SLOTS: 0 0 0 0 0 1 0 0 10 0 5 0 0 0 0 0 0 0
STALLS: 0 0 0 30 0 0 8 0 0 0 0 0 0 0 0 0 0 0
```

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```
=====
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   R3,R2(R4)   0 1 2 3 4 6 7 P3,P2(P1)  ----  LW P3 P1 P2 - 2 2 - ---- 000 R3 - 0 0 1 |LQ(0 )|
001] LW   R7,R2(R5)   0 1 2 4 5 7 8 P5,P2(P4)  ----  LW P5 P4 P2 - 2 2 - ---- 001 R7 - 0 0 1 |PC  OP Pi EFAD Ci|
002] MUL  R7,R7,R3    0 1 2 7 7 12 13 P6,P5,P3  ----  MUL P6 P5 P3 - 7 6 - ---- 002 R7 P5 0 0 1 |---- LW P3 4000 6|
003] ADDI R1,R1,-1    0 1 2 3 3 4 13 P8,P7,-1  ----  ADDI P8 P7 - -1 2 - - ---- 003 R1 P7 0 0 1 |---- LW P5 5000 7|
004] SW   R7,R2(R6)   1 2 3 5 6 12 13 ,P6(P2)<--P9  ----  SW - P9 P2 P6 3 3 - ---- 004 - - 1 0 1 |---- LW P11 4008 9|
005] ADDI R2,R2,8     1 2 3 4 4 5 13 P10,P2,8  ----  ADDI P10 P2 - 8 3 - - ---- 005 R2 P2 0 0 1 |---- LW P12 5008 10|
006] BNE  R1,R0,-7    1 2 3 4 4 5 14 ,P8,P0,-7  ----  BNE - P8 P0 -7 4 3 - ---- 006 - - 0 0 1 |---- LW P16 4010 12|
007] LW   R3,R2(R4)   2 3 4 6 7 9 14 P11,P10(P1)  ----  LW P11 P1 P10 - 4 5 - ---- 000 R3 P3 0 0 1 |---- LW P17 5010 13|
008] LW   R7,R2(R5)   2 3 4 7 8 10 14 P12,P10(P4)  ----  LW P12 P4 P10 - 4 5 - ---- 001 R7 P6 0 0 1 +-----+
009] MUL  R7,R7,R3    2 3 4 10 10 15 16 P13,P12,P11  ----  MUL P13 P12 P11 - 10 9 - ---- 002 R7 P12 0 0 1
010] ADDI R1,R1,-1    2 3 4 5 5 6 16 P14,P8,-1  ----  ADDI P14 P8 - -1 4 - - ---- 003 R1 P8 0 0 1 +-----+
011] SW   R7,R2(R6)   3 4 5 8 9 15 16 ,P13(P10)<--P9  ----  SW - P9 P10 P13 5 5 - ---- 004 - - 1 0 1 |SQ(0 )|
012] ADDI R2,R2,8     3 4 5 6 6 7 16 P15,P10,8  ----  ADDI P15 P10 - 8 5 - - ---- 005 R2 P10 0 0 1 |PC  OP Pi EFAD Cl|
013] BNE  R1,R0,-7    3 4 5 6 6 7 17 ,P14,P0,-7  ----  BNE - P14 P0 -7 6 5 - ---- 006 - - 0 0 1 |---- SW P6 6000 12|
014] LW   R3,R2(R4)   4 5 6 9 10 12 17 P16,P15(P1)  ----  LW P16 P1 P15 - 6 7 - ---- 000 R3 P11 0 0 1 |---- SW P13 6008 15|
015] LW   R7,R2(R5)   4 5 6 10 11 13 17 P17,P15(P4)  ----  LW P17 P4 P15 - 6 7 - ---- 001 R7 P13 0 0 1 |---- SW P18 6010 18|
016] MUL  R7,R7,R3    4 5 6 13 13 18 P18,P17,P16  ----  MUL P18 P17 P16 - 13 12 - ---- 016) 002 R7 P17 0 0 1 +-----+
017] ADDI R1,R1,-1    4 5 6 7 7 8 P19,P14,-1  ----  ADDI P19 P14 - -1 6 - - ---- 017) 003 R1 P14 0 0 1
018] SW   R7,R2(R6)   5 6 7 11 12 18 ,P18(P15)<--P9  ----  SW - P9 P15 P18 7 7 - ---- 018) 004 - - 1 0 1
019] ADDI R2,R2,8     5 6 7 8 8 9 P20,P15,8  ----  ADDI P20 P15 - 8 7 - - ---- 019) 005 R2 P15 0 0 1
020] BNE  R1,R0,-7    5 6 7 8 8 9 ,P19,P0,-7  ----  BNE - P19 P0 -7 8 7 - ---- 020) 006 - - 0 0 1
=====
Press ENTER to continue (PC=8,IC=21,CK=18,CTOT=19,IPC=1.11)...
