

P7 MIPS 微系统设计文档

一、 整体结构

本文档所描述的微系统包括处理器，系统桥和定时器。处理器为 32 位五级流水线处理器，采用 Verilog HDL 实现。该处理器支持的指令集为 MIPS-C4={LB、LBU、LH、LHU、LW、SB、SH、SW、ADD、ADDU、SUB、SUBU、MULT、MULTU、DIV、DIVU、SLL、SRL、SRA、SLLV、SRLV、SRAV、AND、OR、XOR、NOR、ADDI、ADDIU、ANDI、ORI、XORI、LUI、SLT、SLTI、SLTIU、SLTU、BEQ、BNE、BLEZ、BGTZ、BLTZ、BGEZ、J、JAL、JALR、JR、MFHI、MFLO、MTHI、MTLO、ERET、MFC0、MTC0}，且支持异常、中断和延迟槽。

处理器采用模块化和层次化设计，包含 Controller（控制器）、PC（程序计数器）、IM（指令存储器）、Adder（加法器）、NPC（下一条指令地址计算单元）、GRF（通用寄存器组）、CMP（比较单元）、ALU（算术逻辑单元）、MDU（乘除单元）、DM（数据存储器）、EXT（位扩展器）等基本部件。微系统的顶层有效驱动信号有时钟信号 clk、复位信号 reset、中断信号 interrupt 和 EPC 期望赋值 addr。

二、 基本模块规格

1. PC（程序计数器）

1) 基本描述

PC 存储当前指令地址，并在时钟上升沿更新值。

2) 端口说明

表 1 PC 端口说明

信号名	方向	描述
Clk	I	时钟信号。
Reset	I	复位信号（高电平有效）。
En	I	写使能信号（高电平有效）。
In[31:0]	I	输入下一个时钟上升沿 PC 要写入的值。
Out[31:0]	O	输出当前 PC 的值。

3) 功能定义

表 2 PC 功能定义

序号	功能名称	功能描述
1	同步复位	当时钟上升沿到来时，若复位信号有效，PC 被设置为 0x00003000。
2	输出当前指令地址	存储并由 Out 输出当前指令地址。
3	更新 PC	当时钟上升沿到来时，若写使能信号有效且复位信号无效，则更新 PC 为 In 的值。

2. IM（指令存储器）

1) 基本描述

IM 存储 CPU 要执行的指令，并输出输入地址所对应的指令。IM 的容量为 32bit*4096。

2) 端口说明

表 3 IM 端口说明

信号名	方向	描述
Addr[31:0]	I	输入指令地址。
Instr[31:0]	O	输出 Addr 所对应的指令。

3) 功能定义

表 4 IM 功能定义

序号	功能名称	功能描述
1	输出当前指令	由 Instr 输出 Addr 所对应的指令。

3. Adder（加法器）

1) 基本描述

Adder 输入当前 PC 的值，输出 PC+4 的值。

2) 端口说明

表 5 Adder 端口说明

信号名	方向	描述
In[31:0]	I	数据输入信号，输入当前 PC 的值。
Out[31:0]	O	数据输出信号，输出 PC+4 的值。

3) 功能定义

表 6 Adder 功能定义

序号	功能名称	功能描述
1	PC+4	由 Out 输出 PC+4 的值。

4. NPC（下一条指令地址计算单元）

1) 基本描述

NPC 根据当前指令地址和相应的控制信号计算出下一条指令地址，并输出 PC+8 的值。

2) 端口说明

表 7 NPC 端口说明

信号名	方向	描述
NPCOp	I	指定 NPC 要执行的操作： 0：B 型指令； 1：J 型指令。
PC4[31:0]	I	输入 PC+4。
Imm26[25:0]	I	输入 26 位立即数，用于计算分支或跳转后 PC 的值。
Out[31:0]	O	输出计算出的下一条指令地址。
PC8[31:0]	O	输出 PC+8。

3) 功能定义

表 8 NPC 功能定义

序号	功能名称	功能描述
1	计算下一条指令地址	当 NPCOp 为 0 时，Out 输出 $PC4 + \text{SignExt}(\text{Imm26}[15:0] \parallel 0^2)$ ； 当 NPCOp 为 1 时，Out 输出 $(PC4)[31:28] \parallel \text{Imm26} \parallel 0^2$ 。
2	输出 PC+8	由 PC8 输出 PC+8 的值。

5. GRF（通用寄存器组）

1) 基本描述

GRF 内部包括 32 个具有复位功能的寄存器。其中，0 号寄存器的值始终保持为 0，其他寄存器初始值均为 0。GRF 提供同时读取 2 个寄存器和写入 1 个寄存器的功能，并且支持内部转发。

2) 端口说明

表 9 GRF 端口说明

信号名	方向	描述
Clk	I	时钟信号。
Reset	I	复位信号（高电平有效）。
A1[4:0]	I	地址输入信号 1，将其对应寄存器中存储的数据输出至 RD1。
A2[4:0]	I	地址输入信号 2，将其对应寄存器中存储的数据输出至 RD2。
A3[4:0]	I	地址输入信号 3，指定写入操作所对应的寄存器。
WD[31:0]	I	数据输入信号，即要写入寄存器中的数据。
RD1[31:0]	O	数据输出信号，输出 A1 对应寄存器中的 32 位数据。
RD2[31:0]	O	数据输出信号，输出 A2 对应寄存器中的 32 位数据。

注：在 Verilog 实现中增加了 WPC[31:0]输入，用于在线测试时输出 PC 的值。

3) 功能定义

表 10 GRF 功能定义

序号	功能名称	功能描述
1	同步复位	当时钟上升沿到来时，若复位信号有效，GRF 中的每一个寄存器都被设置为 0x00000000。
2	读取数据	读取 A1 和 A2 所对应寄存器中的数据至 RD1 和 RD2（当同一个寄存器同时被写入和读取时，读取的值为写入的值）。
3	写入数据	当时钟上升沿到来时，如果复位信号无效，就将 WD 写入 A3 所对应的寄存器中。

6. CMP（比较单元）

1) 基本描述

CMP 对输入的两个操作数提供相等比较功能，并对输入的第一个操作数提供零比较功能，输出比较结果。

2) 端口说明

表 11 CMP 端口说明

信号名	方向	描述
A[31:0]	I	数据输入信号，输入 CMP 的第一个操作数。
B[31:0]	I	数据输入信号，输入 CMP 的第二个操作数。
Equal	O	相等标志信号（高电平有效），标志两操作数是否相等。
LTZ	O	小于 0 标志信号（高电平有效），标志 A 是否小于 0。
EQZ	O	等于 0 标志信号（高电平有效），标志 A 是否等于 0。

3) 功能定义

表 12 CMP 功能定义

序号	功能名称	功能描述
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1	相等比较运算	若 $A=B$ ，则 Equal 信号有效；否则无效。
2	零比较运算	若 $A<0$ ，则 LTZ 信号有效；否则无效。 若 $A=0$ ，则 EQZ 信号有效；否则无效。

7. ALU（算术逻辑单元）

1) 基本描述

ALU 对输入的两个操作数提供 32 位加、减、或、与、或非、异或和移位运算以及小于置位功能，输出运算结果。

2) 端口说明

表 13 ALU 端口说明

信号名	方向	描述
A[31:0]	I	数据输入信号，输入 ALU 的第一个操作数。
B[31:0]	I	数据输入信号，输入 ALU 的第二个操作数。
ALUOp[3:0]	I	指定 ALU 所要进行的操作： 0000: $A+B$; 0001: $A-B$; 0010: $A B$; 0011: $A\&B$; 0100: $\sim(A B)$; 0101: $A^{\wedge}B$; 0110: $B\ll A[4:0]$; 0111: $B\gg A[4:0]$; 1000: $B\ggg A[4:0]$; 1001: $(A<B)?1:0$; 1010: $((0 A)<(0 B))?1:0$ 。
Result[31:0]	O	数据输出信号，输出 ALU 的计算结果。

3) 功能定义

表 14 ALU 功能定义

序号	功能名称	功能描述
1	加法	当 ALUOp 为 0000 时，Result 输出 $A+B$ 的值。
2	减法	当 ALUOp 为 0001 时，Result 输出 $A-B$ 的值。
3	或运算	当 ALUOp 为 0010 时，Result 输出 $A B$ 的值。
4	与运算	当 ALUOp 为 0011 时，Result 输出 $A\&B$ 的值。
5	或非运算	当 ALUOp 为 0100 时，Result 输出 $\sim(A B)$ 的值。
6	异或运算	当 ALUOp 为 0101 时，Result 输出 $A^{\wedge}B$ 的值。
7	逻辑左移运算	当 ALUOp 为 0110 时，Result 输出 $B\ll A[4:0]$ 的值。
8	逻辑右移运算	当 ALUOp 为 0111 时，Result 输出 $B\gg A[4:0]$ 的值。
9	算术右移运算	当 ALUOp 为 1000 时，Result 输出 $B\ggg A[4:0]$ 的值。
10	小于比较运算	当 ALUOp 为 1001 时，若 $A<B$ ，则 Result 输出 1；否则 Result 输出 0。
11	无符号小于比较运算	当 ALUOp 为 1010 时，若 $(0 A)<(0 B)$ ，则 Result 输出 1；否则 Result 输出 0。

8. MDU（乘除单元）

1) 基本描述

MDU 用于计算乘除法，内置 HI 和 LO 两个寄存器用于保存计算结果，具有启动信号和忙标记。

2) 端口说明

表 15 MDU 端口说明

信号名	方向	描述
Clk	I	时钟信号。
Reset	I	复位信号（高电平有效）。
Start	I	开始计算信号（高电平有效）。
MDUOp[1:0]	I	指定操作： 00：无符号乘法； 01：有符号乘法； 10：无符号除法； 11：有符号除法。
HIWrite	I	HI 寄存器写使能（高电平有效）。
LOWrite	I	LO 寄存器写使能（高电平有效）。
A[31:0]	I	数据输入信号，输入第一个操作数。
B[31:0]	I	数据输入信号，输入第二个操作数。
Busy	O	忙标记（高电平有效）。
HI[31:0]	O	数据输出信号，输出 HI 寄存器的数据。
LO[31:0]	O	数据输出信号，输出 LO 寄存器的数据。

3) 功能定义

表 16 MDU 功能定义

序号	功能名称	功能描述
1	同步复位	当时钟上升沿到来时，若复位信号有效，HI 和 LO 都被设置为 0x00000000。
2	无符号乘法	复位信号无效，Start 信号有效且 Op 信号为 00 后的第一个时钟上升沿后开始计算 $A \times B$ （无符号），5 个周期后将 64 位结果的高低半部分分别存入 HI 和 LO 寄存器。
3	有符号乘法	复位信号无效，Start 信号有效且 Op 信号为 01 后的第一个时钟上升沿后开始计算 $A \times B$ ，5 个周期后将 64 位结果的高低半部分分别存入 HI 和 LO 寄存器。
4	无符号除法	复位信号无效，Start 信号有效且 Op 信号为 10 后的第一个时钟上升沿后开始计算 $A \div B$ （无符号），10 个周期后将余数和商分别存入 HI 和 LO 寄存器。
5	有符号除法	复位信号无效，Start 信号有效且 Op 信号为 11 后的第一个时钟上升沿后开始计算 $A \div B$ ，10 个周期后将余数和商分别存入 HI 和 LO 寄存器。
6	存入 HI	当时钟上升沿到来时，若 HIWrite 信号有效且复位信号无效，则将 A 存入 HI。
7	存入 LO	当时钟上升沿到来时，若 LOWrite 信号有效且复位信号无效，则将 A 存入 LO。

