计算机组成原理实验报告（Verilog流水线plus）

1. 设计通路设计
2. PC

|  |  |  |
| --- | --- | --- |
| 信号名 | 方向 | 描述 |
| clk | I | 处理器时钟信号 |
| reset | I | 复位信号 |
| next\_PC [31:0] | I | 下一个PC的值 |
| PC [31:0] | O | 输出当前指令的地址 |

|  |  |  |
| --- | --- | --- |
| 序号 | 功能名称 | 功能描述 |
| 1 | 取出指令地址 | 取出将要执行的指令地址 |

1. PC\_calculator

|  |  |  |
| --- | --- | --- |
| 信号名 | 方向 | 描述 |
| PC [31:0] | I | 当前PC值 |
| PCOp [1:0] | I | 下条PC输出控制信号 |
| equal | I | 寄存器值是否相等 |
| instr\_index [25:0] | I | 指令的后26位 |
| rs [31:0] | I | 寄存器储存的值 |
| imm [31:0] | I | 扩展后的立即数 |
| PC\_plus\_four [31:0] | O | PC+4 |
| next\_PC [31:0] | O | 下条PC的值 |

|  |  |  |
| --- | --- | --- |
| 序号 | 功能名称 | 功能描述 |
| 1 | 计算下一条PC | 计算下一条指令的地址 |

1. im

|  |  |  |
| --- | --- | --- |
| 信号名 | 方向 | 描述 |
| addr [9:0] | I | 当下PC的值 |
| Instr [31:0] | O | 取出的32位指令 |

|  |  |  |
| --- | --- | --- |
| 序号 | 功能名称 | 功能描述 |
| 1 | 取出指令 | 取出将要执行的指令 |

1. grf

|  |  |  |
| --- | --- | --- |
| 信号名 | 方向 | 描述 |
| clk | I | 处理器时钟信号 |
| reset | I | 清零信号 |
| RA1[4:0] | I | 读寄存器时第一个寄存器的编号（地址） |
| RA2[4:0] | I | 读寄存器时第二个寄存器的编号（地址） |
| WD[31:0] | I | 寄存器写入数据 |
| WA[4:0] | I | 写寄存器时的编号（地址） |
| RegWrite | I | 寄存器写使能信号 |
| WPC | I | 当前PC的值 |
| RD1[31:0] | O | 读寄存器时第一个寄存器的输出数据 |
| RD2[31:0] | O | 读寄存器时第二个寄存器的输出数据 |

|  |  |  |
| --- | --- | --- |
| 序号 | 功能名称 | 功能描述 |
| 1 | 读寄存器 | RD1输出RA1所寻址的寄存器中的数据  RD2输出RA2所寻址的寄存器中的数据 |
| 2 | 写寄存器 | 当时钟上升沿到来且RegWrite信号有效时，WD被写入WA所寻址的寄存器 |

1. alu

|  |  |  |
| --- | --- | --- |
| 信号名 | 方向 | 描述 |
| A[31:0] | I | 参与ALU计算的第一个值 |
| B[31:0] | I | 参与ALU计算的第二个值 |
| ALUOp[2:0] | I | ALU功能的选择信号：  000：ALU进行加法运算  001：ALU进行减法运算  010：ALU进行或运算  011：ALU进行与运算  100：ALU进行逻辑移位  101：ALU进行算术移位 |
| C[31:0] | O | ALU的计算结果 |
| Equal | O | 判断两数是否相等：  0：A!=B  1：A=B |

|  |  |  |
| --- | --- | --- |
| 序号 | 功能名称 | 功能描述 |
| 1 | 无符号加运算 | Result = A + B |
| 2 | 无符号减运算 | Result = A - B |
| 3 | 或运算 | Result = A | B |
| 4 | 与运算 | Result = A & B |
| 5 | 算术移位 | Result=A>>B; |
| 6 | 逻辑移位 | Result=$signed(A)>>>B |
| 7 | 判断是否相等 | If(A == B) Equal=1 |

1. dm

|  |  |  |
| --- | --- | --- |
| 信号名 | 方向 | 描述 |
| clk | I | 控制器时钟信号 |
| reset | I | 存储器复位 |
| MemWrite | I | 写使能信号 |
| Addr [9:0] | I | 读或写时对应存储器时地址 |
| WD[31:0] | I | 写存储器时写入数据 |
| PC[31:0] | I | 存储器写使能信号 |
| RD[31:0] | O | 读存储器时的输出 |

|  |  |  |
| --- | --- | --- |
| 序号 | 功能名称 | 功能描述 |
| 1 | 读存储器 | RD输出存储器中地址Addr存储的数据 |
| 2 | 写存储器 | 当时钟上升沿到来并且MemWrite有效时，WD被写入存储器中地址Addr的位置 |

1. mux32\_4

|  |  |  |
| --- | --- | --- |
| 信号名 | 方向 | 描述 |
| In0 [31:0] | I | 第一个输入 |
| In1 [31:0] | I | 第二个输入 |
| In2 [31:0] | I | 第三个输入 |
| In3 [31:0] | I | 第四个输入 |
| Select [1:0] | I | 选择信号 |
| Out[31:0] | O | 输出结果 |

|  |  |  |
| --- | --- | --- |
| 序号 | 功能名称 | 功能描述 |
| 1 | 选择输出 | Select=0：输出In0  Select=1：输出In1  Select=2：输出In2  Select=3：输出In3 |

1. mux 5\_4

|  |  |  |
| --- | --- | --- |
| 信号名 | 方向 | 描述 |
| In0 [4:0] | I | 第一个输入 |
| In1 [4:0] | I | 第二个输入 |
| In2 [4:0] | I | 第三个输入 |
| In3 [4:0] | I | 第四个输入 |
| Select [1:0] | I | 选择信号 |
| Out[4:0] | O | 输出结果 |

|  |  |  |
| --- | --- | --- |
| 序号 | 功能名称 | 功能描述 |
| 1 | 选择输出 | Select=0：输出In0  Select=1：输出In1  Select=2：输出In2  Select=3：输出In3 |

1. mux 32\_2

|  |  |  |
| --- | --- | --- |
| 信号名 | 方向 | 描述 |
| In0 [31:0] | I | 第一个输入 |
| In1 [31:0] | I | 第二个输入 |
| Select | I | 选择信号 |
| Out[31:0] | O | 输出结果 |

|  |  |  |
| --- | --- | --- |
| 序号 | 功能名称 | 功能描述 |
| 1 | 选择输出 | Select=0：输出In0  Select=1：输出In1 |

1. ext

|  |  |  |
| --- | --- | --- |
| 信号名 | 方向 | 描述 |
| imm[15:0] | I | 需要被扩展的16位立即数 |
| EOp[1:0] | I | 扩展方式选择信号：  00：符号扩展到32位  01：高位0扩展到32位  10：将立即数加载到高位，低位补0  11：符号扩展之后左移两位 |
| ext\_imm | O | 相应扩展后的立即数 |

|  |  |  |
| --- | --- | --- |
| 序号 | 功能名称 | 功能描述 |
| 1 | 符号扩展 | 将imm进行符号扩展到32位 |
| 2 | 零扩展 | 将imm进行高位补0扩展到32位 |
| 3 | 加载到高位 | 将imm加载到高位，低位补0 |
| 4 | 符号扩展之后左移2位 | 将imm进行符号扩展之后左移2位 |

1. D级流水寄存器

|  |  |  |
| --- | --- | --- |
| 信号名 | 方向 | 描述 |
| clk | I | 时钟信号 |
| reset | I | 复位信号 |
| Stall | I | 暂停控制信号 |
| IR\_F[31:0] | I | 来自F级的指令 |
| PC4\_F[31:0] | I | 来自F级的PC+4 |
| IR\_D[31:0] | O | D级指令 |
| PC4\_D[31:0] | O | D级PC +4 |

1. E级流水寄存器

|  |  |  |
| --- | --- | --- |
| 信号名 | 方向 | 描述 |
| clk | I | 时钟信号 |
| reset | I | 复位信号 |
| Stall | I | 暂停控制信号 |
| IR\_D[31:0] | I | 来自D级的指令 |
| PC4\_D[31:0] | I | 来自D级的PC+4 |
| RD1\_D[31:0] | I | 来自D级的寄存器第一个输出值 |
| RD2\_D[31:0] | I | 来自D级的寄存器第二个输出值 |
| Imm\_D[31:0] | I | 来自D级的扩展后的立即数 |
| RegDst\_D[1:0] | I | 来自D级的寄存器WA选择控制信号 |
| ALUOp\_D[2:0] | I | 来自D级的alu控制信号 |
| MemWrite\_D | I | 来自D级的存储器写使能信号 |
| RegWrite\_D | I | 来自D级的寄存器写使能信号 |
| ALUSrc\_D | I | 来自D级的alu B端选择控制信号 |
| MemtoReg\_D[1:0] | I | 来自D级的寄存器WD选择控制信号 |
| IR\_E[31:0] | O | 来自E级的指令 |
| PC4\_E[31:0] | O | 来自E级的PC+4 |
| RD1\_E[31:0] | O | 来自E级的寄存器第一个输出值 |
| RD2\_E[31:0] | O | 来自E级的寄存器第二个输出值 |
| Imm\_E[31:0] | O | 来自E级的扩展后的立即数 |
| RegDst\_E[1:0] | O | 来自E级的寄存器WA选择控制信号 |
| ALUOp\_E[2:0] | O | 来自E级的alu控制信号 |
| MemWrite\_E | O | 来自E级的存储器写使能信号 |
| RegWrite\_E | O | 来自E级的寄存器写使能信号 |
| ALUSrc\_E | O | 来自E级的alu B端选择控制信号 |
| MemtoReg\_E[1:0] | O | 来自E级的寄存器WD选择控制信号 |

(13) M级流水寄存器

|  |  |  |
| --- | --- | --- |
| 信号名 | 方向 | 描述 |
| clk | I | 时钟信号 |
| reset | I | 复位信号 |
| IR\_E[31:0] | I | 来自E级的指令 |
| PC4\_E[31:0] | I | 来自E级的PC+4 |
| RT\_E[31:0] | I | 来自E级的寄存器第二个输出值或者转发值 |
| ALUOut\_E[31:0] | I | 来自E级的ALU结果 |
| Imm\_E[31:0] | I | 来自E级的扩展后的立即数 |
| WA\_E[4:0] | I | 来自E级的寄存器写入地址 |
| MemWrite\_E | I | 来自E级的存储器写使能信号 |
| RegWrite\_E | I | 来自E级的寄存器写使能信号 |
| MemtoReg\_E[1:0] | I | 来自E级的寄存器WD选择控制信号 |
| IR\_M[31:0] | O | 来自M级的指令 |
| PC4\_M[31:0] | O | 来自M级的PC+4 |
| RT\_M[31:0] | O | 来自M级的寄存器第二个输出值或者转发值 |
| ALUOut\_M[31:0] | O | 来自M级的ALU结果 |
| Imm\_M[31:0] | O | 来自M级的扩展后的立即数 |
| WA\_M[4:0] | O | 来自M级的寄存器写入地址 |
| MemWrite\_M | O | 来自M级的存储器写使能信号 |
| RegWrite\_M | O | 来自M级的寄存器写使能信号 |
| MemtoReg\_M[1:0] | O | 来自M级的寄存器WD选择控制信号 |