```

@018 stall due to NO SLOTS when trying to move instnuction SW/011 from stage W to stage C.

```
=====
PHYSICAL REGS:  1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
                *      *      *      *      *      *      *      *
qi:  0 1 1 0 1 1 1 1 0 1 1 1 1 1 0 1 0 0 0 0 1 1 1 1
vi:  00 00 00 00 00 00 00 00 FF 00 08 00 00 00 FE 10 00 00 00 FD 18 00 00 00 00
=====
REG.FILE: Ri:      1      2      3      4      5      6      7      8
Pi:      19      20      16      1      4      9      18      -
Qi:      0      0      0      0      0      0      0      0
Vi:  00000FFE 00000010 00000000 00004000 00005000 00006000 00000000 00000000
=====
STAGES:      F D P I X W C RENAMED-STR  INSTRUCTION-WINDOW  REORDER-BUFFER  A M L S B F X
TOTAL SLOTS:  4 4 16 4 9 4 4 24  16  99  1 1 1 0 1 4 1
BUSY SLOTS:   0 0 0 0 0 1 0 7  0  1  0 0 0 0 0 0 0
STALLS:       0 0 0 30 0 0 8 0  0  0  0 9 6 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   R3,R2(R4)   0 1 2 3 4 6 7 P3,P2(P1)  ----  LW P3 P1 P2 - 2 2 - ---- 000 R3 - 0 0 1 |LQ(0 )|
001] LW   R7,R2(R5)   0 1 2 4 5 7 8 P5,P2(P4)  ----  LW P5 P4 P2 - 2 2 - ---- 001 R7 - 0 0 1 |PC  OP Pi EFAD Ci|
002] MUL  R7,R7,R3    0 1 2 7 7 12 13 P6,P5,P3  ----  MUL P6 P5 P3 - 7 6 - ---- 002 R7 P5 0 0 1 |---- LW P3 4000 6|
003] ADDI R1,R1,-1    0 1 2 3 3 4 13 P8,P7,-1  ----  ADDI P8 P7 - -1 2 - - ---- 003 R1 P7 0 0 1 |---- LW P5 5000 7|
004] SW   R7,R2(R6)   1 2 3 5 6 12 13 ,P6(P2)<--P9  ----  SW - P9 P2 P6 3 3 - ---- 004 - - 1 0 1 |---- LW P11 4008 9|
005] ADDI R2,R2,8     1 2 3 4 4 5 13 P10,P2,8  ----  ADDI P10 P2 - 8 3 - - ---- 005 R2 P2 0 0 1 |---- LW P12 5008 10|
006] BNE  R1,R0,-7    1 2 3 4 4 5 14 ,P8,P0,-7  ----  BNE - P8 P0 -7 4 3 - ---- 006 - - 0 0 1 |---- LW P16 4010 12|
007] LW   R3,R2(R4)   2 3 4 6 7 9 14 P11,P10(P1)  ----  LW P11 P1 P10 - 4 5 - ---- 000 R3 P3 0 0 1 |---- LW P17 5010 13|
008] LW   R7,R2(R5)   2 3 4 7 8 10 14 P12,P10(P4)  ----  LW P12 P4 P10 - 4 5 - ---- 001 R7 P6 0 0 1 +-----+
009] MUL  R7,R7,R3    2 3 4 10 10 15 16 P13,P12,P11  ----  MUL P13 P12 P11 - 10 9 - ---- 002 R7 P12 0 0 1
010] ADDI R1,R1,-1    2 3 4 5 5 6 16 P14,P8,-1  ----  ADDI P14 P8 - -1 4 - - ---- 003 R1 P8 0 0 1 +-----+