9. DM（数据存储寄存器）

1) 基本描述

DM 用于存储数据，其容量为 32bit*4096，起始地址为 0x00000000。DM 支持同步复位功能，并且数据读取和写入端口分离。

2) 端口说明

表 17 DM 端口说明

信号名	方向	描述
Clk	I	时钟信号。
Reset	I	复位信号（高电平有效）。
Addr[31:0]	I	地址信号，指定要操作的存储单元的地址。
WD[31:0]	I	数据输入信号，输入要写入到 Addr 所对应的存储单元的数据。
MemWrite	I	写使能信号（高电平有效）。
OpWidth[1:0]	I	指定操作位宽： 00: Word; 01: Half; 10: Byte。
LoadSigned	I	指定是否进行有符号读取（高电平有效）。
RD[31:0]	O	数据输出信号，输出 Addr 所对应的存储单元的数据。

注：在 Verilog 实现中增加了 WPC[31:0]输入，用于在线测试时输出 PC 的值。

3) 功能定义

表 18 DM 功能定义

序号	功能名称	功能描述
1	同步复位	当时钟上升沿到来时，若复位信号有效，DM 中的每一个存储单元都被设置为 0x00000000。
2	读取	RD 根据 OpWidth 和 LoadSigned 信号输出 Addr 所对应的存储单元的数据。
3	写入	当时钟上升沿到来时，如果 MemWrite 有效且复位信号无效，就根据 OpWidth 信号将 WD 写入 Addr 所对应的存储单元中。

10. EXT（位扩展器）

1) 基本描述

EXT 用于将输入的 16 位立即数根据操作信号扩展成 32 位并输出。

2) 端口说明

表 19 EXT 端口说明

信号名	方向	描述
Imm16[15:0]	I	数据输入信号，输入要进行扩展的数据。
ExtOp[1:0]	I	符号扩展信号（高电平有效）。
Imm32[31:0]	O	数据输出信号，输出扩展后的数据。

3) 功能定义

表 20 EXT 功能定义

序号	功能名称	功能描述
1	无符号扩展	当 ExtOp 为 00 时，将 Imm16 无符号扩展至 32 位并输出至 Imm32。
2	符号扩展	当 ExtOp 为 01 时，将 Imm16 符号扩展至 32 位并输出至 Imm32。
3	左移 16 位	当 ExtOp 为 10 时，将 Imm16 左移 16 位并输出至 Imm32。

三、 数据通路设计

见 Excel 表格。

四、 数据通路参考示意图

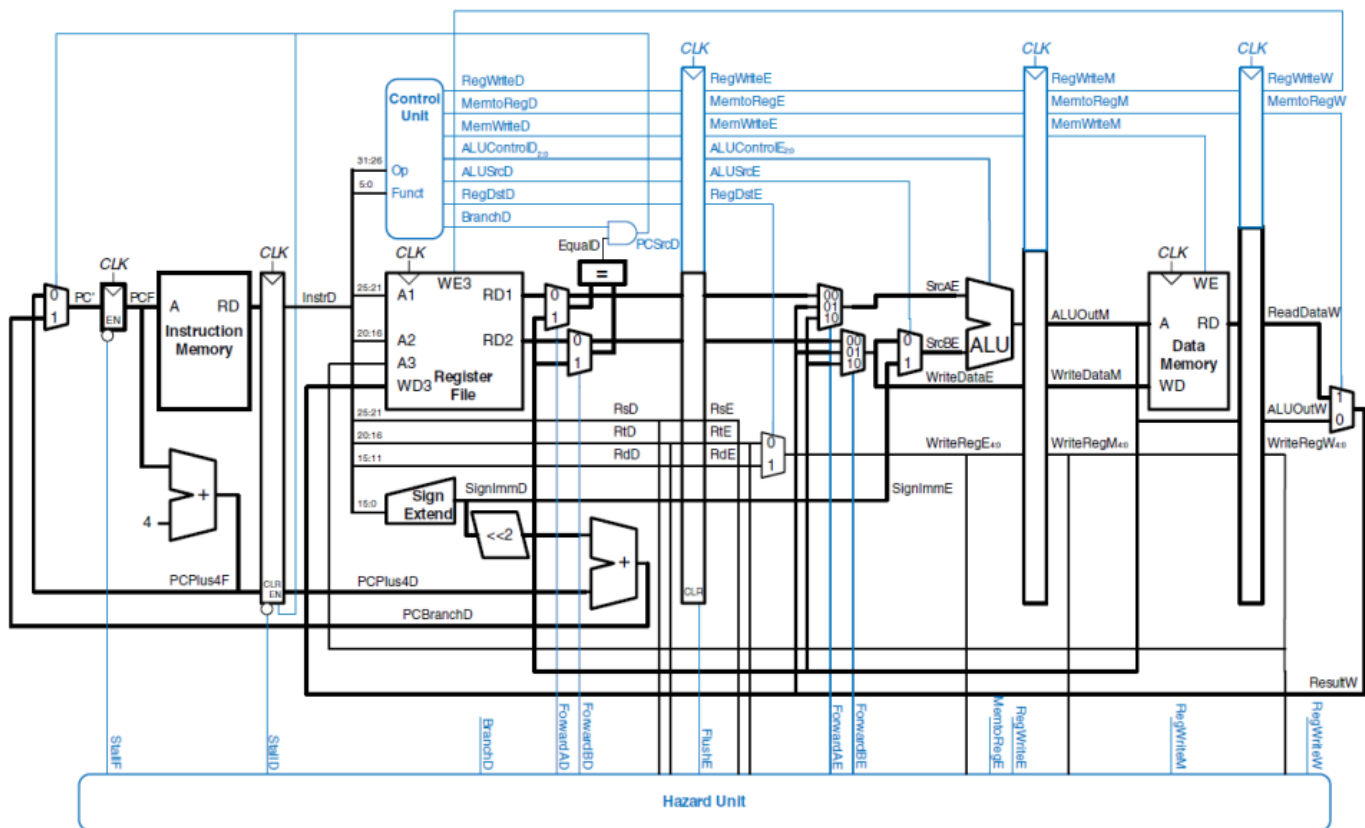


Figure 7.58 Pipelined processor with full hazard handling

五、 控制器（Controller）设计

1. 基本描述

控制器分为主控制器和冒险处理单元。主控制器通过输入的 Op 和 Funct 信号以及 CMP 产生的比较信号产生数据通路所需的控制信号，采用分布式译码，实例化 3 个；冒险处理单元负责为几个转发位点提供数据转发并通过检测无法由转发解决的数据冒险来插入暂停。

2. D 级主控制器真值表

表 21 D 级主控制器真值表

指令(Op/Funct)	NPC Op	ExtOp[1 :0]	PCSrc[1:0]	A3Sel[1 :0]	Gen D	M D	D1U se	D2U se	B D
addu (000000/100001)	x	xx	00	10	0	0	0	0	0
subu (000000/100011)	x	xx	00	10	0	0	0	0	0
ori (001101)	x	00	00	11	0	0	0	0	0
lw (100011)	x	01	00	11	0	0	0	0	0
sw (101011)	x	01	00	00	0	0	0	0	0
beq (000100)	0	01	CMP.Equal?01:00	00	0	0	1	1	1
lui	x	10	00	11	0	0	0	0	0

(001111)									
j (000010)	1	xx	01	00	0	0	0	0	1
jal (000011)	1	xx	01	01	1	0	0	0	1
jr (000000/001000)	x	xx	10	00	0	0	1	0	1
lb (100000)	x	01	00	11	0	0	0	0	0
lbu (100100)	x	01	00	11	0	0	0	0	0
lh (100001)	x	01	00	11	0	0	0	0	0
lhu (100101)	x	01	00	11	0	0	0	0	0
sb (101000)	x	01	00	00	0	0	0	0	0
sh (101001)	x	01	00	00	0	0	0	0	0
add (000000/100000)	x	xx	00	10	0	0	0	0	0
sub (000000/100010)	x	xx	00	10	0	0	0	0	0
mult (000000/011000)	x	xx	00	00	0	1	0	0	0
multu (000000/011001)	x	xx	00	00	0	1	0	0	0
div (000000/011010)	x	xx	00	00	0	1	0	0	0
divu (000000/011011)	x	xx	00	00	0	1	0	0	0
sll (000000/000000)	x	xx	00	10	0	0	0	0	0
srl (000000/000010)	x	xx	00	10	0	0	0	0	0
sra (000000/000011)	x	xx	00	10	0	0	0	0	0
sllv (000000/000100)	x	xx	00	10	0	0	0	0	0
srlv (000000/000110)	x	xx	00	10	0	0	0	0	0
srav (000000/000111)	x	xx	00	10	0	0	0	0	0
and (000000/100100)	x	xx	00	10	0	0	0	0	0
or (000000/100101)	x	xx	00	10	0	0	0	0	0
xor	x	xx	00	10	0	0	0	0	0

(000000/100110)									
nor (000000/100111)	x	xx	00	10	0	0	0	0	0
addi (001000)	x	01	00	11	0	0	0	0	0
addiu (001001)	x	01	00	11	0	0	0	0	0
andi (001100)	x	00	00	11	0	0	0	0	0
xori (001110)	x	00	00	11	0	0	0	0	0
slt (000000/101010)	x	xx	00	10	0	0	0	0	0
slti (001010)	x	01	00	11	0	0	0	0	0
sltiu (001011)	x	01	00	11	0	0	0	0	0
sltu (000000/101011)	x	xx	00	10	0	0	0	0	0
bne (000101)	0	01	!CMP.Equal?01:00	00	0	0	1	1	1
blez (000110)	0	01	(CMP.LTZ CMP.EQZ)?01: 00	00	0	0	1	0	1
bgtz (000111)	0	01	(!CMP.LTZ&&!CMP.EQZ) ?01:00	00	0	0	1	0	1
bltz (000001/Instr[20:16]=0 0000)	0	01	CMP.LTZ?01:00	00	0	0	1	0	1
bgez (000001/Instr[20:16]=0 0001)	0	01	!CMP.LTZ?01:00	00	0	0	1	0	1
jalr (000000/001001)	x	xx	10	10	1	0	1	0	1
mfhi (000000/010000)	x	xx	00	10	0	1	0	0	0
mflo (000000/010010)	x	xx	00	10	0	1	0	0	0
mthi (000000/010001)	x	xx	00	00	0	1	0	0	0
mtlo (000000/010011)	x	xx	00	00	0	1	0	0	0
eret (010000/011000)	x	xx	xx	00	0	0	0	0	0
mfc0 (010000/Instr[25:21]=0 0000)	x	xx	00	11	0	0	0	0	0
mtc0 (010000/Instr[25:21]=0	x	xx	00	00	0	0	0	0	0