(14) W级流水寄存器

|  |  |  |
| --- | --- | --- |
| 信号名 | 方向 | 描述 |
| clk | I | 时钟信号 |
| reset | I | 复位信号 |
| IR\_E[31:0] | I | 来自E级的指令 |
| PC4\_E[31:0] | I | 来自E级的PC+4 |
| RT\_E[31:0] | I | 来自E级的寄存器第二个输出值或者转发值 |
| ALUOut\_E[31:0] | I | 来自E级的ALU结果 |
| Imm\_E[31:0] | I | 来自E级的扩展后的立即数 |
| WA\_E[4:0] | I | 来自E级的寄存器写入地址 |
| MemWrite\_E | I | 来自E级的存储器写使能信号 |
| RegWrite\_E | I | 来自E级的寄存器写使能信号 |
| MemtoReg\_E[1:0] | I | 来自E级的寄存器WD选择控制信号 |
| IR\_M[31:0] | O | 来自M级的指令 |
| PC4\_M[31:0] | O | 来自M级的PC+4 |
| RT\_M[31:0] | O | 来自M级的寄存器第二个输出值或者转发值 |
| ALUOut\_M[31:0] | O | 来自M级的ALU结果 |
| Imm\_M[31:0] | O | 来自M级的扩展后的立即数 |
| WA\_M[4:0] | O | 来自M级的寄存器写入地址 |
| MemWrite\_M | O | 来自M级的存储器写使能信号 |
| RegWrite\_M | O | 来自M级的寄存器写使能信号 |
| MemtoReg\_M[1:0] | O | 来自M级的寄存器WD选择控制信号 |

1. 控制器设计

**详细见excel**

1. 测试程序与结果

观察方法：

1，通过观察转发信号（五个Forward）

2，grf与dm的display

暂停测试代码：

addu $1,$2,$3 #Stall

beq $1,$4,label1

nop

label1:

nop

nop

nop

addu $1,$2,$3 #Stall

beq $4,$1,label2

nop

label2:

nop

nop

nop

ori $1,$2,100 #Stall

beq $3,$1,label3

nop

label3:

nop

nop

nop

ori $1,$2,100 #Stall

beq $1,$3,label4

nop

label4:

nop

nop

nop

#####################

lw $1,($0) #Stall

beq $1,$2,label9

nop

label9:

nop

nop

nop

lw $1,($0) #Stall

beq $2,$1,label10

nop

label10:

nop

nop

nop

lw $1,($0) #Stall

addu $2,$1,$3

nop

nop

nop

lw $1,($0) #Stall

subu $2,$3,$1

nop

nop

nop

lw $1,($0) #Stall

lw $2,($1)

nop

nop

nop

lw $1,($0) #Stall

sw $2,($1)

nop

nop

nop

lw $1,($0) #Stall

sw $1,($2)

nop

nop

nop

lw $1,($0) #Stall

nop

beq $1,$2,label11

nop

label11:

nop

nop

nop

lw $1,($0) #Stall

nop

beq $2,$1,label12

nop

label12:

nop

nop

nop

测试结果：

（注意这里输出只是参考，更重要的是查看波形，Stall=1的峰数是否与注释个数一致）

9@00003000: $ 1 <= 00000000

23@00003018: $ 1 <= 00000000

37@00003030: $ 1 <= 00000064

51@00003048: $ 1 <= 00000064

65@00003060: $ 1 <= 00000000

81@00003078: $ 1 <= 00000000

97@00003090: $ 1 <= 00000000

101@00003094: $ 2 <= 00000000

109@000030a4: $ 1 <= 00000000

113@000030a8: $ 2 <= 00000000

121@000030b8: $ 1 <= 00000000

125@000030bc: $ 2 <= 00000000

133@000030cc: $ 1 <= 00000000

135@000030d0: \*00000000 <= 00000000

145@000030e0: $ 1 <= 00000000

147@000030e4: \*00000000 <= 00000000

157@000030f4: $ 1 <= 00000000

173@00003110: $ 1 <= 00000000

RS\_D测试代码：

lui $1,100 #5

beq $1,$2,label1

nop

label1:

nop

nop

nop

jal label2 #3

label2:

beq $31,$1,label3

nop

label3:

nop

nop

nop

addu $1,$2,$3 #1

nop

beq $1,$2,label4

nop

label4:

nop

nop

nop

ori $1,$2,100 #1

nop

beq $1,$2,label5

nop

label5:

nop

nop

nop

lui $1,100 #4

nop

beq $1,$2,label6

nop

label6:

nop

nop

nop

jal label7 #2

label7:

nop

beq $31,$1,label8

nop

label8:

nop

nop

nop

lw $1,($0) #1

nop

beq $1,$2,label9

nop

label9:

nop

nop

nop

测试结果：

9@00003000: $ 1 <= 00640000

21@00003018: $31 <= 00003020

35@00003030: $ 1 <= 00000000

49@0000304c: $ 1 <= 00000064

63@00003068: $ 1 <= 00640000

77@00003084: $31 <= 0000308c

93@000030a0: $ 1 <= 00000000

RS\_E测试代码：

addu $1,$2,$3 #RS\_E

subu $5,$1,$4

nop

nop

nop

addu $1,$2,$3 #RS\_E

ori $4,$1,7

nop

nop

nop

addu $1,$2,$3 #RS\_E

lw $4,($1)

nop

nop

nop

addu $1,$2,$3 #RS\_E

sw $4,($1)

nop

nop

nop

ori $1,$2,100 #RS\_E

subu $5,$1,$4

nop

nop

nop

ori $1,$2,100 #RS\_E

ori $4,$1,7

nop

nop

nop

ori $1,$2,100 #RS\_E

lw $4,($1)

nop

nop

nop

ori $1,$2,100 #RS\_E

sw $4,($1)

nop

nop

nop

jal label #RS\_E

subu $5,$31,$4

nop

nop

nop

jal label #RS\_E

ori $4,$31,7

nop

nop

nop

jal label #RS\_E

lw $4,($31)

nop

nop

nop

jal label #RS\_E

sw $4,($31)

nop

nop

nop

lui $1,100 #RS\_E

subu $5,$1,$4

nop

nop

nop

lui $1,100 #RS\_E

ori $4,$1,7

nop

nop

nop

lui $1,100 #RS\_E

lw $4,($1)

nop

nop

nop

lui $1,100 #RS\_E

sw $4,($1)

nop

nop

nop

addu $1,$2,$3 #RS\_E

nop

subu $5,$1,$4

nop

nop

nop

addu $1,$2,$3 #RS\_E

nop

ori $4,$1,7

nop

nop

nop

addu $1,$2,$3 #RS\_E

nop

lw $4,($1)

nop

nop

nop

addu $1,$2,$3 #RS\_E

nop

sw $4,($1)

nop

nop

nop

ori $1,$2,100 #RS\_E

nop

subu $5,$1,$4

nop

nop

nop

ori $1,$2,100 #RS\_E

nop

ori $4,$1,7

nop

nop

nop

ori $1,$2,100 #RS\_E

nop

lw $4,($1)

nop

nop

nop

ori $1,$2,100 #RS\_E

nop

sw $4,($1)

nop

nop

nop

jal label #RS\_E

nop

subu $5,$31,$4

nop

nop

nop

jal label #RS\_E

nop

ori $4,$31,7

nop

nop

nop

jal label #RS\_E

nop

lw $4,($31)

nop

nop

nop

jal label #RS\_E

nop

sw $4,($31)

nop

nop

nop

lui $1,100 #RS\_E

nop

subu $5,$1,$4

nop

nop

nop

lui $1,100 #RS\_E

nop

ori $4,$1,7

nop

nop

nop

lui $1,100 #RS\_E

nop

lw $4,($1)

nop

nop

nop

lui $1,100 #RS\_E

nop

sw $4,($1)

nop

nop

nop

nop

nop

nop

nop

nop

nop

label:

jr $31

测试结果：

9@00003000: $ 1 <= 00000000

11@00003004: $ 5 <= 00000000

19@00003014: $ 1 <= 00000000

21@00003018: $ 4 <= 00000007

29@00003028: $ 1 <= 00000000

31@0000302c: $ 4 <= 00000000

39@0000303c: $ 1 <= 00000000

39@00003040: \*00000000 <= 00000000

49@00003050: $ 1 <= 00000064

51@00003054: $ 5 <= 00000064

59@00003064: $ 1 <= 00000064

61@00003068: $ 4 <= 00000067

69@00003078: $ 1 <= 00000064

71@0000307c: $ 4 <= 00000000

79@0000308c: $ 1 <= 00000064

79@00003090: \*00000064 <= 00000000

89@000030a0: $31 <= 000030a8

91@000030a4: $ 5 <= 000030a8

105@000030b4: $31 <= 000030bc

107@000030b8: $ 4 <= 000030bf

121@000030c8: $31 <= 000030d0

123@000030cc: $ 4 <= 00000000

139@000030dc: $31 <= 000030e4

139@000030e0: \*000030e4 <= 00000000

155@000030f0: $ 1 <= 00640000

157@000030f4: $ 5 <= 00640000

165@00003104: $ 1 <= 00640000

167@00003108: $ 4 <= 00640007

175@00003118: $ 1 <= 00640000

177@0000311c: $ 4 <= 00000000

185@0000312c: $ 1 <= 00640000

185@00003130: \*00000000 <= 00000000

195@00003140: $ 1 <= 00000000

199@00003148: $ 5 <= 00000000

207@00003158: $ 1 <= 00000000

211@00003160: $ 4 <= 00000007

219@00003170: $ 1 <= 00000000

223@00003178: $ 4 <= 00000000

231@00003188: $ 1 <= 00000000

233@00003190: \*00000000 <= 00000000

243@000031a0: $ 1 <= 00000064

247@000031a8: $ 5 <= 00000064

255@000031b8: $ 1 <= 00000064

259@000031c0: $ 4 <= 00000067

267@000031d0: $ 1 <= 00000064

271@000031d8: $ 4 <= 00000000

279@000031e8: $ 1 <= 00000064

281@000031f0: \*00000064 <= 00000000

291@00003200: $31 <= 00003208

299@00003208: $ 5 <= 00003208

309@00003218: $31 <= 00003220

317@00003220: $ 4 <= 00003227

327@00003230: $31 <= 00003238

335@00003238: $ 4 <= 00000000

345@00003248: $31 <= 00003250

351@00003250: \*00003250 <= 00000000

363@00003260: $ 1 <= 00640000

367@00003268: $ 5 <= 00640000

375@00003278: $ 1 <= 00640000

379@00003280: $ 4 <= 00640007

387@00003290: $ 1 <= 00640000

391@00003298: $ 4 <= 00000000

399@000032a8: $ 1 <= 00640000

401@000032b0: \*00000000 <= 00000000

425@00003250: \*00003250 <= 00000000

437@00003260: $ 1 <= 00640000

441@00003268: $ 5 <= 00640000

449@00003278: $ 1 <= 00640000

453@00003280: $ 4 <= 00640007

461@00003290: $ 1 <= 00640000

465@00003298: $ 4 <= 00000000

473@000032a8: $ 1 <= 00640000

475@000032b0: \*00000000 <= 00000000

499@00003250: \*00003250 <= 00000000

511@00003260: $ 1 <= 00640000

515@00003268: $ 5 <= 00640000

523@00003278: $ 1 <= 00640000

527@00003280: $ 4 <= 00640007

535@00003290: $ 1 <= 00640000

539@00003298: $ 4 <= 00000000

547@000032a8: $ 1 <= 00640000

549@000032b0: \*00000000 <= 00000000

573@00003250: \*00003250 <= 00000000

585@00003260: $ 1 <= 00640000

589@00003268: $ 5 <= 00640000

597@00003278: $ 1 <= 00640000

601@00003280: $ 4 <= 00640007

609@00003290: $ 1 <= 00640000

613@00003298: $ 4 <= 00000000

621@000032a8: $ 1 <= 00640000

623@000032b0: \*00000000 <= 00000000

647@00003250: \*00003250 <= 00000000

659@00003260: $ 1 <= 00640000

663@00003268: $ 5 <= 00640000

671@00003278: $ 1 <= 00640000

675@00003280: $ 4 <= 00640007

683@00003290: $ 1 <= 00640000

687@00003298: $ 4 <= 00000000

695@000032a8: $ 1 <= 00640000

697@000032b0: \*00000000 <= 00000000

721@00003250: \*00003250 <= 00000000

733@00003260: $ 1 <= 00640000

737@00003268: $ 5 <= 00640000

745@00003278: $ 1 <= 00640000

749@00003280: $ 4 <= 00640007

757@00003290: $ 1 <= 00640000

761@00003298: $ 4 <= 00000000

769@000032a8: $ 1 <= 00640000

771@000032b0: \*00000000 <= 00000000

795@00003250: \*00003250 <= 00000000

807@00003260: $ 1 <= 00640000

811@00003268: $ 5 <= 00640000

819@00003278: $ 1 <= 00640000

823@00003280: $ 4 <= 00640007

831@00003290: $ 1 <= 00640000

835@00003298: $ 4 <= 00000000

843@000032a8: $ 1 <= 00640000

845@000032b0: \*00000000 <= 00000000

869@00003250: \*00003250 <= 00000000

881@00003260: $ 1 <= 00640000

885@00003268: $ 5 <= 00640000

893@00003278: $ 1 <= 00640000

897@00003280: $ 4 <= 00640007

905@00003290: $ 1 <= 00640000

909@00003298: $ 4 <= 00000000

917@000032a8: $ 1 <= 00640000

919@000032b0: \*00000000 <= 00000000

943@00003250: \*00003250 <= 00000000

955@00003260: $ 1 <= 00640000

959@00003268: $ 5 <= 00640000

967@00003278: $ 1 <= 00640000

971@00003280: $ 4 <= 00640007

979@00003290: $ 1 <= 00640000

983@00003298: $ 4 <= 00000000

991@000032a8: $ 1 <= 00640000

993@000032b0: \*00000000 <= 00000000

RT\_D测试代码：

lui $1,100

beq $2,$1,label1

nop

label1:

nop

nop

nop

jal label2 #3

label2:

beq $1,$31,label3

nop

label3:

nop

nop

nop

addu $1,$2,$3 #1

nop

beq $2,$1,label4

nop

label4:

nop

nop

nop

ori $1,$2,100 #1

nop

beq $2,$1,label5

nop

label5:

nop

nop

nop

lui $1,100 #4

nop

beq $2,$1,label6

nop

label6:

nop

nop

nop

jal label7 #2

label7:

nop

beq $1,$31,label8

nop

label8:

nop

nop

nop

lw $1,($0) #1

nop

beq $2,$1,label9

nop

label9:

nop

nop

nop

测试结果：

9@00003000: $ 1 <= 00640000

21@00003018: $31 <= 00003020

35@00003030: $ 1 <= 00000000

49@0000304c: $ 1 <= 00000064

63@00003068: $ 1 <= 00640000

77@00003084: $31 <= 0000308c

93@000030a0: $ 1 <= 00000000

RT\_E测试代码：

addu $1,$2,$3 #RT\_E

subu $5,$4,$1

nop

nop

nop

ori $1,$2,100 #RT\_E

subu $5,$4,$1

nop

nop

nop

jal label #RT\_E

subu $5,$4,$31

nop

nop

nop

lui $1,100 #RT\_E

subu $5,$4,$1

nop

nop

nop

addu $1,$2,$3 #RT\_E

nop

subu $5,$4,$1

nop

nop

nop

ori $1,$2,100 #RT\_E

nop

subu $5,$4,$1

nop

nop

nop

jal label #RT\_E

nop

subu $5,$4,$31

nop

nop

nop

lui $1,100 #RT\_E

nop

subu $5,$4,$1

nop

nop

nop

addu $1,$2,$3 #RT\_E

nop

sw $1,($0)

nop

nop

nop

ori $1,$2,100 #RT\_E

nop

sw $1,($0)

nop

nop

nop

jal label #RT\_E

nop

sw $1,($0)

nop

nop

nop

lui $1,100 #RT\_E

nop

sw $1,($0)

nop

nop

nop

nop

nop

nop

nop

nop

nop

label:

jr $31

测试结果：

9@00003000: $ 1 <= 00000000

11@00003004: $ 5 <= 00000000

19@00003014: $ 1 <= 00000064

21@00003018: $ 5 <= ffffff9c

29@00003028: $31 <= 00003030

31@0000302c: $ 5 <= ffffcfd0

45@0000303c: $ 1 <= 00640000

47@00003040: $ 5 <= ff9c0000

55@00003050: $ 1 <= 00000000

59@00003058: $ 5 <= 00000000

67@00003068: $ 1 <= 00000064

71@00003070: $ 5 <= ffffff9c

79@00003080: $31 <= 00003088

87@00003088: $ 5 <= ffffcf78

97@00003098: $ 1 <= 00640000

101@000030a0: $ 5 <= ff9c0000

109@000030b0: $ 1 <= 00000000

111@000030b8: \*00000000 <= 00000000

121@000030c8: $ 1 <= 00000064

123@000030d0: \*00000000 <= 00000064

133@000030e0: $31 <= 000030e8

139@000030e8: \*00000000 <= 00000064

151@000030f8: $ 1 <= 00640000

153@00003100: \*00000000 <= 00640000

177@000030e8: \*00000000 <= 00640000

189@000030f8: $ 1 <= 00640000

191@00003100: \*00000000 <= 00640000

215@000030e8: \*00000000 <= 00640000

227@000030f8: $ 1 <= 00640000

229@00003100: \*00000000 <= 00640000

253@000030e8: \*00000000 <= 00640000

265@000030f8: $ 1 <= 00640000

267@00003100: \*00000000 <= 00640000

291@000030e8: \*00000000 <= 00640000

303@000030f8: $ 1 <= 00640000

305@00003100: \*00000000 <= 00640000

329@000030e8: \*00000000 <= 00640000

341@000030f8: $ 1 <= 00640000

343@00003100: \*00000000 <= 00640000

367@000030e8: \*00000000 <= 00640000

379@000030f8: $ 1 <= 00640000

381@00003100: \*00000000 <= 00640000

405@000030e8: \*00000000 <= 00640000

417@000030f8: $ 1 <= 00640000

419@00003100: \*00000000 <= 00640000

443@000030e8: \*00000000 <= 00640000

455@000030f8: $ 1 <= 00640000

457@00003100: \*00000000 <= 00640000

481@000030e8: \*00000000 <= 00640000

493@000030f8: $ 1 <= 00640000

495@00003100: \*00000000 <= 00640000

519@000030e8: \*00000000 <= 00640000

531@000030f8: $ 1 <= 00640000

533@00003100: \*00000000 <= 00640000

557@000030e8: \*00000000 <= 00640000

569@000030f8: $ 1 <= 00640000

571@00003100: \*00000000 <= 00640000

595@000030e8: \*00000000 <= 00640000

607@000030f8: $ 1 <= 00640000

609@00003100: \*00000000 <= 00640000

633@000030e8: \*00000000 <= 00640000

645@000030f8: $ 1 <= 00640000

647@00003100: \*00000000 <= 00640000

671@000030e8: \*00000000 <= 00640000

683@000030f8: $ 1 <= 00640000

685@00003100: \*00000000 <= 00640000

709@000030e8: \*00000000 <= 00640000

721@000030f8: $ 1 <= 00640000

723@00003100: \*00000000 <= 00640000

747@000030e8: \*00000000 <= 00640000

759@000030f8: $ 1 <= 00640000

761@00003100: \*00000000 <= 00640000

785@000030e8: \*00000000 <= 00640000

797@000030f8: $ 1 <= 00640000

799@00003100: \*00000000 <= 00640000

823@000030e8: \*00000000 <= 00640000

835@000030f8: $ 1 <= 00640000

837@00003100: \*00000000 <= 00640000

861@000030e8: \*00000000 <= 00640000

873@000030f8: $ 1 <= 00640000

875@00003100: \*00000000 <= 00640000

899@000030e8: \*00000000 <= 00640000

911@000030f8: $ 1 <= 00640000

913@00003100: \*00000000 <= 00640000

937@000030e8: \*00000000 <= 00640000

949@000030f8: $ 1 <= 00640000

951@00003100: \*00000000 <= 00640000

975@000030e8: \*00000000 <= 00640000

987@000030f8: $ 1 <= 00640000

989@00003100: \*00000000 <= 00640000

跳转指令强测：

jal label1 #Stall

nop

jal label2 #Stall

nop

jal label3 #Stall

nop

jal label4 #Stall

nop

beq $5,$6,end

addu $5,$6,$7

addu $6,$7,$8

label4:

sw $31,($0)

lw $31,($0)

nop

jr $31

nop

addu $5,$6,$7

addu $6,$7,$8

label3:

sw $31,($0)

lw $31,($0)

jr $31

nop

addu $5,$6,$7

addu $6,$7,$8

label2:

ori $31,$31,0

jr $31

nop

addu $5,$6,$7

addu $6,$7,$8

label1:

addu $31,$31,$0

jr $31

nop

end:

addu $1,$0,$0

nop

nop

nop

nop

nop

nop

测试结果：

9@00003000: $31 <= 00003008

13@00003074: $31 <= 00003008

21@00003008: $31 <= 00003010

25@00003060: $31 <= 00003010

33@00003010: $31 <= 00003018

35@00003048: \*00000000 <= 00003018

39@0000304c: $31 <= 00003018

49@00003018: $31 <= 00003020

51@0000302c: \*00000000 <= 00003020

55@00003030: $31 <= 00003020

67@00003024: $ 5 <= 00000000

69@00003080: $ 1 <= 00000000

乘除模块测试：

li $t0, 0x7fffffff

li $t1, 0xffffffff

li $t2, 0x80000000

mult $t0, $t0

mfhi $s0

mflo $s1

multu $t0, $t0

mfhi $s2

mfhi $s3

mult $t1, $t1

mfhi $s4

mflo $s5

multu $t1, $t1

mfhi $s6

mflo $s7

mult $t2, $t2

mfhi $s0

mflo $s1

multu $t2, $t2

mfhi $s2

mflo $s3

mult $t0, $t1

mfhi $s0

mflo $s1

multu $t0, $t1

mfhi $s2

mflo $s3

mult $t0, $t2

mfhi $s4

mflo $s5

multu $t0, $t2

mfhi $s6

mflo $s7

mult $t1, $t2

mfhi $s0

mflo $s1

multu $t1, $t2

mfhi $s2

mflo $s3

mult $0, $t1

mfhi $s2

mflo $s3

multu $t1, $0

mfhi $s4

mflo $s5

div $t0, $t0

mfhi $s0

mflo $s1

divu $t0, $t0

mfhi $s2

mflo $s3

div $t1, $t1

mfhi $s4

mflo $s5

divu $t1, $t1

mfhi $s6

mflo $s7

div $t2, $t2

mfhi $s0

mflo $s1

divu $t2, $t2

mfhi $s2

mflo $s3

div $t0, $t1

mfhi $s0

mflo $s1

div $t1, $t0

mfhi $s2

mflo $s3

divu $t0, $t1

mfhi $s4

mflo $s5

divu $t1, $t0

mfhi $s6

mflo $s7

div $t0, $t2

mfhi $s0

mflo $s1

div $t2, $t0

mfhi $s2

mfhi $s3

divu $t0, $t2

mfhi $s4

mflo $s5

divu $t2, $t0

mfhi $s6

mflo $s7

div $t1, $t2

mfhi $s0

mflo $s1

div $t2, $t1

mfhi $s2

mflo $s3

divu $t1, $t2

mfhi $s4

mflo $s5

divu $t2, $t1

mfhi $s6

mflo $s7

div $0, $t1

mfhi $s0

mflo $s1

divu $0, $t1

mfhi $s0

mflo $s1

ori $t1, 1234

add $t0, $0, $t1

mthi $t0

mtlo $t0

mfhi $s0

mflo $s1

add $t0, $0, $t1

mtlo $t0

mthi $t0

mfhi $s2

mflo $s3

ori $t0 $0, 423

nop

mthi $t0

mtlo $t1

mfhi $s4

mflo $s5

ori $t0, $0, 8765

nop

nop

mthi $t0

mtlo $t0

mflo $s6

mfhi $s7

ori $t0, $0, 6543

nop

nop

nop

mthi $t0

mtlo $t0

mflo $s0

mfhi $s1

测试结果：

9@00003000: $ 1 <= 7fff0000

11@00003004: $ 8 <= 7fffffff

13@00003008: $ 9 <= ffffffff

15@0000300c: $ 1 <= 80000000

17@00003010: $10 <= 80000000

33@00003018: $16 <= 3fffffff

35@0000301c: $17 <= 00000001

51@00003024: $18 <= 3fffffff

53@00003028: $19 <= 3fffffff

69@00003030: $20 <= 00000000

71@00003034: $21 <= 00000001

87@0000303c: $22 <= fffffffe

89@00003040: $23 <= 00000001

105@00003048: $16 <= 40000000

107@0000304c: $17 <= 00000000

123@00003054: $18 <= 40000000

125@00003058: $19 <= 00000000

141@00003060: $16 <= ffffffff

143@00003064: $17 <= 80000001

159@0000306c: $18 <= 7ffffffe

161@00003070: $19 <= 80000001

177@00003078: $20 <= c0000000

179@0000307c: $21 <= 80000000

195@00003084: $22 <= 3fffffff

197@00003088: $23 <= 80000000

213@00003090: $16 <= 00000000

215@00003094: $17 <= 80000000

231@0000309c: $18 <= 7fffffff

233@000030a0: $19 <= 80000000

249@000030a8: $18 <= 00000000

251@000030ac: $19 <= 00000000

267@000030b4: $20 <= 00000000

269@000030b8: $21 <= 00000000

295@000030c0: $16 <= 00000000

297@000030c4: $17 <= 00000001

323@000030cc: $18 <= 00000000

325@000030d0: $19 <= 00000001

351@000030d8: $20 <= 00000000

353@000030dc: $21 <= 00000001

379@000030e4: $22 <= 00000000

381@000030e8: $23 <= 00000001

407@000030f0: $16 <= 00000000

409@000030f4: $17 <= 00000001

435@000030fc: $18 <= 00000000

437@00003100: $19 <= 00000001

463@00003108: $16 <= 00000000

465@0000310c: $17 <= 80000001

491@00003114: $18 <= ffffffff

493@00003118: $19 <= 00000000

519@00003120: $20 <= 7fffffff

521@00003124: $21 <= 00000000

547@0000312c: $22 <= 00000001

549@00003130: $23 <= 00000002

575@00003138: $16 <= 7fffffff

577@0000313c: $17 <= 00000000

603@00003144: $18 <= ffffffff

605@00003148: $19 <= ffffffff

631@00003150: $20 <= 7fffffff

633@00003154: $21 <= 00000000

659@0000315c: $22 <= 00000001

661@00003160: $23 <= 00000001

687@00003168: $16 <= ffffffff

689@0000316c: $17 <= 00000000

715@00003174: $18 <= 00000000

717@00003178: $19 <= 80000000

743@00003180: $20 <= 7fffffff

745@00003184: $21 <= 00000001

771@0000318c: $22 <= 80000000

773@00003190: $23 <= 00000000

799@00003198: $16 <= 00000000

801@0000319c: $17 <= 00000000

827@000031a4: $16 <= 00000000

829@000031a8: $17 <= 00000000

831@000031ac: $ 9 <= ffffffff

833@000031b0: $ 8 <= ffffffff

843@000031bc: $16 <= ffffffff

845@000031c0: $17 <= ffffffff

847@000031c4: $ 8 <= ffffffff

857@000031d0: $18 <= ffffffff

859@000031d4: $19 <= ffffffff

861@000031d8: $ 8 <= 000001a7

873@000031e8: $20 <= 000001a7

875@000031ec: $21 <= ffffffff

877@000031f0: $ 8 <= 0000223d

891@00003204: $22 <= 0000223d

893@00003208: $23 <= 0000223d

895@0000320c: $ 8 <= 0000198f

911@00003224: $16 <= 0000198f

913@00003228: $17 <= 0000198f

综合测试：

init\_1:j init\_44

lui $0, 58479

init\_2:j init\_61

lui $26, 40699

init\_3:nop

j init\_26

ori $29, 12340

init\_4:j init\_21

lui $9, 18793

init\_5:nop

j init\_9

ori $13, 19610

init\_6:j init\_38

ori $28, 17819

init\_7:nop

j init\_37

ori $27, 17810

init\_8:j init\_48

ori $14, 1324

init\_9:j init\_8

lui $14, 20958

init\_10:j init\_31

lui $4, 28505

init\_11:nop

j init\_13

ori $23, 24263

init\_12:j init\_16

ori $12, 2525

init\_13:j init\_62

lui $24, 49213

init\_14:j init\_59

ori $6, 27235

init\_15:j init\_52

ori $16, 28030

init\_16:j init\_5

lui $13, 39021

init\_17:j init\_23

lui $20, 45636

init\_18:nop

j init\_57

ori $7, 34738

init\_19:j init\_56

lui $22, 48232

init\_20:j init\_7

lui $27, 21269

init\_21:nop

j init\_24

ori $9, 60940

init\_22:j init\_47

lui $19, 24579

init\_23:j init\_53

ori $20, 23617

init\_24:j init\_27

lui $10, 4700

init\_25:nop

j init\_60

ori $5, 25135

init\_26:j init\_34

lui $30, 14559

init\_27:j init\_29

ori $10, 45253

init\_28:j init\_12

lui $12, 55820

init\_29:j init\_36

lui $11, 49875

init\_30:j init\_25

lui $5, 35220

init\_31:j init\_30

ori $4, 7615

init\_32:j begin

lui $31, 60984

init\_33:j init\_43

ori $2, 18084

init\_34:j init\_63

ori $30, 41019

init\_35:j init\_15

lui $16, 54272

init\_36:nop

j init\_28

ori $11, 2111

init\_37:j init\_6

lui $28, 33755

init\_38:j init\_3

lui $29, 26291

init\_39:nop

j init\_2

ori $25, 48740

init\_40:j init\_42

lui $1, 43965

init\_41:nop

j init\_19

ori $21, 27953

init\_42:nop

j init\_50

ori $1, 18337

init\_43:j init\_54

lui $3, 36555

init\_44:j init\_40

ori $0, 39840

init\_45:j init\_22

ori $18, 28396

init\_46:j init\_4

ori $8, 13173

init\_47:nop

j init\_17

ori $19, 60189

init\_48:j init\_49

lui $15, 28446

init\_49:nop

j init\_35

ori $15, 43996

init\_50:j init\_33

lui $2, 50534

init\_51:j init\_45

lui $18, 47692

init\_52:j init\_58

lui $17, 18098

init\_53:j init\_41

lui $21, 23125

init\_54:nop

j init\_10

ori $3, 34935

init\_55:j init\_39

lui $25, 37200

init\_56:j init\_64

ori $22, 41245

init\_57:j init\_46

lui $8, 16690

init\_58:nop

j init\_51

ori $17, 23659

init\_59:j init\_18

lui $7, 16431

init\_60:j init\_14

lui $6, 20586

init\_61:j init\_20

ori $26, 21724

init\_62:j init\_55

ori $24, 64211

init\_63:j init\_32

lui $31, 32491

init\_64:j init\_11

lui $23, 36591

begin:

ori $11, $11, 39941

sw $11, 0($0)

ori $22, $22, 13378

nop

sw $22, 4($0)

addu $8, $31, $16

nop

nop

sw $8, 8($0)

subu $20, $16, $6

sw $20, 12($0)

addu $9, $15, $7

nop

sw $9, 16($0)

addu $19, $23, $27

nop

nop

sw $19, 20($0)

subu $5, $1, $31

sw $5, 24($0)

addu $22, $6, $26

nop

sw $22, 28($0)

addu $10, $4, $18

nop

nop

sw $10, 32($0)

subu $19, $3, $0

sw $19, 36($0)

subu $22, $24, $1

nop

sw $22, 40($0)

subu $19, $10, $14

nop

nop

sw $19, 44($0)

subu $0, $19, $15

sw $0, 48($0)

ori $21, $21, 728

nop

sw $21, 52($0)

subu $13, $29, $4

nop

nop

sw $13, 56($0)

addu $11, $3, $1

sw $11, 60($0)

addu $27, $19, $11

nop

sw $27, 64($0)

addu $27, $16, $28

nop

nop

sw $27, 68($0)

ori $25, $25, 7272

sw $25, 72($0)

ori $31, $31, 65375

nop

sw $31, 76($0)

ori $13, $13, 65318

nop

nop

sw $13, 80($0)

ori $5, $5, 27677

sw $5, 84($0)

ori $13, $13, 30209

nop

sw $13, 88($0)

subu $16, $28, $20

nop

nop

sw $16, 92($0)

addu $6, $16, $21

sw $6, 96($0)

subu $22, $11, $31

nop

sw $22, 100($0)

subu $25, $23, $19

nop

nop

sw $25, 104($0)

ori $0, $0, 8927

sw $0, 108($0)

ori $24, $24, 21563

nop

sw $24, 112($0)

addu $13, $16, $11

nop

nop

sw $13, 116($0)

subu $14, $12, $27

sw $14, 120($0)

addu $15, $24, $27

nop

sw $15, 124($0)

subu $20, $1, $24

nop

nop

sw $20, 128($0)

subu $13, $28, $15

sw $13, 132($0)

ori $28, $28, 56842

nop

sw $28, 136($0)

addu $31, $6, $23

nop

nop

sw $31, 140($0)

ori $10, $10, 11112

sw $10, 144($0)

addu $21, $23, $9

nop

sw $21, 148($0)

subu $22, $16, $29

nop

nop

sw $22, 152($0)

addu $16, $1, $31

sw $16, 156($0)

subu $12, $15, $28

nop

sw $12, 160($0)

addu $6, $10, $22

nop

nop

sw $6, 164($0)

ori $12, $12, 14691

sw $12, 168($0)

ori $16, $16, 34145

nop

sw $16, 172($0)

ori $11, $11, 18551

nop

nop

sw $11, 176($0)

sw $sp, 180($0)

sw $ra, 184($0)

sw $at, 188($0)

ori $sp, $0, 4060

ori $1, $0, 32

jal foo1

nop

lui $1, 0

ori $1, 0

beq $1, $0, skip\_manual1

nop

j dl

nop

skip\_manual1:

lui $1, 10994

lui $2, 10994

beq $1, $2, skip\_manual2

nop

j dl

nop

skip\_manual2:

lui $3, 10995

nop

nop

beq $1, $3, dl

addu $4, $4, $3

lui $1, 0x6183

addu $2, $2, $1

lui $5, 0x8124

addu $4, $5, $1

subu $6, $6, $5

jal skip\_manual3

nop

sw $0, 4($0)

skip\_manual3:

sw $7, -0x3000($ra)

lw $ra, -0x3000($ra)

ori $ra, $0, 0

jal skip\_manual4

nop

sw $0, 8($0)

skip\_manual4:

beq $ra, $0, dl

nop

ori $ra, $0, 0

jal skip\_manual5

nop

sw $ra, 12($0)

skip\_manual5:

nop

beq $ra, $0, dl

nop

ori $4, $0, 4

ori $5, $0, 5

ori $1, $0, 1

addu $4, $4, $1

nop

nop

beq $4, $5, skip\_manual6

nop

sw $0, 16($0)

skip\_manual6:

ori $1, $0, 1

ori $2, $0, 2

ori $3, $0, 3

ori $4, $0, 4

ori $5, $0, 6

ori $6, $0, 5

subu $5, $5, $1

addu $6, $2, $1

beq $5, $6, dl

nop

jal skip\_manual8

nop

skip\_manual8:

addu $3, $3, $ra

subu $4, $4, $ra

jal foo

nop

jal fooo

nop

bgezal $0, foooo

nop

bgezal $0, fooooo

nop

sw $0, 192($0)

sw $1, 196($0)

sw $2, 200($0)

sw $3, 204($0)