011] SW   R7,R2(R6)   3 4 5 8 9 15 16 ,P13(P10)<--P9  ----  SW - P9 P10 P13 5 5 - ---- 004 - - 1 0 1 |SQ(0 )|
012] ADDI R2,R2,8     3 4 5 6 6 7 16 P15,P10,8  ----  ADDI P15 P10 - 8 5 - - ---- 005 R2 P10 0 0 1 |PC  OP Pi EFAD Cl|
013] BNE  R1,R0,-7    3 4 5 6 6 7 17 ,P14,P0,-7  ----  BNE - P14 P0 -7 6 5 - ---- 006 - - 0 0 1 |---- SW P6 6000 12|
014] LW   R3,R2(R4)   4 5 6 9 10 12 17 P16,P15(P1)  ----  LW P16 P1 P15 - 6 7 - ---- 000 R3 P11 0 0 1 |---- SW P13 6008 15|
015] LW   R7,R2(R5)   4 5 6 10 11 13 17 P17,P15(P4)  ----  LW P17 P4 P15 - 6 7 - ---- 001 R7 P13 0 0 1 |---- SW P18 6010 18|
016] MUL  R7,R7,R3    4 5 6 13 13 18 P18,P17,P16  ----  MUL P18 P17 P16 - 13 12 - ---- 002 R7 P17 0 0 1 +-----+
017] ADDI R1,R1,-1    4 5 6 7 7 8 P19,P14,-1  ----  ADDI P19 P14 - -1 6 - - ---- 003 R1 P14 0 0 1
018] SW   R7,R2(R6)   5 6 7 11 12 18 ,P18(P15)<--P9  ----  SW - P9 P15 P18 7 7 - ---- 004 - - 1 0 1
019] ADDI R2,R2,8     5 6 7 8 8 9 P20,P15,8  ----  ADDI P20 P15 - 8 7 - - ---- 005 R2 P15 0 0 1
020] BNE  R1,R0,-7    5 6 7 8 8 9 ,P19,P0,-7  ----  BNE - P19 P0 -7 8 7 - ---- 020) 006 - - 0 0 1
=====
Press ENTER to continue (PC=8,IC=21,CK=19,CTOT=20,IPC=1.05)...
```

```
=====
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 0 1 1 1 1 0 1 1 1 1 1 0 1 0 0 0 0 1 1 1 1
vi:  00 00 00 00 00 00 00 00 FF 00 08 00 00 00 FE 10 00 00 00 FD 18 00 00 00 00
=====
```

=====																													
REG.FILE:	Ri:	1	2	3	4	5	6	7	8																				
	Pi:	19	20	16	1	4	9	18	-																				
	Qi:	0	0	0	0	0	0	0	0																				
	Vi:	00000FFE	00000010	00000000	00004000	00005000	00006000	00000000	00000000																				
=====																													
STAGES:	F	D	P	I	X	W	C	RENAMED-STR	INSTRUCTION-WINDOW	REORDER-BUFFER	A	M	L	S	B	F	X												
TOTAL SLOTS:	4	4	16	4	9	4	4	24	16	99	1	1	1	0	1	4	1												
BUSY SLOTS:	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0												
STALLS:	0	0	0	30	0	0	8	0	0	0	0	9	6	0	0	0	0												
=====																													
PC	INSTRUCTION	F	D	P	I	X	W	C	Pi,Pj	Pk	P1	IW#	OPCD	Pi	Pj	Pk	I/P1	Cj	Ck	C1	ROB#	PC	Ri	oPi	x	s	c	+-----+ LQ(0)	