0100)									
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3. E 级主控制器真值表

表 22 E 级主控制器真值表

指令(Op/Funct)	ALUOp[3:0]	ALUSrcA	ALUSrcB	Start	MDUOp[1:0]	HIWrite	LOWrite	GenE[1:0]	E1Use	E2Use
addu (000000/100001)	0000	0	0	0	xx	0	0	01	1	1
subu (000000/100011)	0001	0	0	0	xx	0	0	01	1	1
ori (001101)	0010	0	1	0	xx	0	0	01	1	0
lw (100011)	0000	0	1	0	xx	0	0	00	1	0
sw (101011)	0000	0	1	0	xx	0	0	00	1	0
beq (000100)	xxxx	x	x	0	xx	0	0	00	0	0
lui (001111)	0000	0	1	0	xx	0	0	01	0	0
j (000010)	xxxx	x	x	0	xx	0	0	00	0	0
jal (000011)	xxxx	x	x	0	xx	0	0	00	0	0
jr (000000/001000)	xxxx	x	x	0	xx	0	0	00	0	0
lb (100000)	0000	0	1	0	xx	0	0	00	1	0
lbu (100100)	0000	0	1	0	xx	0	0	00	1	0
lh (100001)	0000	0	1	0	xx	0	0	00	1	0
lhu (100101)	0000	0	1	0	xx	0	0	00	1	0
sb (101000)	0000	0	1	0	xx	0	0	00	1	0
sh (101001)	0000	0	1	0	xx	0	0	00	1	0
add (000000/100000)	0000	0	0	0	xx	0	0	01	1	1
sub (000000/100010)	0001	0	0	0	xx	0	0	01	1	1
mult (000000/011000)	xxxx	x	x	1	01	0	0	00	1	1
multu (000000/011001)	xxxx	x	x	1	00	0	0	00	1	1
div (000000/011010)	xxxx	x	x	1	11	0	0	00	1	1

divu (000000/011011)	xxxx	x	x	1	10	0	0	00	1	1
sll (000000/000000)	0110	1	0	0	xx	0	0	01	0	1
srl (000000/000010)	0111	1	0	0	xx	0	0	01	0	1
sra (000000/000011)	1000	1	0	0	xx	0	0	01	0	1
slv (000000/000100)	0110	0	0	0	xx	0	0	01	1	1
srlv (000000/000110)	0111	0	0	0	xx	0	0	01	1	1
srav (000000/000111)	1000	0	0	0	xx	0	0	01	1	1
and (000000/100100)	0011	0	0	0	xx	0	0	01	1	1
or (000000/100101)	0010	0	0	0	xx	0	0	01	1	1
xor (000000/100110)	0101	0	0	0	xx	0	0	01	1	1
nor (000000/100111)	0100	0	0	0	xx	0	0	01	1	1
addi (001000)	0000	0	1	0	xx	0	0	01	1	0
addiu (001001)	0000	0	1	0	xx	0	0	01	1	0
andi (001100)	0011	0	1	0	xx	0	0	01	1	0
xori (001110)	0101	0	1	0	xx	0	0	01	1	0
slt (000000/101010)	1001	0	0	0	xx	0	0	01	1	1
slti (001010)	1001	0	1	0	xx	0	0	01	1	0
sltiu (001011)	1010	0	1	0	xx	0	0	01	1	0
sltu (000000/101011)	1010	0	0	0	xx	0	0	01	1	1
bne (000101)	xxxx	x	x	0	xx	0	0	00	0	0
blez (000110)	xxxx	x	x	0	xx	0	0	00	0	0
bgtz (000111)	xxxx	x	x	0	xx	0	0	00	0	0
bltz (000001/Instr[20:16]= 00000)	xxxx	x	x	0	xx	0	0	00	0	0
bgez	xxxx	x	x	0	xx	0	0	00	0	0

(000001/Instr[20:16]= 00001)										
jalr (000000/001001)	xxxx	x	x	0	xx	0	0	00	0	0
mfhi (000000/010000)	xxxx	x	x	0	xx	0	0	10	0	0
mflo (000000/010010)	xxxx	x	x	0	xx	0	0	11	0	0
mthi (000000/010001)	xxxx	x	x	0	xx	1	0	00	1	0
mtlo (000000/010011)	xxxx	x	x	0	xx	0	1	00	1	0
eret (010000/011000)	xxxx	x	x	0	xx	0	0	00	0	0
mfc0 (010000/Instr[25:21]= 00000)	xxxx	x	x	0	xx	0	0	00	0	0
mtc0 (010000/Instr[25:21]= 00100)	xxxx	x	x	0	xx	0	0	00	0	0

4. M 级主控制器真值表

表 23 M 级主控制器真值表

指令(Op/Funct)	MemWrite	OpWidth[1:0]	LoadSigned	GenM[1:0]	M2Use	CP0Write
addu (000000/100001)	0	xx	x	00	0	0
subu (000000/100011)	0	xx	x	00	0	0
ori (001101)	0	xx	x	00	0	0
lw (100011)	0	00	x	01	0	0
sw (101011)	1	00	x	00	1	0
beq (000100)	0	xx	x	00	0	0
lui (001111)	0	xx	x	00	0	0
j (000010)	0	xx	x	00	0	0
jal (000011)	0	xx	x	00	0	0
jr (000000/001000)	0	xx	x	00	0	0
lb (100000)	0	10	1	01	0	0
lbu (100100)	0	10	0	01	0	0

lh (100001)	0	01	1	01	0	0
lhu (100101)	0	01	0	01	0	0
sb (101000)	1	10	x	00	1	0
sh (101001)	1	01	x	00	1	0
add (000000/100000)	0	xx	x	00	0	0
sub (000000/100010)	0	xx	x	00	0	0
mult (000000/011000)	0	xx	x	00	0	0
multu (000000/011001)	0	xx	x	00	0	0
div (000000/011010)	0	xx	x	00	0	0
divu (000000/011011)	0	xx	x	00	0	0
sll (000000/000000)	0	xx	x	00	0	0
srl (000000/000010)	0	xx	x	00	0	0
sra (000000/000011)	0	xx	x	00	0	0
sllv (000000/000100)	0	xx	x	00	0	0
srlv (000000/000110)	0	xx	x	00	0	0
srav (000000/000111)	0	xx	x	00	0	0
and (000000/100100)	0	xx	x	00	0	0
or (000000/100101)	0	xx	x	00	0	0
xor (000000/100110)	0	xx	x	00	0	0
nor (000000/100111)	0	xx	x	00	0	0
addi (001000)	0	xx	x	00	0	0
addiu (001001)	0	xx	x	00	0	0
andi (001100)	0	xx	x	00	0	0
xori (001110)	0	xx	x	00	0	0

slt (000000/101010)	0	xx	x	00	0	0
slti (001010)	0	xx	x	00	0	0
sltiu (001011)	0	xx	x	00	0	0
sltu (000000/101011)	0	xx	x	00	0	0
bne (000101)	0	xx	x	00	0	0
blez (000110)	0	xx	x	00	0	0
bgtz (000111)	0	xx	x	00	0	0
bltz (000001/Instr[20:16]=00000)	0	xx	x	00	0	0
bgez (000001/Instr[20:16]=00001)	0	xx	x	00	0	0
jalr (000000/001001)	0	xx	x	00	0	0
mfhi (000000/010000)	0	xx	x	00	0	0
mflo (000000/010010)	0	xx	x	00	0	0
mthi (000000/010001)	0	xx	x	00	0	0
mtlo (000000/010011)	0	xx	x	00	0	0
eret (010000/011000)	0	xx	x	00	0	0
mfc0 (010000/Instr[25:21]=00000)	0	xx	x	10	0	0
mtc0 (010000/Instr[25:21]=00100)	0	xx	x	00	1	1

5. 暂停策略

采用标记转发法，当需求寄存器的值尚未算出时暂停，具体策略如下：

```

assign StallD = (D1Use && A1D == A3E && A3E != 0 && WDE === 32'bz) ||
                (D1Use && A1D == A3M && A3M != 0 && WDM === 32'bz && !(A1D
== A3E && A3E != 0 && WDE !== 32'bz)) ||
                (D2Use && A2D == A3E && A3E != 0 && WDE === 32'bz) ||
                (D2Use && A2D == A3M && A3M != 0 && WDM === 32'bz && !(A2D
== A3E && A3E != 0 && WDE !== 32'bz)) ||
                ((Start || Busy) && MD);

```

```

assign StallE = (E1Use && A1E == A3M && A3M != 0 && WDM === 32'bz) ||
                (E2Use && A2E == A3M && A3M != 0 && WDM === 32'bz);

assign PCEn = ~(StallD || StallE);
assign DRegEn = ~(StallD || StallE);
assign ERegEn = ~StallE;
assign ERegFlush = StallD;
assign MRegFlush = StallE;

```

6. 转发策略

采用标记转发法，为每一个需求者增加转发，具体策略如下：

```

assign ForwardD1 = (A1D == A3E && A3E != 0) ? WDE :
                  (A1D == A3M && A3M != 0) ? WDM :
                  RD1D;

assign ForwardD2 = (A2D == A3E && A3E != 0) ? WDE :
                  (A2D == A3M && A3M != 0) ? WDM :
                  RD2D;

assign ForwardE1 = (A1E == A3M && A3M != 0) ? WDM :
                  (A1E == A3W && A3W != 0) ? WDW :
                  (A1E == A3T && A3T != 0) ? WDT :
                  RD1E;

assign ForwardE2 = (A2E == A3M && A3M != 0) ? WDM :
                  (A2E == A3W && A3W != 0) ? WDW :
                  (A2E == A3T && A3T != 0) ? WDT :
                  RD2E;

assign ForwardM2 = (A2M == A3W && A3W != 0) ? WDW :
                  RD2M;

```

六、 CP0 设计

1. 基本描述

CP0 内部包含 SR 寄存器的部分位、CAUSE 寄存器的部分位、EPC 寄存器、PrID 寄存器以及产生中断信号的组合逻辑，用于处理 CPU 的异常与中断状态。

2. 端口说明

表 24 CP0 端口说明

信号名	方向	描述
Clk	I	时钟信号。
Reset	I	复位信号（高电平有效）。
Addr[4:0]	I	地址信号，用于指定操作 CP0 寄存器的地址。
DIn[31:0]	I	数据输入信号，用于指定向 CP0 寄存器中写入的值。
PC[31:2]	I	输入当前流水级 PC 相应位的值。
ExcCode[6:2]	I	输入异常代码。
HWInt[7:2]	I	输入外部中断信号。
WE	I	寄存器写使能（高电平有效）。
ExlSet	I	异常进入信号。
ExlClr	I	异常返回信号。
BD	I	延迟槽信号，用于指定当前指令是否为延迟槽指令。
IntReq	O	中断请求指令（高电平有效）。
EPC[31:0]	O	输出 EPC 寄存器的值。
DOut[31:0]	O	数据输出信号，用于输出指定寄存器的值。