sw $4, 208($0)

sw $5, 212($0)

sw $6, 216($0)

sw $7, 220($0)

sw $8, 224($0)

sw $9, 228($0)

sw $10, 232($0)

sw $11, 236($0)

sw $12, 240($0)

sw $13, 244($0)

sw $14, 248($0)

sw $15, 252($0)

sw $16, 256($0)

sw $17, 260($0)

sw $18, 264($0)

sw $19, 268($0)

sw $20, 272($0)

sw $21, 276($0)

sw $22, 280($0)

sw $23, 284($0)

sw $24, 288($0)

sw $25, 292($0)

sw $26, 296($0)

sw $27, 300($0)

sw $28, 304($0)

sw $29, 308($0)

sw $30, 312($0)

sw $31, 316($0)

lui $31, 63605

bgezal $31, tag\_0

nop

ori $ra, $0, 2

tag\_0:sw $ra, 320($0)

addu $14, $13, $7

bgezal $14, tag\_1

nop

ori $ra, $0, 2

tag\_1:sw $ra, 324($0)

lw $25, 12($0)

bgezal $25, tag\_2

nop

ori $ra, $0, 2

tag\_2:sw $ra, 328($0)

lui $29, 14949

nop

bgezal $29, tag\_3

nop

ori $ra, $0, 2

tag\_3:sw $ra, 332($0)

addu $10, $24, $1

nop

bgezal $10, tag\_4

nop

ori $ra, $0, 2

tag\_4:sw $ra, 336($0)

lw $12, 164($0)

nop

bgezal $12, tag\_5

nop

ori $ra, $0, 2

tag\_5:sw $ra, 340($0)

lui $31, 58593

nop

nop

bgezal $31, tag\_6

nop

ori $ra, $0, 2

tag\_6:sw $ra, 344($0)

addu $1, $7, $12

nop

nop

bgezal $1, tag\_7

nop

ori $ra, $0, 2

tag\_7:sw $ra, 348($0)

lw $20, 256($0)

nop

nop

bgezal $20, tag\_8

nop

ori $ra, $0, 2

tag\_8:sw $ra, 352($0)

lui $17, 19367

bgezal $17, tag\_9

nop

ori $ra, $0, 2

tag\_9:sw $ra, 356($0)

addu $8, $11, $11

bgezal $8, tag\_10

nop

ori $ra, $0, 2

tag\_10:sw $ra, 360($0)

lw $1, 132($0)

bgezal $1, tag\_11

nop

ori $ra, $0, 2

tag\_11:sw $ra, 364($0)

lui $18, 56313

nop

bgezal $18, tag\_12

nop

ori $ra, $0, 2

tag\_12:sw $ra, 368($0)

addu $23, $25, $24

nop

bgezal $23, tag\_13

nop

ori $ra, $0, 2

tag\_13:sw $ra, 372($0)

lw $20, 368($0)

nop

bgezal $20, tag\_14

nop

ori $ra, $0, 2

tag\_14:sw $ra, 376($0)

lui $21, 22951

nop

nop

bgezal $21, tag\_15

nop

ori $ra, $0, 2

tag\_15:sw $ra, 380($0)

addu $8, $10, $1

nop

nop

bgezal $8, tag\_16

nop

ori $ra, $0, 2

tag\_16:sw $ra, 384($0)

lw $4, 88($0)

nop

nop

bgezal $4, tag\_17

nop

ori $ra, $0, 2

tag\_17:sw $ra, 388($0)

ori $4, $0, 12

jal skip\_manual7

nop

skip\_manual7:

addu $ra, $ra, $4

jr $ra

ori $4, $0, 8

addu $ra, $ra, $4

nop

jr $ra

nop

dl:addu $ra, $0, $0

beq $0, $0, dl

nop

foo: jr $ra

ori $ra, $ra, 0xff

fooo: ori $6, $ra, 0xa

jr $ra

nop

foooo: jr $ra

ori $t8, $ra, 0xff

fooooo: ori $t9, $ra, 0xa

jr $ra

nop

foo1:

sw $a0, 0($sp)

sw $ra, 16($sp)

sw $a1, 4($sp)

sw $a2, 8($sp)

sw $a3, 12($sp)

sw $t0, 20($sp)

sw $t1, 24($sp)

sw $t2, 28($sp)

ori $s1, $0, 84

ori $s2, $0, 220

lw $t0, -40($s1)

lw $t1, -88($s2)

addu $a3, $t0, $t1

addu $a0, $a0, $t0

addu $a1, $a1, $t1

addu $t2, $a0, $a1

ori $a0, $t2, 11072

addu $t2, $t2, $t2

addu $t2, $t2, $t2

ori $a1, $t2, 30986

ori $a2, $a1, 0xf0

nop

beq $a2, $a1, skip1

nop

jal foo2

subu $sp, $sp, $1

skip1: lw $a3, 16($sp)

addu $sp, $sp, $1

nop

jr $a3

nop

foo2:

sw $a0, 0($sp)

sw $a1, 4($sp)

sw $ra, 16($sp)

sw $a2, 8($sp)

sw $a3, 12($sp)

sw $t0, 20($sp)

sw $t1, 24($sp)

sw $t2, 28($sp)

ori $s1, $0, 152

ori $s2, $0, 54

lw $t1, 326($s2)

lw $t0, 160($s1)

addu $a3, $t0, $t1

addu $a0, $a0, $t0

addu $a1, $a1, $t1

addu $t2, $a0, $a1

ori $a0, $t2, 21109

addu $t2, $t2, $t2

addu $t2, $t2, $t2

ori $a1, $t2, 60683

ori $a2, $a1, 0xf0

beq $a2, $a1, skip2

nop

jal foo3

subu $sp, $sp, $1

skip2: lw $a3, 16($sp)

jr $a3

addu $sp, $sp, $1

foo3:

sw $ra, 16($sp)

sw $a0, 0($sp)

sw $a1, 4($sp)

sw $a2, 8($sp)

sw $a3, 12($sp)

sw $t0, 20($sp)

sw $t1, 24($sp)

sw $t2, 28($sp)

ori $s1, $0, 139

ori $s2, $0, 302

lw $t0, -35($s1)

lw $t1, -34($s2)

addu $a3, $t0, $t1

addu $a0, $a0, $t0

addu $a1, $a1, $t1

addu $t2, $a0, $a1

ori $a0, $t2, 29202

addu $t2, $t2, $t2

addu $t2, $t2, $t2

ori $a1, $t2, 43269

ori $a2, $a1, 0xf0

nop

beq $a2, $a1, skip3

nop

jal foo13

subu $sp, $sp, $1

skip3: lw $a3, 16($sp)

addu $sp, $sp, $1

jr $a3

nop

foo4:

sw $a0, 0($sp)

sw $ra, 16($sp)

sw $a1, 4($sp)

sw $a2, 8($sp)

sw $a3, 12($sp)

sw $t0, 20($sp)

sw $t1, 24($sp)

sw $t2, 28($sp)

ori $s1, $0, 297

ori $s2, $0, 96

lw $t1, 104($s2)

lw $t0, -197($s1)

addu $a3, $t0, $t1

addu $a0, $a0, $t0

addu $a1, $a1, $t1

addu $t2, $a0, $a1

ori $a0, $t2, 14171

addu $t2, $t2, $t2

addu $t2, $t2, $t2

ori $a1, $t2, 18179

ori $a2, $a1, 0xf0

beq $a2, $a1, skip4

nop

jal foo11

subu $sp, $sp, $1

skip4: lw $a3, 16($sp)

addu $sp, $sp, $1

nop

jr $a3

nop

foo5:

sw $a0, 0($sp)

sw $a1, 4($sp)

sw $ra, 16($sp)

sw $a2, 8($sp)

sw $a3, 12($sp)

sw $t0, 20($sp)

sw $t1, 24($sp)

sw $t2, 28($sp)

ori $s1, $0, 106

ori $s2, $0, 190

lw $t0, -26($s1)

lw $t1, -82($s2)

addu $a3, $t0, $t1

addu $a0, $a0, $t0

addu $a1, $a1, $t1

addu $t2, $a0, $a1

ori $a0, $t2, 49045

addu $t2, $t2, $t2

addu $t2, $t2, $t2

ori $a1, $t2, 36619

ori $a2, $a1, 0xf0

nop

beq $a2, $a1, skip5

nop

jal foo1

subu $sp, $sp, $1

skip5: lw $a3, 16($sp)

jr $a3

addu $sp, $sp, $1

foo6:

sw $ra, 16($sp)

sw $a0, 0($sp)

sw $a1, 4($sp)

sw $a2, 8($sp)

sw $a3, 12($sp)

sw $t0, 20($sp)

sw $t1, 24($sp)

sw $t2, 28($sp)

ori $s1, $0, 345

ori $s2, $0, 52

lw $t1, -32($s2)

lw $t0, 15($s1)

addu $a3, $t0, $t1

addu $a0, $a0, $t0

addu $a1, $a1, $t1

addu $t2, $a0, $a1

ori $a0, $t2, 25874

addu $t2, $t2, $t2

addu $t2, $t2, $t2

ori $a1, $t2, 45316

ori $a2, $a1, 0xf0

beq $a2, $a1, skip6

nop

jal foo4

subu $sp, $sp, $1

skip6: lw $a3, 16($sp)

addu $sp, $sp, $1

jr $a3

nop

foo7:

sw $a0, 0($sp)

sw $ra, 16($sp)

sw $a1, 4($sp)

sw $a2, 8($sp)

sw $a3, 12($sp)

sw $t0, 20($sp)

sw $t1, 24($sp)

sw $t2, 28($sp)

ori $s1, $0, 319

ori $s2, $0, 212

lw $t0, -167($s1)

lw $t1, 120($s2)

addu $a3, $t0, $t1

addu $a0, $a0, $t0

addu $a1, $a1, $t1

addu $t2, $a0, $a1

ori $a0, $t2, 44079

addu $t2, $t2, $t2

addu $t2, $t2, $t2

ori $a1, $t2, 38407

ori $a2, $a1, 0xf0

nop

beq $a2, $a1, skip7

nop

jal foo10

subu $sp, $sp, $1

skip7: lw $a3, 16($sp)

addu $sp, $sp, $1

nop

jr $a3

nop

foo8:

sw $a0, 0($sp)

sw $a1, 4($sp)

sw $ra, 16($sp)

sw $a2, 8($sp)

sw $a3, 12($sp)

sw $t0, 20($sp)

sw $t1, 24($sp)

sw $t2, 28($sp)

ori $s1, $0, 366

ori $s2, $0, 244

lw $t1, -116($s2)

lw $t0, -290($s1)

addu $a3, $t0, $t1

addu $a0, $a0, $t0

addu $a1, $a1, $t1

addu $t2, $a0, $a1

ori $a0, $t2, 20552

addu $t2, $t2, $t2

addu $t2, $t2, $t2

ori $a1, $t2, 22025

ori $a2, $a1, 0xf0

beq $a2, $a1, skip8

nop

jal foo5

subu $sp, $sp, $1

skip8: lw $a3, 16($sp)

jr $a3

addu $sp, $sp, $1

foo9:

sw $ra, 16($sp)

sw $a0, 0($sp)

sw $a1, 4($sp)

sw $a2, 8($sp)

sw $a3, 12($sp)

sw $t0, 20($sp)

sw $t1, 24($sp)

sw $t2, 28($sp)

ori $s1, $0, 223

ori $s2, $0, 283

lw $t0, 13($s1)

lw $t1, -27($s2)

addu $a3, $t0, $t1

addu $a0, $a0, $t0

addu $a1, $a1, $t1

addu $t2, $a0, $a1

ori $a0, $t2, 28872

addu $t2, $t2, $t2

addu $t2, $t2, $t2

ori $a1, $t2, 52993

ori $a2, $a1, 0xf0

nop

beq $a2, $a1, skip9

nop

jal foo15

subu $sp, $sp, $1

skip9: lw $a3, 16($sp)