000]	LW R3,R2(R4)	0	1	2	3	4	6	7	P3,P2	P1		----	LW	P3	P1	P2	-	2	2	-	----	000	R3	-	0	0	1		
001]	LW R7,R2(R5)	0	1	2	4	5	7	8	P5,P2	P4		----	LW	P5	P4	P2	-	2	2	-	----	001	R7	-	0	0	1		
002]	MUL R7,R7,R3	0	1	2	7	7	12	13	P6,P5	P3		----	MUL	P6	P5	P3	-	7	6	-	----	002	R7	P5	0	0	1		
003]	ADDI R1,R1,-1	0	1	2	3	3	4	13	P8,P7	-1		----	ADDI	P8	P7	-	-1	2	-	-	----	003	R1	P7	0	0	1		
004]	SW R7,R2(R6)	1	2	3	5	6	12	13	P6(P2)<-P9			----	SW	-	P9	P2	P6	3	3	-	----	004	-	-	1	0	1		
005]	ADDI R2,R2,8	1	2	3	4	4	5	13	P10,P2	8		----	ADDI	P10	P2	-	8	3	-	-	----	005	R2	P2	0	0	1		
006]	BNE R1,R0,-7	1	2	3	4	4	5	14	P8,P0	-7		----	BNE	-	P8	P0	-7	4	3	-	----	006	-	-	0	0	1		
007]	LW R3,R2(R4)	2	3	4	6	7	9	14	P11,P10	P1		----	LW	P11	P1	P10	-	4	5	-	----	000	R3	P3	0	0	1		
008]	LW R7,R2(R5)	2	3	4	7	8	10	14	P12,P10	P4		----	LW	P12	P4	P10	-	4	5	-	----	001	R7	P6	0	0	1		
009]	MUL R7,R7,R3	2	3	4	10	10	15	16	P13,P12	P11		----	MUL	P13	P12	P11	-	10	9	-	----	002	R7	P12	0	0	1		
010]	ADDI R1,R1,-1	2	3	4	5	5	6	16	P14,P8	-1		----	ADDI	P14	P8	-	-1	4	-	-	----	003	R1	P8	0	0	1		
011]	SW R7,R2(R6)	3	4	5	8	9	15	16	P13(P10)<-P9			----	SW	-	P9	P10	P13	5	5	-	----	004	-	-	1	0	1		
012]	ADDI R2,R2,8	3	4	5	6	6	7	16	P15,P10	8		----	ADDI	P15	P10	-	8	5	-	-	----	005	R2	P10	0	0	1		
013]	BNE R1,R0,-7	3	4	5	6	6	7	17	P14,P0	-7		----	BNE	-	P14	P0	-7	6	5	-	----	006	-	-	0	0	1		
014]	LW R3,R2(R4)	4	5	6	9	10	12	17	P16,P15	P1		----	LW	P16	P1	P15	-	6	7	-	----	000	R3	P11	0	0	1		
015]	LW R7,R2(R5)	4	5	6	10	11	13	17	P17,P15	P4		----	LW	P17	P4	P15	-	6	7	-	----	001	R7	P13	0	0	1		
016]	MUL R7,R7,R3	4	5	6	13	13	18	19	P18,P17	P16		----	MUL	P18	P17	P16	-	13	12	-	----	002	R7	P17	0	0	1		
017]	ADDI R1,R1,-1	4	5	6	7	7	8	19	P19,P14	-1		----	ADDI	P19	P14	-	-1	6	-	-	----	003	R1	P14	0	0	1		
018]	SW R7,R2(R6)	5	6	7	11	12	18	19	P18(P15)<-P9			----	SW	-	P9	P15	P18	7	7	-	----	004	-	-	1	0	1		
019]	ADDI R2,R2,8	5	6	7	8	8	9	19	P20,P15	8		----	ADDI	P20	P15	-	8	7	-	-	----	005	R2	P15	0	0	1		
020]	BNE R1,R0,-7	5	6	7	8	8	9	20	P19,P0	-7		----	BNE	-	P19	P0	-7	8	7	-	----	006	-	-	0	0	1		
----- Press ENTER to continue (PC=8,IC=21,CK=20,CTOT=21,IPC=1.00)...																													

Program 'prog_ex1' FINISHED

PC=8,IC=21,CK=21,IPC=1.00
Goodbye.