3. 功能定义

表 25 CP0 功能定义

序号	功能名称	功能描述
1	同步复位	当时钟上升沿到来时，若复位信号有效，CP0 中的每一个寄存器都被设置为 0x00000000（PrID 寄存器除外）。
2	读取寄存器	DOut 输出 Addr 所对应的寄存器的数据（未定义寄存器及未定义位输出 0）。
3	写入寄存器	当时钟上升沿到来时，如果 WE 信号有效且复位信号无效，就将 DIn 写入 Addr 所对应的寄存器中。
4	输出 EPC	输出 EPC 寄存器的值。
5	中断请求	如果 EXLSet 信号或中断条件有效且 EXL 信号无效且复位信号无效，IntReq 信号就有效，否则无效。
6	中断异常处理	当时钟上升沿到来时，如果 EXLSet 信号或中断条件有效且 EXL 信号无效且复位信号无效，就将 SR 寄存器的 EXL 位置 1，将 CAUSE 寄存器的 BD 位和 ExcCode 位设置为相应的输入，将 EPC 寄存器设置为相应的输入。
7	中断异常返回	当时钟上升沿到来时，如果 EXLClr 信号有效且复位信号无效，就将 SR 寄存器的 EXL 位置 0。
8	更新 IP	当时钟上升沿到来时，如果复位信号无效，就将 HWInt 存入 CAUSE 寄存器的 IP 位中。

七、 桥与 IO 设计

1. 基本描述

微系统通过桥实现 IO，外部设备为两个计时器，仅支持整字存取。

2. 端口说明

表 26 Bridge 端口说明

信号名	方向	描述
PrAddr[31:2]	I	输入处理器操作地址。

PrWD[31:0]	I	输入处理器要向外设中写入的数据。
DEV RD0[31:0]	I	输入外设 0 读出的数据。
DEV RD1[31:0]	I	输入外设 1 读出的数据。
PrWE	I	处理器写使能信号（高电平有效）。
PrRD[31:0]	O	输出处理器从外设中读取的数据。
DEVAddr[31:2]	O	输出对外设操作的地址。
DEVWD[31:0]	O	输出将要写入外设的数据。
DEVWE0	O	设备 0 写使能信号（高电平有效）。
DEVWE1	O	设备 1 写使能信号（高电平有效）。

3. 功能定义

表 27 Bridge 功能定义

序号	功能名称	功能描述
1	外设读取	根据 PrAddr 从对应外设中读取数据并驱动 PrRD。
2	外设写入	当 PrWE 信号有效时，根据 PrAddr 将 PrWD 写入对应外设中。

八、 测试软件

1. CPU 基本功能测试

1) 测试程序

```
lui $t0, 0x1234
ori $t0, $0, 0x5678
addi $s0, $0, 16
sb $t0, 1($0)
lb $t4, -15($s0)
lbu $t5, -15($s0)
sb $t0, -16($s0)
lb $t6, 0($0)
lbu $t7, 0($0)
sh $t0, 2($0)
lh $t4, -14($s0)
lhu $t5, -14($s0)
sh $t0, -14($s0)
lh $t6, 2($0)
lhu $t7, 2($0)
sw $t0, 4($0)
lw $t1, -12($s0)
sw $t0, -8($s0)
lw $t2, 8($0)
```

```
addu $t3, $t1, $t0
subu $t4, $t0, $t1
add $t7, $t1, $t0
sub $t8, $t0, $t1
li $a0, -1
mult $t0, $a0
mfhi $t3
multu $t0, $a0
mflo $t4
li $a0, -3
li $a1, 2
div $a0, $a1
mfhi $s1
mflo $s2
divu $a0, $a1
mfhi $s1
mflo $s2
mthi $t0
mtlo $t1
mfhi $s3
mflo $s4
sll $s1, $s1, 2
srl $s2, $s2, 3
sra $a0, $a0, 4
li $t5, 4
li $t6, 3
li $t7, 2
sllv $s1, $s1, $t5
srlv $s2, $s2, $t6
srav $a0, $a0, $t7
and $s3, $s2, $s1
or $s3, $s2, $s1
xor $s3, $s2, $s1
```

```
nor $s3, $s2, $s1
addiu $s3, $s3, -1
andi $s3, $s2, 0x1010
xori $s3, $s2, 0x1010
slt $s4, $t0, $t1
slti $s4, $t0, -1
sltiu $s4, $t0, -1
li $a0, -1
sltu $s4, $s4, $a0
```

LabelEQ:

```
beq $t2, $0, SkipEQ
lui $t5, 1
lui $s3, 1
beq $t0, $0, LabelEQ
nop
beq $t1, $t2, SkipEQ
nop
lui $t6, 1
SkipEQ:
nop
```

LabelNE:

```
bne $t2, $t1, SkipNE
lui $t5, 2
lui $s3, 2
bne $t1, $t2, LabelNE
nop
bne $t1, $0, SkipNE
nop
lui $t6, 2
SkipNE:
nop
```

```
li $s5, -1
```

```
li $s6, 1
```

```
LabelLEZ:
```

```
blez $s5, SkipLEZ
```

```
li $t5, 1
```

```
li $t6, 1
```

```
SkipLEZ:
```

```
blez $s6, LabelLEZ
```

```
nop
```

```
LabelLTZ:
```

```
bltz $s5, SkipLTZ
```

```
li $t5, 2
```

```
li $t6, 2
```

```
SkipLTZ:
```

```
bltz $s6, LabelLTZ
```

```
nop
```

```
LabelGTZ:
```

```
bgtz $s6, SkipGTZ
```

```
li $t5, 1
```

```
li $t6, 1
```

```
SkipGTZ:
```

```
bgtz $s5, LabelGTZ
```

```
nop
```

```
LabelGEZ:
```

```
bgez $s6, SkipGEZ
```

```
li $t5, 2
```

```
li $t6, 2
```

```
SkipGEZ:
```

bgez \$s5, LabelGEZ

nop

jal Funct

lui \$s4, 64

ori \$t9, \$0, 0x3054

la \$a0, End

jalr \$ra, \$a0

lui \$s5, 256

Funct:

ori \$t8, \$0, 16

jr \$ra

lui \$s6, 1024

Target:

lui \$s7, 1027

j Cal_r

nop

End:

j Target

ori \$s2, \$0, 129

Cal_r:

addu \$t2, \$t1, \$t0

subu \$t3, \$t2, \$t1

addu \$t2, \$t1, \$t0

subu \$t3, \$t1, \$t2

addu \$t2, \$t1, \$t0

ori \$s0, \$s0, 10

subu \$t3, \$t2, \$t1

addu \$t2, \$t1, \$t0

```
ori $s0, $s0, 1
subu $t3, $t1, $t2
lui $t2, 129
subu $t3, $t2, $t1
lui $t4, 129
subu $t3, $t1, $t4
lui $t2, 127
addu $s1, $s2, $s3
subu $t3, $t2, $t1
lui $t4, 127
subu $s1, $s2, $s3
subu $t3, $t1, $t4
lw $t4, 0($0)
addu $t3, $t4, $t1
lw $t5, 4($0)
addu $t3, $t2, $t5
lw $t4, 0($0)
subu $s1, $s2, $s3
addu $t3, $t4, $t1
lw $t5, 4($0)
subu $s1, $s2, $s3
addu $t3, $t2, $t5
jal Label1
addu $s4, $ra, $0
Label1:
jal Label2
addu $s5, $0, $ra
Label2:
jal Label3
nop
Label3:
addu $s4, $ra, $0
jal Label4
```

nop

Label14:

addu \$s5, \$0, \$ra

la \$a0, Label150

jalr \$ra, \$a0

addu \$s4, \$ra, \$0

Label150:

la \$a0, Label151

jalr \$ra, \$a0

addu \$s5, \$0, \$ra

Label151:

la \$a0, Label152

jalr \$ra, \$a0

nop

Label152:

addu \$s4, \$ra, \$0

la \$a0, Label153

jalr \$ra, \$a0

nop

Label153:

addu \$s5, \$0, \$ra

mthi \$t0

mfhi \$s4

addu \$s5, \$s4, \$t0

mtlo \$t1

mflo \$s5

addu \$s4, \$t0, \$s5

mthi \$t0

mfhi \$s4

mult \$t0, \$s4

addu \$s5, \$s4, \$t0

mtlo \$t1

mflo \$s5

```

mult $t1, $s5
addu $s4, $t0, $s5
sll $s4, $t0, 5
subu $s5, $s4, $t1
sll $s4, $t1, 4
subu $s5, $t0, $s4
sll $s4, $t0, 5
srl $s5, $t1, 4
subu $s5, $s4, $t1
sll $s4, $t1, 4
sra $s5, $t0, 3
subu $s5, $t0, $s4

```

Cal_i:

```

addu $t2, $t1, $t0
ori $t3, $t2, 31
addu $t2, $t1, $t3
ori $s0, $s0, 10
ori $t3, $t2, 127
lui $t2, 129
ori $t3, $t2, 1
lui $t2, 127
addu $s1, $s2, $s3
ori $t3, $t2, 6
lw $t4, 0($0)
ori $t3, $t4, 98
lw $t5, 4($0)
subu $s1, $s2, $s3
ori $t3, $t5, 101
jal Label5
ori $s4, $ra, 6
Label5:
jal Label6

```


nop

Label16:

ori \$s4, \$ra, 9

la \$a0, Label154

jalr \$ra, \$a0

addi \$s4, \$ra, 11

Label154:

la \$a0, Label155

jalr \$ra, \$a0

nop

Label155:

addi \$s4, \$ra, 22

mthi \$t0

mfhi \$s4

addi \$s5, \$s4, 33

mthi \$t0

mfhi \$s4

mult \$t0, \$s4

addi \$s5, \$s4, 44

sll \$s4, \$t0, 5

ori \$s5, \$s4, 321

sll \$s4, \$t0, 5

srl \$s5, \$t1, 4

ori \$s5, \$s4, 123

Load:

ori \$t1, \$0, 2

ori \$t2, \$0, 2

addu \$t3, \$t2, \$t1

lw \$t4, 0(\$t3)

ori \$t2, \$0, 4

addu \$t3, \$t2, \$0

addu \$s0, \$s1, \$s2

```

lw $t4, 0($t3)
ori $t2, $0, 4
lw $t5, 0($t2)
ori $t2, $0, 4
addu $s2, $s1, $s0
lw $t5, 0($t2)
ori $t3, $0, 8
sw $t3, 0($t3)
lw $t4, 0($t3)
lw $t5, 0($t4)
lw $t6, 0($t3)
addu $s1, $s0, $s2
lw $t5, 0($t6)
mthi $t3
mfhi $s4
lw $s5, 0($s4)
mthi $t3
mfhi $s5
div $t3, $s5
lw $s4, 0($s5)
sra $s4, $t3, 1
lw $s5, 0($s4)
sra $s5, $t3, 1
sll $t3, $t3, 1
lw $s4, 0($s5)