addu $sp, $sp, $1

jr $a3

nop

foo10:

sw $a0, 0($sp)

sw $ra, 16($sp)

sw $a1, 4($sp)

sw $a2, 8($sp)

sw $a3, 12($sp)

sw $t0, 20($sp)

sw $t1, 24($sp)

sw $t2, 28($sp)

ori $s1, $0, 228

ori $s2, $0, 255

lw $t1, -155($s2)

lw $t0, 12($s1)

addu $a3, $t0, $t1

addu $a0, $a0, $t0

addu $a1, $a1, $t1

addu $t2, $a0, $a1

ori $a0, $t2, 56866

addu $t2, $t2, $t2

addu $t2, $t2, $t2

ori $a1, $t2, 21770

ori $a2, $a1, 0xf0

beq $a2, $a1, skip10

nop

jal foo12

subu $sp, $sp, $1

skip10: lw $a3, 16($sp)

addu $sp, $sp, $1

nop

jr $a3

nop

foo11:

sw $a0, 0($sp)

sw $a1, 4($sp)

sw $ra, 16($sp)

sw $a2, 8($sp)

sw $a3, 12($sp)

sw $t0, 20($sp)

sw $t1, 24($sp)

sw $t2, 28($sp)

ori $s1, $0, 54

ori $s2, $0, 306

lw $t0, 278($s1)

lw $t1, -238($s2)

addu $a3, $t0, $t1

addu $a0, $a0, $t0

addu $a1, $a1, $t1

addu $t2, $a0, $a1

ori $a0, $t2, 34513

addu $t2, $t2, $t2

addu $t2, $t2, $t2

ori $a1, $t2, 36103

ori $a2, $a1, 0xf0

nop

beq $a2, $a1, skip11

nop

jal foo8

subu $sp, $sp, $1

skip11: lw $a3, 16($sp)

jr $a3

addu $sp, $sp, $1

foo12:

sw $ra, 16($sp)

sw $a0, 0($sp)

sw $a1, 4($sp)

sw $a2, 8($sp)

sw $a3, 12($sp)

sw $t0, 20($sp)

sw $t1, 24($sp)

sw $t2, 28($sp)

ori $s1, $0, 248

ori $s2, $0, 72

lw $t1, 152($s2)

lw $t0, 76($s1)

addu $a3, $t0, $t1

addu $a0, $a0, $t0

addu $a1, $a1, $t1

addu $t2, $a0, $a1

ori $a0, $t2, 1104

addu $t2, $t2, $t2

addu $t2, $t2, $t2

ori $a1, $t2, 24322

ori $a2, $a1, 0xf0

beq $a2, $a1, skip12

nop

jal foo9

subu $sp, $sp, $1

skip12: lw $a3, 16($sp)

addu $sp, $sp, $1

jr $a3

nop

foo13:

sw $a0, 0($sp)

sw $ra, 16($sp)

sw $a1, 4($sp)

sw $a2, 8($sp)

sw $a3, 12($sp)

sw $t0, 20($sp)

sw $t1, 24($sp)

sw $t2, 28($sp)

ori $s1, $0, 386

ori $s2, $0, 194

lw $t0, -82($s1)

lw $t1, -142($s2)

addu $a3, $t0, $t1

addu $a0, $a0, $t0

addu $a1, $a1, $t1

addu $t2, $a0, $a1

ori $a0, $t2, 18477

addu $t2, $t2, $t2

addu $t2, $t2, $t2

ori $a1, $t2, 2816

ori $a2, $a1, 0xf0

nop

beq $a2, $a1, skip13

nop

jal foo7

subu $sp, $sp, $1

skip13: lw $a3, 16($sp)

addu $sp, $sp, $1

nop

jr $a3

nop

foo14:

sw $a0, 0($sp)

sw $a1, 4($sp)

sw $ra, 16($sp)

sw $a2, 8($sp)

sw $a3, 12($sp)

sw $t0, 20($sp)

sw $t1, 24($sp)

sw $t2, 28($sp)

ori $s1, $0, 184

ori $s2, $0, 255

lw $t1, 13($s2)

lw $t0, -88($s1)

addu $a3, $t0, $t1

addu $a0, $a0, $t0

addu $a1, $a1, $t1

addu $t2, $a0, $a1

ori $a0, $t2, 26871

addu $t2, $t2, $t2

addu $t2, $t2, $t2

ori $a1, $t2, 23821

ori $a2, $a1, 0xf0

beq $a2, $a1, skip14

nop

jal foo16

subu $sp, $sp, $1

skip14: lw $a3, 16($sp)

jr $a3

addu $sp, $sp, $1

foo15:

sw $ra, 16($sp)

sw $a0, 0($sp)

sw $a1, 4($sp)

sw $a2, 8($sp)

sw $a3, 12($sp)

sw $t0, 20($sp)

sw $t1, 24($sp)

sw $t2, 28($sp)

ori $s1, $0, 264

ori $s2, $0, 366

lw $t0, -212($s1)

lw $t1, -2($s2)

addu $a3, $t0, $t1

addu $a0, $a0, $t0

addu $a1, $a1, $t1

addu $t2, $a0, $a1

ori $a0, $t2, 36680

addu $t2, $t2, $t2

addu $t2, $t2, $t2

ori $a1, $t2, 1289

ori $a2, $a1, 0xf0

nop

beq $a2, $a1, skip15

nop

jal foo14

subu $sp, $sp, $1

skip15: lw $a3, 16($sp)

addu $sp, $sp, $1

jr $a3

nop

foo16:

sw $a0, 0($sp)

sw $ra, 16($sp)

sw $a1, 4($sp)

sw $a2, 8($sp)

sw $a3, 12($sp)

sw $t0, 20($sp)

sw $t1, 24($sp)

sw $t2, 28($sp)

ori $s1, $0, 39

ori $s2, $0, 301

lw $t1, -17($s2)

lw $t0, 317($s1)

addu $a3, $t0, $t1

addu $a0, $a0, $t0

addu $a1, $a1, $t1

addu $t2, $a0, $a1

ori $a0, $t2, 706

addu $t2, $t2, $t2

addu $t2, $t2, $t2

ori $a1, $t2, 2561

ori $a2, $a1, 0xf0

beq $a2, $a1, skip16

nop

jal foo6

subu $sp, $sp, $1

skip16: lw $a3, 16($sp)

addu $sp, $sp, $1

nop

jr $a3

nop

测试结果：

11@00003004: $ 0 <= e46f0000

15@00003188: $ 0 <= 00009ba0

19@00003160: $ 1 <= abbd0000

25@00003178: $ 1 <= abbd47a1

29@000031c0: $ 2 <= c5660000

33@00003120: $ 2 <= c56646a4

37@00003180: $ 3 <= 8ecb0000

43@000031e4: $ 3 <= 8ecb8877

47@00003058: $ 4 <= 6f590000

51@00003110: $ 4 <= 6f591dbf

55@00003108: $ 5 <= 89940000

61@000030e0: $ 5 <= 8994622f

65@00003218: $ 6 <= 506a0000

69@0000307c: $ 6 <= 506a6a63

73@00003210: $ 7 <= 402f0000

79@000030a0: $ 7 <= 402f87b2

83@000031fc: $ 8 <= 41320000

87@00003198: $ 8 <= 41323375

91@00003020: $ 9 <= 49690000

97@000030bc: $ 9 <= 4969ee0c

101@000030d4: $10 <= 125c0000

105@000030f0: $10 <= 125cb0c5

109@00003100: $11 <= c2d30000

115@0000313c: $11 <= c2d3083f

119@000030f8: $12 <= da0c0000

123@0000306c: $12 <= da0c09dd

127@0000308c: $13 <= 986d0000

133@0000302c: $13 <= 986d4c9a

137@00003050: $14 <= 51de0000

141@00003048: $14 <= 51de052c

145@000031ac: $15 <= 6f1e0000

151@000031b8: $15 <= 6f1eabdc

155@00003130: $16 <= d4000000

159@00003084: $16 <= d4006d7e

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173@000031c8: $18 <= ba4c0000

177@00003190: $18 <= ba4c6eec

181@000030c4: $19 <= 60030000

187@000031a4: $19 <= 6003eb1d

191@00003094: $20 <= b2440000

195@000030cc: $20 <= b2445c41

199@000031d8: $21 <= 5a550000

205@0000316c: $21 <= 5a556d31

209@000030a8: $22 <= bc680000

213@000031f4: $22 <= bc68a11d

217@00003238: $23 <= 8eef0000

223@00003064: $23 <= 8eef5ec7

227@00003074: $24 <= c03d0000

231@00003228: $24 <= c03dfad3

235@000031ec: $25 <= 91500000

241@00003158: $25 <= 9150be64

245@0000300c: $26 <= 9efb0000

249@00003220: $26 <= 9efb54dc

253@000030b0: $27 <= 53150000

259@00003040: $27 <= 53154592

263@00003144: $28 <= 83db0000

267@00003034: $28 <= 83db459b

271@0000314c: $29 <= 66b30000

277@00003018: $29 <= 66b33034

281@000030e8: $30 <= 38df0000

285@00003128: $30 <= 38dfa03b

289@00003230: $31 <= 7eeb0000

293@00003118: $31 <= ee380000

295@0000323c: $11 <= c2d39c3f

295@00003240: \*00000000 <= c2d39c3f

299@00003244: $22 <= bc68b55f

301@0000324c: \*00000004 <= bc68b55f

305@00003250: $ 8 <= c2386d7e

309@0000325c: \*00000008 <= c2386d7e

313@00003260: $20 <= 8396031b

313@00003264: \*0000000c <= 8396031b

317@00003268: $ 9 <= af4e338e

319@00003270: \*00000010 <= af4e338e

323@00003274: $19 <= e204a459

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331@00003284: $ 5 <= bd8547a1

331@00003288: \*00000018 <= bd8547a1

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337@00003294: \*0000001c <= ef65bf3f

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363@000032c8: \*0000002c <= d7c7877f

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367@000032d0: \*00000030 <= 00000000

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373@000032dc: \*00000034 <= 5a556ff9

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385@000032f4: \*0000003c <= 3a88d018

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395@00003304: $27 <= 57dbb319

399@00003310: \*00000044 <= 57dbb319

403@00003314: $25 <= 9150be6c

403@00003318: \*00000048 <= 9150be6c

407@0000331c: $31 <= ee38ff5f

409@00003324: \*0000004c <= ee38ff5f

413@00003328: $13 <= f75aff77

417@00003334: \*00000050 <= f75aff77

421@00003338: $ 5 <= bd856fbd

421@0000333c: \*00000054 <= bd856fbd

425@00003340: $13 <= f75aff77

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435@00003358: \*0000005c <= 00454280

439@0000335c: $ 6 <= 5a9ab279

439@00003360: \*00000060 <= 5a9ab279

443@00003364: $22 <= 4c4fd0b9

445@0000336c: \*00000064 <= 4c4fd0b9

449@00003370: $25 <= b727d748

453@0000337c: \*00000068 <= b727d748

457@00003380: $ 0 <= 000022df

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461@00003388: $24 <= c03dfefb

463@00003390: \*00000070 <= c03dfefb

467@00003394: $13 <= 3ace1298

471@000033a0: \*00000074 <= 3ace1298

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475@000033a8: \*00000078 <= 823056c4

479@000033ac: $15 <= 1819b214

481@000033b4: \*0000007c <= 1819b214

485@000033b8: $20 <= eb7f48a6

489@000033c4: \*00000080 <= eb7f48a6

493@000033c8: $13 <= 6bc19387

493@000033cc: \*00000084 <= 6bc19387

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499@000033d8: \*00000088 <= 83dbdf9b

503@000033dc: $31 <= e98a1140

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511@000033f0: \*00000090 <= 29a5afeb

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517@000033fc: \*00000094 <= 3e3d9255