```

Store:

```

ori $t1, $0, 4
ori $t2, $0, 8
addu $t3, $t2, $t1
sw $t3, 0($t3)
ori $t2, $0, 48
addu $t3, $t2, $0

```

```
addu $s0, $s1, $s2
sw $t4, 0($t3)
ori $t2, $0, 40
sw $t5, 0($t2)
ori $t2, $0, 32
addu $s2, $s1, $s0
sw $t5, 0($t2)
ori $t3, $0, 80
sw $t3, 0($t3)
lw $t4, 0($t3)
sw $t5, 0($t4)
lw $t6, 0($t3)
addu $s1, $s0, $s2
sw $t5, 0($t6)
li $t3, 100
mthi $t3
mfhi $s4
sw $s5, 0($s4)
li $t3, 104
mthi $t3
mfhi $s4
mult $t3, $s4
sw $s5, 0($s4)
li $t3, 70
sll $s4, $t3, 2
sw $s5, 0($s4)
li $t3, 71
sll $s4, $t3, 2
sra $s5, $s4, 3
sw $s5, 0($s4)
ori $t1, $0, 4
ori $t2, $0, 8
addu $t3, $t2, $t1
```

```

sw $t3, 0($t3)
ori $t2, $0, 84
sw $t2, 0($t2)
ori $t3, $0, 8
lw $t4, 0($t3)
sw $t4, 4($t3)
jal Label56
sw $ra, 200($t3)
Label56:
la $t3, Label57
jalr $ra, $t3
sw $ra, 260($0)
Label57:
mfhi $t3
sw $t3, 264($0)
sll $t3, $t3, 2
sw $t3, 268($0)

```

```

Branch:
addu $t1, $t2, $t3
addu $t4, $t2, $t3
beq $t4, $t1, Label111
nop
addu $s1, $s2, $s3
Label111:
addu $t2, $t1, $t3
addu $t4, $t1, $t3
beq $t2, $t4, Label112
nop
addu $s1, $s2, $s3
Label112:
addu $t1, $t2, $t3
addu $t4, $t2, $t3

```

beq \$t1, \$t4, Label13

nop

addu \$s1, \$s2, \$s3

Label13:

addu \$t2, \$t1, \$t3

addu \$t4, \$t1, \$t3

beq \$t4, \$t2, Label14

nop

addu \$s1, \$s2, \$s3

Label14:

addu \$t1, \$t2, \$t3

addu \$t4, \$t2, \$t3

addu \$s1, \$s2, \$s3

beq \$t1, \$t4, Label15

nop

addu \$s1, \$s2, \$s3

Label15:

addu \$t2, \$t1, \$t3

addu \$t4, \$t1, \$t3

addu \$s1, \$s2, \$s3

beq \$t4, \$t2, Label16

nop

addu \$s1, \$s2, \$s3

Label16:

ori \$t1, \$0, 1

ori \$t2, \$0, 1

beq \$t2, \$t1, Label17

nop

addu \$s1, \$s2, \$s3

Label17:

ori \$t1, \$0, 2

ori \$t2, \$0, 2

beq \$t1, \$t2, Label18

```
nop
addu $s1, $s2, $s3
Label18:
ori $t1, $0, 3
ori $t2, $0, 3
addu $s1, $s2, $s3
beq $t1, $t2, Label19
nop
addu $s1, $s2, $s3
Label19:
ori $t1, $0, 4
ori $t2, $0, 4
addu $s1, $s2, $s3
beq $t2, $t1, Label20
nop
addu $s1, $s2, $s3
Label20:
ori $t3, $0, 20
sw $s0, 0($t3)
lw $t2, 0($t3)
beq $t2, $s0, Label21
nop
addu $s1, $s2, $s3
Label21:
ori $t4, $0, 24
sw $s0, 0($t4)
lw $t1, 0($t4)
beq $s0, $t1, Label22
nop
addu $s1, $s2, $s3
Label22:
ori $t3, $0, 28
sw $s0, 0($t3)
```

```
lw $t2, 0($t3)
addu $s1, $s2, $s3
beq $t2, $s0, Label123
nop
addu $s1, $s2, $s3
Label123:
ori $t4, $0, 32
sw $s0, 0($t4)
lw $t1, 0($t4)
addu $s1, $s2, $s3
beq $s0, $t1, Label124
nop
addu $s1, $s2, $s3
Label124:
ori $t3, $0, 36
sw $s0, 0($t3)
lw $t2, 0($t3)
addu $s1, $s2, $s3
nop
beq $t2, $s0, Label125
nop
addu $s1, $s2, $s3
Label125:
ori $t4, $0, 44
sw $s0, 0($t4)
lw $t1, 0($t4)
addu $s1, $s2, $s3
nop
beq $s0, $t1, Label126
nop
addu $s1, $s2, $s3
Label126:
jal Label127
```

```
addu $t1, $0, $ra
Label127:
beq $ra, $t1, Label128
nop
addu $s1, $s2, $s3
Label128:
jal Label129
addu $t1, $0, $ra
Label129:
beq $t1, $ra, Label130
nop
addu $s1, $s2, $s3
Label130:
jal Label131
nop
Label131:
addu $t1, $0, $ra
beq $ra, $t1, Label132
nop
addu $s1, $s2, $s3
Label132:
jal Label133
nop
Label133:
addu $t1, $0, $ra
beq $t1, $ra, Label134
nop
addu $s1, $s2, $s3
Label134:
la $a0, Label158
jalr $ra, $a0
addu $t1, $0, $ra
Label158:
```


beq \$ra, \$t1, Label159

nop

addu \$s1, \$s2, \$s3

Label159:

la \$a0, Label160

jalr \$ra, \$a0

addu \$t1, \$0, \$ra

Label160:

beq \$t1, \$ra, Label161

nop

addu \$s1, \$s2, \$s3

Label161:

la \$a0, Label162

jalr \$ra, \$a0

nop

Label162:

addu \$t1, \$0, \$ra

beq \$ra, \$t1, Label163

nop

addu \$s1, \$s2, \$s3

Label163:

la \$a0, Label164

jalr \$ra, \$a0

nop

Label164:

addu \$t1, \$0, \$ra

beq \$t1, \$ra, Label165

nop

addu \$s1, \$s2, \$s3

Label165:

mthi \$t0

mfhi \$s0

beq \$s0, \$t0, Label166

```
nop
addu $s1, $s2, $s3
Label66:
mthi $t1
mfhi $s0
beq $t1, $s0, Label67
nop
addu $s1, $s2, $s3
Label67:
mthi $t0
mfhi $s0
nop
beq $s0, $t0, Label68
nop
addu $s1, $s2, $s3
Label68:
mthi $t1
mfhi $s0
nop
beq $t1, $s0, Label69
nop
addu $s1, $s2, $s3
Label69:
mthi $t0
mfhi $s0
nop
beq $s0, $t0, Label70
nop
addu $s1, $s2, $s3
Label70:
mthi $t1
mfhi $s0
nop
```

```
beq $t1, $s0, Label71
nop
addu $s1, $s2, $s3
Label71:
li $a0, 4
li $a1, 2
sll $a1, $a1, 1
beq $a1, $a0, Label72
nop
addu $s2, $s1, $s3
Label72:
li $a0, 8
li $a1, 16
sra $a1, $a1, 1
beq $a0, $a1, Label73
nop
addu $s1, $s2, $s3
Label73:
li $a0, 4
li $a1, 2
sll $a1, $a1, 1
nop
beq $a1, $a0, Label74
nop
addu $s2, $s1, $s3
Label74:
li $a0, 8
li $a1, 16
sra $a1, $a1, 1
nop
beq $a0, $a1, Label75
nop
addu $s1, $s2, $s3
```

```
Label175:
li $a0, 4
li $a1, 2
sll $a1, $a1, 1
nop
nop
beq $a1, $a0, Label176
nop
addu $s2, $s1, $s3
```

```
Label176:
li $a0, 8
li $a1, 16
sra $a1, $a1, 1
nop
nop
beq $a0, $a1, Label177
nop
addu $s1, $s2, $s3
```

```
Label177:
```

```
Jr:
jal Label135
ori $t2, $0, 12
```

```
Label135:
addu $t1, $t2, $ra
jr $t1
nop
```

```
jal Label136
ori $t2, $0, 16
```

```
Label136:
addu $t1, $t2, $ra
nop
jr $t1
```

```
nop
jal Label37
ori $t2, $0, 20
Label37:
addu $t1, $t2, $ra
nop
nop
jr $t1
nop
jal Label38
ori $t2, $0, 16
Label38:
addu $t1, $t2, $ra
ori $t4, $t1, 0
jr $t4
nop
jal Label39
ori $t2, $0, 20
Label39:
addu $t1, $t2, $ra
ori $t4, $t1, 0
nop
jr $t4
nop
jal Label40
ori $t2, $0, 24
Label40:
addu $t1, $t2, $ra
ori $t4, $t1, 0
nop
nop
jr $t4
nop
```

```
jal Label41
ori $t2, $0, 20
Label41:
addu $t1, $t2, $ra
sw $t1, 0($t2)
lw $t3, 0($t2)
jr $t3
nop
jal Label42
ori $t2, $0, 24
Label42:
addu $t1, $t2, $ra
sw $t1, 0($t2)
lw $t3, 0($t2)
nop
jr $t3
nop
jal Label43
ori $t2, $0, 28
Label43:
addu $t1, $t2, $ra
sw $t1, 0($t2)
lw $t3, 0($t2)
nop
nop
jr $t3
nop
jal Label44
nop
j Label45
nop
Label44:
jr $ra
```

nop

Label45:

jal Label47

nop

j Label48

nop

Label47:

addu \$s1, \$s2, \$s3

jr \$ra

nop

Label48:

la \$a0, Label78

jalr \$ra, \$a0

nop

j Label79

nop

Label78:

jr \$ra

nop

Label79:

la \$a0, Label80

jalr \$ra, \$a0

nop

j Label81

nop

Label80:

addu \$s2, \$s1, \$s3

jr \$ra

nop

Label81:

la \$a0, Label82

mthi \$a0

mfhi \$ra

```
jr $ra
nop
Label82:
la $a0, Label83
mthi $a0
mfhi $ra
sll $a0, $a0, 1
jr $ra
nop
Label83:
la $a0, Label84
mthi $a0
mfhi $ra
sll $a0, $a0, 1
nop
jr $ra
nop
Label84:
```

```
Shift:
addu $t0, $t1, $t2
sll $t0, $t0, 1
subu $t3, $t4, $t5
xori $s0, $s0, 0x1111
srl $t3, $t0, 1
addi $s0, $s0, 125
srl $s1, $s0, 2
addi $s0, $s0, 127
andi $s1, $s1, 0x1010
srl $s1, $s0, 2
lw $a0, 0($0)
sll $a0, $a0, 2
lw $a0, 4($0)
```



```

sll $a0, $a0, 3
jal Label85
sll $ra, $ra, 3
Label85:
jal Label86
nop
Label86:
sll $ra, $ra, 3
la $a0, Label87
jalr $ra, $a0
sll $ra, $ra, 3
Label87:
la $a0, Label88
jalr $ra, $a0
nop
Label88:
sll $ra, $ra, 2
mfhi $a0
sra $a0, $a0, 2
mfhi $a1
sll $a1, $a1, 4
srl $a1, $a1, 2
sll $a1, $a1, 2
sll $s0, $s0, 3
srav $a1, $a1, $a1
srl $s0, $s0, 4