521@00003400: $22 <= 9992124c

525@0000340c: \*00000098 <= 9992124c

529@00003410: $16 <= 954758e1

529@00003414: \*0000009c <= 954758e1

533@00003418: $12 <= 943dd279

535@00003420: \*000000a0 <= 943dd279

539@00003424: $ 6 <= c337c237

543@00003430: \*000000a4 <= c337c237

547@00003434: $12 <= 943dfb7b

547@00003438: \*000000a8 <= 943dfb7b

551@0000343c: $16 <= 9547dde1

553@00003444: \*000000ac <= 9547dde1

557@00003448: $11 <= 3a88d87f

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565@0000345c: \*000000b8 <= e98a1140

567@00003460: \*000000bc <= abbd47a1

571@00003464: $29 <= 00000fdc

573@00003468: $ 1 <= 00000020

575@0000346c: $31 <= 00003474

577@0000381c: \*00000fdc <= 6f591dbf

579@00003820: \*00000fec <= 00003474

581@00003824: \*00000fe0 <= bd856fbd

583@00003828: \*00000fe4 <= c337c237

585@0000382c: \*00000fe8 <= 402f87b2

587@00003830: \*00000ff0 <= c2386d7e

589@00003834: \*00000ff4 <= af4e338e

591@00003838: \*00000ff8 <= 29a5afeb

595@0000383c: $17 <= 00000054

597@00003840: $18 <= 000000dc

599@00003844: $ 8 <= d7c7877f

601@00003848: $ 9 <= 6bc19387

605@0000384c: $ 7 <= 43891b06

607@00003850: $ 4 <= 4720a53e

609@00003854: $ 5 <= 29470344

611@00003858: $10 <= 7067a882

613@0000385c: $ 4 <= 7067abc2

615@00003860: $10 <= e0cf5104

617@00003864: $10 <= c19ea208

619@00003868: $ 5 <= c19efb0a

621@0000386c: $ 6 <= c19efbfa

629@0000387c: $31 <= 00003884

631@00003880: $29 <= 00000fbc

631@00003898: \*00000fbc <= 7067abc2

633@0000389c: \*00000fc0 <= c19efb0a

635@000038a0: \*00000fcc <= 00003884

637@000038a4: \*00000fc4 <= c19efbfa

639@000038a8: \*00000fc8 <= 43891b06

641@000038ac: \*00000fd0 <= d7c7877f

643@000038b0: \*00000fd4 <= 6bc19387

645@000038b4: \*00000fd8 <= c19ea208

649@000038b8: $17 <= 00000098

651@000038bc: $18 <= 00000036

653@000038c0: $ 9 <= 00000000

655@000038c4: $ 8 <= 00000000

659@000038c8: $ 7 <= 00000000

661@000038cc: $ 4 <= 7067abc2

663@000038d0: $ 5 <= c19efb0a

665@000038d4: $10 <= 3206a6cc

667@000038d8: $ 4 <= 3206f6fd

669@000038dc: $10 <= 640d4d98

671@000038e0: $10 <= c81a9b30

673@000038e4: $ 5 <= c81aff3b

675@000038e8: $ 6 <= c81afffb

683@000038f4: $31 <= 000038fc

685@000038f8: $29 <= 00000f9c

685@00003908: \*00000fac <= 000038fc

687@0000390c: \*00000f9c <= 3206f6fd

689@00003910: \*00000fa0 <= c81aff3b

691@00003914: \*00000fa4 <= c81afffb

693@00003918: \*00000fa8 <= 00000000

695@0000391c: \*00000fb0 <= 00000000

697@00003920: \*00000fb4 <= 00000000

699@00003924: \*00000fb8 <= c81a9b30

703@00003928: $17 <= 0000008b

705@0000392c: $18 <= 0000012e

707@00003930: $ 8 <= b727d748

709@00003934: $ 9 <= 00000000

713@00003938: $ 7 <= b727d748

715@0000393c: $ 4 <= e92ece45

717@00003940: $ 5 <= c81aff3b

719@00003944: $10 <= b149cd80

721@00003948: $ 4 <= b149ff92

723@0000394c: $10 <= 62939b00

725@00003950: $10 <= c5273600

727@00003954: $ 5 <= c527bf05

729@00003958: $ 6 <= c527bff5

737@00003968: $31 <= 00003970

739@0000396c: $29 <= 00000f7c

739@00003da4: \*00000f7c <= b149ff92

741@00003da8: \*00000f8c <= 00003970

743@00003dac: \*00000f80 <= c527bf05

745@00003db0: \*00000f84 <= c527bff5

747@00003db4: \*00000f88 <= b727d748

749@00003db8: \*00000f90 <= b727d748

751@00003dbc: \*00000f94 <= 00000000

753@00003dc0: \*00000f98 <= c5273600

757@00003dc4: $17 <= 00000182

759@00003dc8: $18 <= 000000c2

761@00003dcc: $ 8 <= 00000000

763@00003dd0: $ 9 <= 5a556ff9

767@00003dd4: $ 7 <= 5a556ff9

769@00003dd8: $ 4 <= b149ff92

771@00003ddc: $ 5 <= 1f7d2efe

773@00003de0: $10 <= d0c72e90

775@00003de4: $ 4 <= d0c76ebd

777@00003de8: $10 <= a18e5d20

779@00003dec: $10 <= 431cba40

781@00003df0: $ 5 <= 431cbb40

783@00003df4: $ 6 <= 431cbbf0

791@00003e04: $31 <= 00003e0c

793@00003e08: $29 <= 00000f5c

793@00003ae0: \*00000f5c <= d0c76ebd

795@00003ae4: \*00000f6c <= 00003e0c

797@00003ae8: \*00000f60 <= 431cbb40

799@00003aec: \*00000f64 <= 431cbbf0

801@00003af0: \*00000f68 <= 5a556ff9

803@00003af4: \*00000f70 <= 00000000

805@00003af8: \*00000f74 <= 5a556ff9

807@00003afc: \*00000f78 <= 431cba40

811@00003b00: $17 <= 0000013f

813@00003b04: $18 <= 000000d4

815@00003b08: $ 8 <= 9992124c

817@00003b0c: $ 9 <= 00000000

821@00003b10: $ 7 <= 9992124c

823@00003b14: $ 4 <= 6a598109

825@00003b18: $ 5 <= 431cbb40

827@00003b1c: $10 <= ad763c49

829@00003b20: $ 4 <= ad76bc6f

831@00003b24: $10 <= 5aec7892

833@00003b28: $10 <= b5d8f124

835@00003b2c: $ 5 <= b5d8f727

837@00003b30: $ 6 <= b5d8f7f7

845@00003b40: $31 <= 00003b48

847@00003b44: $29 <= 00000f3c

847@00003c44: \*00000f3c <= ad76bc6f

849@00003c48: \*00000f4c <= 00003b48

851@00003c4c: \*00000f40 <= b5d8f727

853@00003c50: \*00000f44 <= b5d8f7f7

855@00003c54: \*00000f48 <= 9992124c

857@00003c58: \*00000f50 <= 9992124c

859@00003c5c: \*00000f54 <= 00000000

861@00003c60: \*00000f58 <= b5d8f124

865@00003c64: $17 <= 000000e4

867@00003c68: $18 <= 000000ff

869@00003c6c: $ 9 <= 4c4fd0b9

871@00003c70: $ 8 <= 00000000

875@00003c74: $ 7 <= 4c4fd0b9

877@00003c78: $ 4 <= ad76bc6f

879@00003c7c: $ 5 <= 0228c7e0

881@00003c80: $10 <= af9f844f

883@00003c84: $ 4 <= af9fde6f

885@00003c88: $10 <= 5f3f089e

887@00003c8c: $10 <= be7e113c

889@00003c90: $ 5 <= be7e553e

891@00003c94: $ 6 <= be7e55fe

899@00003ca0: $31 <= 00003ca8

901@00003ca4: $29 <= 00000f1c

901@00003d30: \*00000f2c <= 00003ca8

903@00003d34: \*00000f1c <= af9fde6f

905@00003d38: \*00000f20 <= be7e553e

907@00003d3c: \*00000f24 <= be7e55fe

909@00003d40: \*00000f28 <= 4c4fd0b9

911@00003d44: \*00000f30 <= 00000000

913@00003d48: \*00000f34 <= 4c4fd0b9

915@00003d4c: \*00000f38 <= be7e113c

919@00003d50: $17 <= 000000f8

921@00003d54: $18 <= 00000048

923@00003d58: $ 9 <= 00000000

925@00003d5c: $ 8 <= 00000000

929@00003d60: $ 7 <= 00000000

931@00003d64: $ 4 <= af9fde6f

933@00003d68: $ 5 <= be7e553e

935@00003d6c: $10 <= 6e1e33ad

937@00003d70: $ 4 <= 6e1e37fd

939@00003d74: $10 <= dc3c675a

941@00003d78: $10 <= b878ceb4

943@00003d7c: $ 5 <= b878dfb6

945@00003d80: $ 6 <= b878dff6

953@00003d8c: $31 <= 00003d94

955@00003d90: $29 <= 00000efc

955@00003bcc: \*00000f0c <= 00003d94

957@00003bd0: \*00000efc <= 6e1e37fd

959@00003bd4: \*00000f00 <= b878dfb6

961@00003bd8: \*00000f04 <= b878dff6

963@00003bdc: \*00000f08 <= 00000000

965@00003be0: \*00000f10 <= 00000000

967@00003be4: \*00000f14 <= 00000000

969@00003be8: \*00000f18 <= b878ceb4

973@00003bec: $17 <= 000000df

975@00003bf0: $18 <= 0000011b

977@00003bf4: $ 8 <= 00000000

979@00003bf8: $ 9 <= 00000000

983@00003bfc: $ 7 <= 00000000

985@00003c00: $ 4 <= 6e1e37fd

987@00003c04: $ 5 <= b878dfb6

989@00003c08: $10 <= 269717b3

991@00003c0c: $ 4 <= 269777fb

993@00003c10: $10 <= 4d2e2f66

995@00003c14: $10 <= 9a5c5ecc

997@00003c18: $ 5 <= 9a5cdfcd

999@00003c1c: $ 6 <= 9a5cdffd

1007@00003c2c: $31 <= 00003c34

1009@00003c30: $29 <= 00000edc

1009@00003e90: \*00000eec <= 00003c34

1011@00003e94: \*00000edc <= 269777fb

1013@00003e98: \*00000ee0 <= 9a5cdfcd

1015@00003e9c: \*00000ee4 <= 9a5cdffd

1017@00003ea0: \*00000ee8 <= 00000000

1019@00003ea4: \*00000ef0 <= 00000000

1021@00003ea8: \*00000ef4 <= 00000000

1023@00003eac: \*00000ef8 <= 9a5c5ecc

1027@00003eb0: $17 <= 00000108

1029@00003eb4: $18 <= 0000016e

1031@00003eb8: $ 8 <= 5a556ff9

1033@00003ebc: $ 9 <= 00000000

1037@00003ec0: $ 7 <= 5a556ff9

1039@00003ec4: $ 4 <= 80ece7f4

1041@00003ec8: $ 5 <= 9a5cdfcd

1043@00003ecc: $10 <= 1b49c7c1

1045@00003ed0: $ 4 <= 1b49cfc9

1047@00003ed4: $10 <= 36938f82

1049@00003ed8: $10 <= 6d271f04

1051@00003edc: $ 5 <= 6d271f0d

1053@00003ee0: $ 6 <= 6d271ffd

1061@00003ef0: $31 <= 00003ef8

1063@00003ef4: $29 <= 00000ebc

1063@00003e20: \*00000ebc <= 1b49cfc9