```

2) 期望结果

```

@00003000: $ 8 <= 12340000
@00003004: $ 8 <= 00005678
@00003008: $16 <= 00000010
@0000300c: *00000000 <= 00007800
@00003010: $12 <= 00000078
@00003014: $13 <= 00000078

```

@00003018: *00000000 <= 00007878

@0000301c: \$14 <= 00000078

@00003020: \$15 <= 00000078

@00003024: *00000000 <= 56787878

@00003028: \$12 <= 00005678

@0000302c: \$13 <= 00005678

@00003030: *00000000 <= 56787878

@00003034: \$14 <= 00005678

@00003038: \$15 <= 00005678

@0000303c: *00000004 <= 00005678

@00003040: \$ 9 <= 00005678

@00003044: *00000008 <= 00005678

@00003048: \$10 <= 00005678

@0000304c: \$11 <= 0000acf0

@00003050: \$12 <= 00000000

@00003054: \$15 <= 0000acf0

@00003058: \$24 <= 00000000

@0000305c: \$ 4 <= ffffffff

@00003064: \$11 <= ffffffff

@0000306c: \$12 <= fffa988

@00003070: \$ 4 <= fffffffd

@00003074: \$ 5 <= 00000002

@0000307c: \$17 <= ffffffff

@00003080: \$18 <= ffffffff

@00003088: \$17 <= 00000001

@0000308c: \$18 <= 7ffffffe

@00003098: \$19 <= 00005678

@0000309c: \$20 <= 00005678

@000030a0: \$17 <= 00000004

@000030a4: \$18 <= 0fffffff

@000030a8: \$ 4 <= ffffffff

@000030ac: \$13 <= 00000004

@000030b0: \$14 <= 00000003

@000030b4: \$15 <= 00000002
@000030b8: \$17 <= 00000040
@000030bc: \$18 <= 01ffffff
@000030c0: \$ 4 <= ffffffff
@000030c4: \$19 <= 00000040
@000030c8: \$19 <= 01ffffff
@000030cc: \$19 <= 01ffffbf
@000030d0: \$19 <= fe000000
@000030d4: \$19 <= fdffffff
@000030d8: \$19 <= 00001010
@000030dc: \$19 <= 01ffefef
@000030e0: \$20 <= 00000000
@000030e4: \$20 <= 00000000
@000030e8: \$20 <= 00000001
@000030ec: \$ 4 <= ffffffff
@000030f0: \$20 <= 00000001
@000030f8: \$13 <= 00010000
@000030fc: \$19 <= 00010000
@0000311c: \$13 <= 00020000
@00003120: \$19 <= 00020000
@0000313c: \$21 <= ffffffff
@00003140: \$22 <= 00000001
@00003148: \$13 <= 00000001
@0000315c: \$13 <= 00000002
@00003170: \$13 <= 00000001
@00003184: \$13 <= 00000002
@00003194: \$31 <= 0000319c
@00003198: \$20 <= 00400000
@000031ac: \$24 <= 00000010
@000031b4: \$22 <= 04000000
@0000319c: \$25 <= 00003054
@000031a0: \$ 4 <= 000031c4
@000031a4: \$31 <= 000031ac

@000031a8: \$21 <= 01000000
@000031c8: \$18 <= 00000081
@000031b8: \$23 <= 04030000
@000031cc: \$10 <= 0000acf0
@000031d0: \$11 <= 00005678
@000031d4: \$10 <= 0000acf0
@000031d8: \$11 <= ffffa988
@000031dc: \$10 <= 0000acf0
@000031e0: \$16 <= 0000001a
@000031e4: \$11 <= 00005678
@000031e8: \$10 <= 0000acf0
@000031ec: \$16 <= 0000001b
@000031f0: \$11 <= ffffa988
@000031f4: \$10 <= 00810000
@000031f8: \$11 <= 0080a988
@000031fc: \$12 <= 00810000
@00003200: \$11 <= ff7f5678
@00003204: \$10 <= 007f0000
@00003208: \$17 <= 00020081
@0000320c: \$11 <= 007ea988
@00003210: \$12 <= 007f0000
@00003214: \$17 <= fffe0081
@00003218: \$11 <= ff815678
@0000321c: \$12 <= 56787878
@00003220: \$11 <= 5678cef0
@00003224: \$13 <= 00005678
@00003228: \$11 <= 007f5678
@0000322c: \$12 <= 56787878
@00003230: \$17 <= fffe0081
@00003234: \$11 <= 5678cef0
@00003238: \$13 <= 00005678
@0000323c: \$17 <= fffe0081
@00003240: \$11 <= 007f5678

@00003244: \$31 <= 0000324c
@00003248: \$20 <= 0000324c
@0000324c: \$31 <= 00003254
@00003250: \$21 <= 00003254
@00003254: \$31 <= 0000325c
@0000325c: \$20 <= 0000325c
@00003260: \$31 <= 00003268
@00003268: \$21 <= 00003268
@0000326c: \$ 4 <= 00003278
@00003270: \$31 <= 00003278
@00003274: \$20 <= 00003278
@00003278: \$ 4 <= 00003284
@0000327c: \$31 <= 00003284
@00003280: \$21 <= 00003284
@00003284: \$ 4 <= 00003290
@00003288: \$31 <= 00003290
@00003290: \$20 <= 00003290
@00003294: \$ 4 <= 000032a0
@00003298: \$31 <= 000032a0
@000032a0: \$21 <= 000032a0
@000032a8: \$20 <= 00005678
@000032ac: \$21 <= 0000acf0
@000032b4: \$21 <= 00005678
@000032b8: \$20 <= 0000acf0
@000032c0: \$20 <= 00005678
@000032c8: \$21 <= 0000acf0
@000032d0: \$21 <= 00005678
@000032d8: \$20 <= 0000acf0
@000032dc: \$20 <= 000acf00
@000032e0: \$21 <= 000a7888
@000032e4: \$20 <= 00056780
@000032e8: \$21 <= fffaeef8
@000032ec: \$20 <= 000acf00

@000032f0: \$21 <= 00000567
@000032f4: \$21 <= 000a7888
@000032f8: \$20 <= 00056780
@000032fc: \$21 <= 00000acf
@00003300: \$21 <= fffaef8
@00003304: \$10 <= 0000acf0
@00003308: \$11 <= 0000acff
@0000330c: \$10 <= 00010377
@00003310: \$16 <= 0000001b
@00003314: \$11 <= 0001037f
@00003318: \$10 <= 00810000
@0000331c: \$11 <= 00810001
@00003320: \$10 <= 007f0000
@00003324: \$17 <= 00020081
@00003328: \$11 <= 007f0006
@0000332c: \$12 <= 56787878
@00003330: \$11 <= 5678787a
@00003334: \$13 <= 00005678
@00003338: \$17 <= fffe0081
@0000333c: \$11 <= 0000567d
@00003340: \$31 <= 00003348
@00003344: \$20 <= 0000334e
@00003348: \$31 <= 00003350
@00003350: \$20 <= 00003359
@00003354: \$ 4 <= 00003360
@00003358: \$31 <= 00003360
@0000335c: \$20 <= 0000336b
@00003360: \$ 4 <= 0000336c
@00003364: \$31 <= 0000336c
@0000336c: \$20 <= 00003382
@00003374: \$20 <= 00005678
@00003378: \$21 <= 00005699
@00003380: \$20 <= 00005678

@00003388: \$21 <= 000056a4
@0000338c: \$20 <= 000acf00
@00003390: \$21 <= 000acf41
@00003394: \$20 <= 000acf00
@00003398: \$21 <= 00000567
@0000339c: \$21 <= 000acf7b
@000033a0: \$ 9 <= 00000002
@000033a4: \$10 <= 00000002
@000033a8: \$11 <= 00000004
@000033ac: \$12 <= 00005678
@000033b0: \$10 <= 00000004
@000033b4: \$11 <= 00000004
@000033b8: \$16 <= fffe0102
@000033bc: \$12 <= 00005678
@000033c0: \$10 <= 00000004
@000033c4: \$13 <= 00005678
@000033c8: \$10 <= 00000004
@000033cc: \$18 <= fffc0183
@000033d0: \$13 <= 00005678
@000033d4: \$11 <= 00000008
@000033d8: *00000008 <= 00000008
@000033dc: \$12 <= 00000008
@000033e0: \$13 <= 00000008
@000033e4: \$14 <= 00000008
@000033e8: \$17 <= fffa0285
@000033ec: \$13 <= 00000008
@000033f4: \$20 <= 00000008
@000033f8: \$21 <= 00000008
@00003400: \$21 <= 00000008
@00003408: \$20 <= 00000008
@0000340c: \$20 <= 00000004
@00003410: \$21 <= 00005678
@00003414: \$21 <= 00000004

@00003418: \$11 <= 00000010
@0000341c: \$20 <= 00005678
@00003420: \$ 9 <= 00000004
@00003424: \$10 <= 00000008
@00003428: \$11 <= 0000000c
@0000342c: *0000000c <= 0000000c
@00003430: \$10 <= 00000030
@00003434: \$11 <= 00000030
@00003438: \$16 <= fff60408
@0000343c: *00000030 <= 00000008
@00003440: \$10 <= 00000028
@00003444: *00000028 <= 00000008
@00003448: \$10 <= 00000020
@0000344c: \$18 <= fff0068d
@00003450: *00000020 <= 00000008
@00003454: \$11 <= 00000050
@00003458: *00000050 <= 00000050
@0000345c: \$12 <= 00000050
@00003460: *00000050 <= 00000008
@00003464: \$14 <= 00000008
@00003468: \$17 <= ffe60a95
@0000346c: *00000008 <= 00000008
@00003470: \$11 <= 00000064
@00003478: \$20 <= 00000064
@0000347c: *00000064 <= 00000004
@00003480: \$11 <= 00000068
@00003488: \$20 <= 00000068
@00003490: *00000068 <= 00000004
@00003494: \$11 <= 00000046
@00003498: \$20 <= 00000118
@0000349c: *00000118 <= 00000004
@000034a0: \$11 <= 00000047
@000034a4: \$20 <= 0000011c

@000034a8: \$21 <= 00000023
@000034ac: *0000011c <= 00000023
@000034b0: \$ 9 <= 00000004
@000034b4: \$10 <= 00000008
@000034b8: \$11 <= 0000000c
@000034bc: *0000000c <= 0000000c
@000034c0: \$10 <= 00000054
@000034c4: *00000054 <= 00000054
@000034c8: \$11 <= 00000008
@000034cc: \$12 <= 00000008
@000034d0: *0000000c <= 00000008
@000034d4: \$31 <= 000034dc
@000034d8: *000000d0 <= 000034dc
@000034dc: \$11 <= 000034e8
@000034e0: \$31 <= 000034e8
@000034e4: *00000104 <= 000034e8
@000034e8: \$11 <= 00000000
@000034ec: *00000108 <= 00000000
@000034f0: \$11 <= 00000000
@000034f4: *0000010c <= 00000000
@000034f8: \$ 9 <= 00000054
@000034fc: \$12 <= 00000054
@0000350c: \$10 <= 00000054
@00003510: \$12 <= 00000054
@00003520: \$ 9 <= 00000054
@00003524: \$12 <= 00000054
@00003534: \$10 <= 00000054
@00003538: \$12 <= 00000054
@00003548: \$ 9 <= 00000054
@0000354c: \$12 <= 00000054
@00003550: \$17 <= fff2068d
@00003560: \$10 <= 00000054
@00003564: \$12 <= 00000054

@00003568: \$17 <= fff2068d
@00003578: \$ 9 <= 00000001
@0000357c: \$10 <= 00000001
@0000358c: \$ 9 <= 00000002
@00003590: \$10 <= 00000002
@000035a0: \$ 9 <= 00000003
@000035a4: \$10 <= 00000003
@000035a8: \$17 <= fff2068d
@000035b8: \$ 9 <= 00000004
@000035bc: \$10 <= 00000004
@000035c0: \$17 <= fff2068d
@000035d0: \$11 <= 00000014
@000035d4: *00000014 <= fff60408
@000035d8: \$10 <= fff60408
@000035e8: \$12 <= 00000018
@000035ec: *00000018 <= fff60408
@000035f0: \$ 9 <= fff60408
@00003600: \$11 <= 0000001c
@00003604: *0000001c <= fff60408
@00003608: \$10 <= fff60408
@0000360c: \$17 <= fff2068d
@0000361c: \$12 <= 00000020
@00003620: *00000020 <= fff60408
@00003624: \$ 9 <= fff60408
@00003628: \$17 <= fff2068d
@00003638: \$11 <= 00000024
@0000363c: *00000024 <= fff60408
@00003640: \$10 <= fff60408
@00003644: \$17 <= fff2068d
@00003658: \$12 <= 0000002c
@0000365c: *0000002c <= fff60408
@00003660: \$ 9 <= fff60408
@00003664: \$17 <= fff2068d

@00003678: \$31 <= 00003680
@0000367c: \$ 9 <= 00003680
@0000368c: \$31 <= 00003694
@00003690: \$ 9 <= 00003694
@000036a0: \$31 <= 000036a8
@000036a8: \$ 9 <= 000036a8
@000036b8: \$31 <= 000036c0
@000036c0: \$ 9 <= 000036c0
@000036d0: \$ 4 <= 000036dc
@000036d4: \$31 <= 000036dc
@000036d8: \$ 9 <= 000036dc
@000036e8: \$ 4 <= 000036f4
@000036ec: \$31 <= 000036f4
@000036f0: \$ 9 <= 000036f4
@00003700: \$ 4 <= 0000370c
@00003704: \$31 <= 0000370c
@0000370c: \$ 9 <= 0000370c
@0000371c: \$ 4 <= 00003728
@00003720: \$31 <= 00003728
@00003728: \$ 9 <= 00003728
@0000373c: \$16 <= 00005678
@00003750: \$16 <= 00003728
@00003764: \$16 <= 00005678
@0000377c: \$16 <= 00003728
@00003794: \$16 <= 00005678
@000037ac: \$16 <= 00003728
@000037c0: \$ 4 <= 00000004
@000037c4: \$ 5 <= 00000002
@000037c8: \$ 5 <= 00000004
@000037d8: \$ 4 <= 00000008
@000037dc: \$ 5 <= 00000010
@000037e0: \$ 5 <= 00000008
@000037f0: \$ 4 <= 00000004

@000037f4: \$ 5 <= 00000002
@000037f8: \$ 5 <= 00000004
@0000380c: \$ 4 <= 00000008
@00003810: \$ 5 <= 00000010
@00003814: \$ 5 <= 00000008
@00003828: \$ 4 <= 00000004
@0000382c: \$ 5 <= 00000002
@00003830: \$ 5 <= 00000004
@00003848: \$ 4 <= 00000008
@0000384c: \$ 5 <= 00000010
@00003850: \$ 5 <= 00000008
@00003868: \$31 <= 00003870
@0000386c: \$10 <= 0000000c
@00003870: \$ 9 <= 0000387c
@0000387c: \$31 <= 00003884
@00003880: \$10 <= 00000010
@00003884: \$ 9 <= 00003894
@00003894: \$31 <= 0000389c
@00003898: \$10 <= 00000014
@0000389c: \$ 9 <= 000038b0
@000038b0: \$31 <= 000038b8
@000038b4: \$10 <= 00000010
@000038b8: \$ 9 <= 000038c8
@000038bc: \$12 <= 000038c8
@000038c8: \$31 <= 000038d0
@000038cc: \$10 <= 00000014
@000038d0: \$ 9 <= 000038e4
@000038d4: \$12 <= 000038e4
@000038e4: \$31 <= 000038ec
@000038e8: \$10 <= 00000018
@000038ec: \$ 9 <= 00003904
@000038f0: \$12 <= 00003904
@00003904: \$31 <= 0000390c

@00003908: \$10 <= 00000014
@0000390c: \$ 9 <= 00003920
@00003910: *00000014 <= 00003920
@00003914: \$11 <= 00003920
@00003920: \$31 <= 00003928
@00003924: \$10 <= 00000018
@00003928: \$ 9 <= 00003940
@0000392c: *00000018 <= 00003940
@00003930: \$11 <= 00003940
@00003940: \$31 <= 00003948
@00003944: \$10 <= 0000001c
@00003948: \$ 9 <= 00003964
@0000394c: *0000001c <= 00003964
@00003950: \$11 <= 00003964
@00003964: \$31 <= 0000396c
@0000397c: \$31 <= 00003984
@0000398c: \$17 <= fff2068d
@00003998: \$ 4 <= 000039ac
@0000399c: \$31 <= 000039a4
@000039b4: \$ 4 <= 000039c8
@000039b8: \$31 <= 000039c0
@000039c8: \$18 <= fff4068d
@000039d4: \$ 4 <= 000039e8
@000039dc: \$31 <= 000039e8
@000039e8: \$ 4 <= 00003a00
@000039f0: \$31 <= 00003a00
@000039f4: \$ 4 <= 00007400
@00003a00: \$ 4 <= 00003a1c
@00003a08: \$31 <= 00003a1c
@00003a0c: \$ 4 <= 00007438
@00003a1c: \$ 8 <= 00003980
@00003a20: \$ 8 <= 00007300
@00003a24: \$11 <= 000038fc

@00003a28: \$16 <= 00002639
@00003a2c: \$11 <= 00003980
@00003a30: \$16 <= 000026b6
@00003a34: \$17 <= 000009ad
@00003a38: \$16 <= 00002735
@00003a3c: \$17 <= 00000000
@00003a40: \$17 <= 000009cd
@00003a44: \$ 4 <= 56787878
@00003a48: \$ 4 <= 59e1e1e0
@00003a4c: \$ 4 <= 00005678
@00003a50: \$ 4 <= 0002b3c0
@00003a54: \$31 <= 00003a5c
@00003a58: \$31 <= 0001d2e0
@00003a5c: \$31 <= 00003a64
@00003a64: \$31 <= 0001d320
@00003a68: \$ 4 <= 00003a74
@00003a6c: \$31 <= 00003a74
@00003a70: \$31 <= 0001d3a0
@00003a74: \$ 4 <= 00003a80
@00003a78: \$31 <= 00003a80
@00003a80: \$31 <= 0000ea00
@00003a84: \$ 4 <= 00003a1c
@00003a88: \$ 4 <= 00000e87
@00003a8c: \$ 5 <= 00003a1c
@00003a90: \$ 5 <= 0003a1c0
@00003a94: \$ 5 <= 0000e870
@00003a98: \$ 5 <= 0003a1c0
@00003a9c: \$16 <= 000139a8
@00003aa0: \$ 5 <= 0003a1c0
@00003aa4: \$16 <= 0000139a

2. 异常测试

1) 测试程序

```
.ktext 0x4180
```

```
_entry:
```

```
    mfc0    $k0, $14
```

```
    mfc0    $k1, $13
```

```
    ori$k0, $0, 0x1000
```

```
    sw      $sp, -4($k0)
```

```
    addiu   $k0, $k0, -256
```

```
    move    $sp, $k0
```

```
    j       _save_context
```

```
    nop
```

```
_main_handler:
```

```
    mfc0    $k0, $13
```

```
    ori     $k1, $0, 0x007c
```

```
    and$k0, $k1, $k0
```

```
    beq     $0, $k0, _restore_context
```

```
    nop
```

```
    mfc0    $k0, $14
```

```
    addu    $k0, $k0, 4
```

```
    mtc0    $k0, $14
```

```
    j       _restore_context
```

```
    nop
```

```
_restore:
```

```
    eret
```

```
_save_context:
```

```
    sw      $1, 4($sp)
```

```
        sw      $2, 8($sp)
```

```
        sw      $3, 12($sp)
```

```
        sw      $4, 16($sp)
```

```
sw    $5, 20($sp)
sw    $6, 24($sp)
sw    $7, 28($sp)
sw    $8, 32($sp)
sw    $9, 36($sp)
sw    $10, 40($sp)
sw    $11, 44($sp)
sw    $12, 48($sp)
sw    $13, 52($sp)
sw    $14, 56($sp)
sw    $15, 60($sp)
sw    $16, 64($sp)
sw    $17, 68($sp)
sw    $18, 72($sp)
sw    $19, 76($sp)
sw    $20, 80($sp)
sw    $21, 84($sp)
sw    $22, 88($sp)
sw    $23, 92($sp)
sw    $24, 96($sp)
sw    $25, 100($sp)
sw    $26, 104($sp)
sw    $27, 108($sp)
sw    $28, 112($sp)
sw    $29, 116($sp)
sw    $30, 120($sp)
sw    $31, 124($sp)
mfhi  $k0
sw    $k0, 128($sp)
mflo  $k0
sw    $k0, 132($sp)
j     _main_handler
nop
```


_restore_context:

```
lw $1, 4($sp)
    lw    $2, 8($sp)
    lw    $3, 12($sp)
    lw    $4, 16($sp)
    lw    $5, 20($sp)
    lw    $6, 24($sp)
    lw    $7, 28($sp)
    lw    $8, 32($sp)
    lw    $9, 36($sp)
    lw   $10, 40($sp)
    lw   $11, 44($sp)
    lw   $12, 48($sp)
    lw   $13, 52($sp)
    lw   $14, 56($sp)
    lw   $15, 60($sp)
    lw   $16, 64($sp)
    lw   $17, 68($sp)
    lw   $18, 72($sp)
    lw   $19, 76($sp)
    lw   $20, 80($sp)
    lw   $21, 84($sp)
    lw   $22, 88($sp)
    lw   $23, 92($sp)
    lw   $24, 96($sp)
    lw   $25, 100($sp)
    lw   $26, 104($sp)
    lw   $27, 108($sp)
    lw   $28, 112($sp)
    lw   $29, 116($sp)
```

```

        lw    $30, 120($sp)
        lw    $31, 124($sp)
lw $k0, 128($sp)
mthi $k0
lw $k0, 132($sp)
mtlo $k0
        j    _restore
nop