1065@00003e24: \*00000ec0 <= 6d271f0d

1067@00003e28: \*00000ecc <= 00003ef8

1069@00003e2c: \*00000ec4 <= 6d271ffd

1071@00003e30: \*00000ec8 <= 5a556ff9

1073@00003e34: \*00000ed0 <= 5a556ff9

1075@00003e38: \*00000ed4 <= 00000000

1077@00003e3c: \*00000ed8 <= 6d271f04

1081@00003e40: $17 <= 000000b8

1083@00003e44: $18 <= 000000ff

1085@00003e48: $ 9 <= 00000000

1087@00003e4c: $ 8 <= 5a9ab279

1091@00003e50: $ 7 <= 5a9ab279

1093@00003e54: $ 4 <= 75e48242

1095@00003e58: $ 5 <= 6d271f0d

1097@00003e5c: $10 <= e30ba14f

1099@00003e60: $ 4 <= e30be9ff

1101@00003e64: $10 <= c617429e

1103@00003e68: $10 <= 8c2e853c

1105@00003e6c: $ 5 <= 8c2edd3d

1107@00003e70: $ 6 <= 8c2eddfd

1115@00003e7c: $31 <= 00003e84

1117@00003e80: $29 <= 00000e9c

1117@00003f08: \*00000e9c <= e30be9ff

1119@00003f0c: \*00000eac <= 00003e84

1121@00003f10: \*00000ea0 <= 8c2edd3d

1123@00003f14: \*00000ea4 <= 8c2eddfd

1125@00003f18: \*00000ea8 <= 5a9ab279

1127@00003f1c: \*00000eb0 <= 5a9ab279

1129@00003f20: \*00000eb4 <= 00000000

1131@00003f24: \*00000eb8 <= 8c2e853c

1135@00003f28: $17 <= 00000027

1137@00003f2c: $18 <= 0000012d

1139@00003f30: $ 9 <= 00000000

1141@00003f34: $ 8 <= 00000000

1145@00003f38: $ 7 <= 00000000

1147@00003f3c: $ 4 <= e30be9ff

1149@00003f40: $ 5 <= 8c2edd3d

1151@00003f44: $10 <= 6f3ac73c

1153@00003f48: $ 4 <= 6f3ac7fe

1155@00003f4c: $10 <= de758e78

1157@00003f50: $10 <= bceb1cf0

1159@00003f54: $ 5 <= bceb1ef1

1161@00003f58: $ 6 <= bceb1ef1

1169@00003f6c: $ 7 <= 00003e84

1171@00003f70: $29 <= 00000ebc

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1187@00003e8c: $29 <= 00000edc

1189@00003ef8: $ 7 <= 00003c34

1191@00003efc: $29 <= 00000efc

1199@00003c34: $ 7 <= 00003d94

1201@00003c38: $29 <= 00000f1c

1209@00003d94: $ 7 <= 00003ca8

1211@00003d98: $29 <= 00000f3c

1219@00003ca8: $ 7 <= 00003b48

1221@00003cac: $29 <= 00000f5c

1229@00003b48: $ 7 <= 00003e0c

1231@00003b4c: $29 <= 00000f7c

1239@00003e0c: $ 7 <= 00003970

1241@00003e10: $29 <= 00000f9c

1249@00003970: $ 7 <= 000038fc

1251@00003974: $29 <= 00000fbc

1259@000038fc: $ 7 <= 00003884

1267@00003904: $29 <= 00000fdc

1269@00003884: $ 7 <= 00003474

1271@00003888: $29 <= 00000ffc

1279@00003474: $ 1 <= 00000000

1281@00003478: $ 1 <= 00000000

1289@0000348c: $ 1 <= 2af20000

1291@00003490: $ 2 <= 2af20000

1297@000034a4: $ 3 <= 2af30000

1305@000034b4: $ 4 <= 9a2dc7fe

1307@000034b8: $ 1 <= 61830000

1309@000034bc: $ 2 <= 8c750000

1311@000034c0: $ 5 <= 81240000

1313@000034c4: $ 4 <= e2a70000

1315@000034c8: $ 6 <= 3bc71ef1

1317@000034cc: $31 <= 000034d4

1319@000034d8: \*000004d4 <= 00003474

1323@000034dc: $31 <= 00003474

1325@000034e0: $31 <= 00000000

1327@000034e4: $31 <= 000034ec

1335@000034f8: $31 <= 00000000

1337@000034fc: $31 <= 00003504

1347@00003514: $ 4 <= 00000004

1349@00003518: $ 5 <= 00000005

1351@0000351c: $ 1 <= 00000001

1353@00003520: $ 4 <= 00000005

1363@00003538: $ 1 <= 00000001

1365@0000353c: $ 2 <= 00000002

1367@00003540: $ 3 <= 00000003

1369@00003544: $ 4 <= 00000004

1371@00003548: $ 5 <= 00000006

1373@0000354c: $ 6 <= 00000005

1375@00003550: $ 5 <= 00000005

1377@00003554: $ 6 <= 00000003

1385@00003560: $31 <= 00003568

1389@00003568: $ 3 <= 0000356b

1391@0000356c: $ 4 <= ffffca9c

1393@00003570: $31 <= 00003578

1399@000037f8: $31 <= 000035ff

1401@00003578: $31 <= 00003580

1405@000037fc: $ 6 <= 0000358a

1411@00003580: $31 <= 00003588

1417@0000380c: $24 <= 000035ff

1419@00003588: $31 <= 00003590

1423@00003810: $25 <= 0000359a

1427@00003590: \*000000c0 <= 00000000

1429@00003594: \*000000c4 <= 00000001

1431@00003598: \*000000c8 <= 00000002

1433@0000359c: \*000000cc <= 0000356b

1435@000035a0: \*000000d0 <= ffffca9c

1437@000035a4: \*000000d4 <= 00000005

1439@000035a8: \*000000d8 <= 0000358a

1441@000035ac: \*000000dc <= 00003474

1443@000035b0: \*000000e0 <= 00000000

1445@000035b4: \*000000e4 <= 00000000

1447@000035b8: \*000000e8 <= bceb1cf0

1449@000035bc: \*000000ec <= 3a88d87f

1451@000035c0: \*000000f0 <= 943dfb7b

1453@000035c4: \*000000f4 <= 6bc19387

1455@000035c8: \*000000f8 <= 823056c4

1457@000035cc: \*000000fc <= 1819b214

1459@000035d0: \*00000100 <= 9547dde1

1461@000035d4: \*00000104 <= 00000027

1463@000035d8: \*00000108 <= 0000012d

1465@000035dc: \*0000010c <= d7c7877f

1467@000035e0: \*00000110 <= eb7f48a6

1469@000035e4: \*00000114 <= 3e3d9255

1471@000035e8: \*00000118 <= 9992124c

1473@000035ec: \*0000011c <= 8eef5ec7

1475@000035f0: \*00000120 <= 000035ff

1477@000035f4: \*00000124 <= 0000359a

1479@000035f8: \*00000128 <= 9efb54dc

1481@000035fc: \*0000012c <= 57dbb319

1483@00003600: \*00000130 <= 83dbdf9b

1485@00003604: \*00000134 <= 00000ffc

1487@00003608: \*00000138 <= 38dfa03b

1489@0000360c: \*0000013c <= 00003590

1493@00003610: $31 <= f8750000

1499@0000361c: $31 <= 00000002

1499@00003620: \*00000140 <= 00000002

1503@00003624: $14 <= 6bc1c7fb

1507@00003628: $31 <= 00003630

1509@00003634: \*00000144 <= 00003630

1513@00003638: $25 <= 8396031b

1523@00003644: $31 <= 00000002

1523@00003648: \*00000148 <= 00000002

1527@0000364c: $29 <= 3a650000

1531@00003654: $31 <= 0000365c

1533@00003660: \*0000014c <= 0000365c

1537@00003664: $10 <= 00003600

1541@0000366c: $31 <= 00003674

1543@00003678: \*00000150 <= 00003674

1547@0000367c: $12 <= c337c237

1557@0000368c: $31 <= 00000002

1557@00003690: \*00000154 <= 00000002

1561@00003694: $31 <= e4e10000

1571@000036a8: $31 <= 00000002

1571@000036ac: \*00000158 <= 00000002

1575@000036b0: $ 1 <= c337f6ab

1585@000036c4: $31 <= 00000002

1585@000036c8: \*0000015c <= 00000002

1589@000036cc: $20 <= 9547dde1

1599@000036e0: $31 <= 00000002

1599@000036e4: \*00000160 <= 00000002

1603@000036e8: $17 <= 4ba70000

1605@000036ec: $31 <= 000036f4

1607@000036f8: \*00000164 <= 000036f4

1611@000036fc: $ 8 <= 7511b0fe

1615@00003700: $31 <= 00003708

1617@0000370c: \*00000168 <= 00003708

1621@00003710: $ 1 <= 6bc19387

1627@00003714: $31 <= 0000371c

1629@00003720: \*0000016c <= 0000371c

1633@00003724: $18 <= dbf90000

1641@00003734: $31 <= 00000002

1641@00003738: \*00000170 <= 00000002

1645@0000373c: $23 <= 8396391a

1653@0000374c: $31 <= 00000002

1653@00003750: \*00000174 <= 00000002

1657@00003754: $20 <= 00000002

1663@0000375c: $31 <= 00003764

1665@00003768: \*00000178 <= 00003764

1669@0000376c: $21 <= 59a70000

1675@00003778: $31 <= 00003780

1677@00003784: \*0000017c <= 00003780

1681@00003788: $ 8 <= 6bc1c987

1687@00003794: $31 <= 0000379c

1689@000037a0: \*00000180 <= 0000379c

1693@000037a4: $ 4 <= f75aff77

1703@000037b8: $31 <= 00000002

1703@000037bc: \*00000184 <= 00000002

1707@000037c0: $ 4 <= 0000000c

1709@000037c4: $31 <= 000037cc

1713@000037cc: $31 <= 000037d8

1719@000037d4: $ 4 <= 00000008

1721@000037d8: $31 <= 000037e0

1. 思考题
2. 乘除法耗时比其他的ALU中进行的运算长，整合将会阻塞后续指令，使得CPU性能下降。因此将乘除法运算与ALU分开有利于CPU的整体性能。如果不单独设置HI,LO寄存器，则彼此结果容易混淆，产生混乱
3. 乘除槽就是当乘除运算时，往往有较长的延迟，这时候乘除类型的指令将会被阻塞，而为了不浪费时间周期，因此可以像跳转延迟槽一样，安排一些与乘除无关且不影响结果的指令正常运行。题目中我们已经简单化：不考虑调整指令顺序，只要是乘除就阻塞。
4. 放在W级流水寄存器之后而不是DM之后的理由：
5. DM是整个流水线中最慢的模块，因此M级周期长短直接决定流水线的周期，如果继续增加其中的元件，将会进一步增加流水线周期，降低流水线的性能。进而拖慢整个流水线，而W级本身周期较短，加上也不会对整体性能造成影响。
6. 放在W级之后更符合高内聚低耦合的原则，M级只需做访存的工作，只需要拿出相应的字即可，对于写回信号的分选、处理等工作，更应该是W级应该完成的工作。
7. 当向DM中存入一个字符串时，更有优势。字符的ASCII码仅需8位二进制码即可确定，一个word中可以放入4个ASCII字符。如果按字来访问则还需另外的处理才能拿到需要的字节。
8. 我个人属于Planner型。主要通过以下方式克服复杂的问题：
9. 规范加指令的步骤：需不需要增加部件模块？（一般不用）控制信号如何选取？（这是重点）
10. 处理冒险与暂停：尽量参考已有的，即便不能直接归为一类也依然可以借鉴。
11. detector型更适合写代码经验更为丰富的同学，他们经过长期地训练，对编程方面更多地有自己的理解，已经形成了有效的，完备的思考模式，用自己的方式去处理问题，他们更容易得心应手。

而planner更适合编程经历，编程感觉不如前者的同学。按照一定的，可以复制的方法论逐步完善设计，同样能达成目标，从结果上来看，降低了流水线CPU设计与实现的智力壁垒。此外，planner的设计更方便广泛的交流，在现实中的工程实践里，这种设计更容易被团队中的其他人，合作伙伴等方所理解，接纳。