```

.text

```

ori$28, $0, 0x0000
ori$29, $0, 0x0000
li $s0, 1
lw $t0, 2($0)
addi $s0, $s0, 1
lh $t0, 1($0)
addi $s0, $s0, 1
lb $t0, 0x7f00($0)
addi $s0, $s0, 1
lw $t0, -1($0)
addi $s0, $s0, 1
li $t1, 0x7fffffff
lw $t0, 1000($t1)
addi $s0, $s0, 1
sw $t0, 2($0)
addi $s0, $s0, 1
sh $t0, 1($0)
addi $s0, $s0, 1
sb $t0, 0x7f00($0)
addi $s0, $s0, 1
sw $t0, -1($0)

```

```

addi $s0, $s0, 1
li $t1, 0x7fffffff
sw $t0, 1000($t1)
addi $s0, $s0, 1
sw $t1, 0x7f08($0)
addi $s0, $s0, 1
madd $t1, $t1
addi $s0, $s0, 1
add $t1, $t1, $t1
addi $s0, $s0, 1

```

end:

```
beq $0, $0, end
```

nop

2) 期望结果

38@00003000: \$28 <= 00000000

42@00003004: \$29 <= 00000000

46@00003008: \$16 <= 00000001

66@00004180: \$26 <= 0000300c

70@00004184: \$27 <= 00000010

74@00004188: \$26 <= 00001000

74@0000418c: *00000ffc <= 00000000

82@00004190: \$26 <= 00000f00

86@00004194: \$29 <= 00000f00

94@000041d4: *00000f04 <= 00000000

98@000041d8: *00000f08 <= 00000000

102@000041dc: *00000f0c <= 00000000

106@000041e0: *00000f10 <= 00000000

110@000041e4: *00000f14 <= 00000000

114@000041e8: *00000f18 <= 00000000

118@000041ec: *00000f1c <= 00000000

122@000041f0: *00000f20 <= 00000000

126@000041f4: *00000f24 <= 00000000

130@000041f8: *00000f28 <= 00000000
134@000041fc: *00000f2c <= 00000000
138@00004200: *00000f30 <= 00000000
142@00004204: *00000f34 <= 00000000
146@00004208: *00000f38 <= 00000000
150@0000420c: *00000f3c <= 00000000
154@00004210: *00000f40 <= 00000001
158@00004214: *00000f44 <= 00000000
162@00004218: *00000f48 <= 00000000
166@0000421c: *00000f4c <= 00000000
170@00004220: *00000f50 <= 00000000
174@00004224: *00000f54 <= 00000000
178@00004228: *00000f58 <= 00000000
182@0000422c: *00000f5c <= 00000000
186@00004230: *00000f60 <= 00000000
190@00004234: *00000f64 <= 00000000
194@00004238: *00000f68 <= 00000f00
198@0000423c: *00000f6c <= 00000010
202@00004240: *00000f70 <= 00000000
206@00004244: *00000f74 <= 00000f00
210@00004248: *00000f78 <= 00000000
214@0000424c: *00000f7c <= 00000000
222@00004250: \$26 <= 00000000
222@00004254: *00000f80 <= 00000000
230@00004258: \$26 <= 00000000
230@0000425c: *00000f84 <= 00000000
246@000041a0: \$26 <= 00000010
250@000041a4: \$27 <= 0000007c
254@000041a8: \$26 <= 00000010
270@000041b4: \$26 <= 0000300c
274@000041b8: \$ 1 <= 00000000
278@000041bc: \$ 1 <= 00000004
282@000041c0: \$26 <= 00003010

298@00004268: \$ 1 <= 00000000
302@0000426c: \$ 2 <= 00000000
306@00004270: \$ 3 <= 00000000
310@00004274: \$ 4 <= 00000000
314@00004278: \$ 5 <= 00000000
318@0000427c: \$ 6 <= 00000000
322@00004280: \$ 7 <= 00000000
326@00004284: \$ 8 <= 00000000
330@00004288: \$ 9 <= 00000000
334@0000428c: \$10 <= 00000000
338@00004290: \$11 <= 00000000
342@00004294: \$12 <= 00000000
346@00004298: \$13 <= 00000000
350@0000429c: \$14 <= 00000000
354@000042a0: \$15 <= 00000000
358@000042a4: \$16 <= 00000001
362@000042a8: \$17 <= 00000000
366@000042ac: \$18 <= 00000000
370@000042b0: \$19 <= 00000000
374@000042b4: \$20 <= 00000000
378@000042b8: \$21 <= 00000000
382@000042bc: \$22 <= 00000000
386@000042c0: \$23 <= 00000000
390@000042c4: \$24 <= 00000000
394@000042c8: \$25 <= 00000000
398@000042cc: \$26 <= 00000f00
402@000042d0: \$27 <= 00000010
406@000042d4: \$28 <= 00000000
410@000042d8: \$29 <= 00000f00
418@000042dc: \$30 <= 00000000
422@000042e0: \$31 <= 00000000
426@000042e4: \$26 <= 00000000
438@000042ec: \$26 <= 00000000

474@00003010: \$16 <= 00000002
494@00004180: \$26 <= 00003014
498@00004184: \$27 <= 00000010
502@00004188: \$26 <= 00001000
502@0000418c: *0000ffc <= 00000f00
510@00004190: \$26 <= 00000f00
514@00004194: \$29 <= 00000f00
522@000041d4: *00000f04 <= 00000000
526@000041d8: *00000f08 <= 00000000
530@000041dc: *00000f0c <= 00000000
534@000041e0: *00000f10 <= 00000000
538@000041e4: *00000f14 <= 00000000
542@000041e8: *00000f18 <= 00000000
546@000041ec: *00000f1c <= 00000000
550@000041f0: *00000f20 <= 00000000
554@000041f4: *00000f24 <= 00000000
558@000041f8: *00000f28 <= 00000000
562@000041fc: *00000f2c <= 00000000
566@00004200: *00000f30 <= 00000000
570@00004204: *00000f34 <= 00000000
574@00004208: *00000f38 <= 00000000
578@0000420c: *00000f3c <= 00000000
582@00004210: *00000f40 <= 00000002
586@00004214: *00000f44 <= 00000000
590@00004218: *00000f48 <= 00000000
594@0000421c: *00000f4c <= 00000000
598@00004220: *00000f50 <= 00000000
602@00004224: *00000f54 <= 00000000
606@00004228: *00000f58 <= 00000000
610@0000422c: *00000f5c <= 00000000
614@00004230: *00000f60 <= 00000000
618@00004234: *00000f64 <= 00000000
622@00004238: *00000f68 <= 00000f00

626@0000423c: *00000f6c <= 00000010
630@00004240: *00000f70 <= 00000000
634@00004244: *00000f74 <= 00000f00
638@00004248: *00000f78 <= 00000000
642@0000424c: *00000f7c <= 00000000
650@00004250: \$26 <= 00000000
650@00004254: *00000f80 <= 00000000
658@00004258: \$26 <= 00000000
658@0000425c: *00000f84 <= 00000000
674@000041a0: \$26 <= 00000010
678@000041a4: \$27 <= 0000007c
682@000041a8: \$26 <= 00000010
698@000041b4: \$26 <= 00003014
702@000041b8: \$ 1 <= 00000000
706@000041bc: \$ 1 <= 00000004
710@000041c0: \$26 <= 00003018
726@00004268: \$ 1 <= 00000000
730@0000426c: \$ 2 <= 00000000
734@00004270: \$ 3 <= 00000000
738@00004274: \$ 4 <= 00000000
742@00004278: \$ 5 <= 00000000
746@0000427c: \$ 6 <= 00000000
750@00004280: \$ 7 <= 00000000
754@00004284: \$ 8 <= 00000000
758@00004288: \$ 9 <= 00000000
762@0000428c: \$10 <= 00000000
766@00004290: \$11 <= 00000000
770@00004294: \$12 <= 00000000
774@00004298: \$13 <= 00000000
778@0000429c: \$14 <= 00000000
782@000042a0: \$15 <= 00000000
786@000042a4: \$16 <= 00000002
790@000042a8: \$17 <= 00000000

794@000042ac: \$18 <= 00000000
798@000042b0: \$19 <= 00000000
802@000042b4: \$20 <= 00000000
806@000042b8: \$21 <= 00000000
810@000042bc: \$22 <= 00000000
814@000042c0: \$23 <= 00000000
818@000042c4: \$24 <= 00000000
822@000042c8: \$25 <= 00000000
826@000042cc: \$26 <= 00000f00
830@000042d0: \$27 <= 00000010
834@000042d4: \$28 <= 00000000
838@000042d8: \$29 <= 00000f00
846@000042dc: \$30 <= 00000000
850@000042e0: \$31 <= 00000000
854@000042e4: \$26 <= 00000000
866@000042ec: \$26 <= 00000000
902@00003018: \$16 <= 00000003
922@00004180: \$26 <= 0000301c
926@00004184: \$27 <= 00000010
930@00004188: \$26 <= 00001000
930@0000418c: *0000ffc <= 00000f00
938@00004190: \$26 <= 00000f00
942@00004194: \$29 <= 00000f00
950@000041d4: *0000f04 <= 00000000
954@000041d8: *0000f08 <= 00000000
958@000041dc: *0000f0c <= 00000000
962@000041e0: *0000f10 <= 00000000
966@000041e4: *0000f14 <= 00000000
970@000041e8: *0000f18 <= 00000000
974@000041ec: *0000f1c <= 00000000
978@000041f0: *0000f20 <= 00000000
982@000041f4: *0000f24 <= 00000000
986@000041f8: *0000f28 <= 00000000

990@000041fc: *00000f2c <= 00000000
994@00004200: *00000f30 <= 00000000
998@00004204: *00000f34 <= 00000000
1002@00004208: *00000f38 <= 00000000
1006@0000420c: *00000f3c <= 00000000
1010@00004210: *00000f40 <= 00000003
1014@00004214: *00000f44 <= 00000000
1018@00004218: *00000f48 <= 00000000
1022@0000421c: *00000f4c <= 00000000
1026@00004220: *00000f50 <= 00000000
1030@00004224: *00000f54 <= 00000000
1034@00004228: *00000f58 <= 00000000
1038@0000422c: *00000f5c <= 00000000
1042@00004230: *00000f60 <= 00000000
1046@00004234: *00000f64 <= 00000000
1050@00004238: *00000f68 <= 00000f00
1054@0000423c: *00000f6c <= 00000010
1058@00004240: *00000f70 <= 00000000
1062@00004244: *00000f74 <= 00000f00
1066@00004248: *00000f78 <= 00000000
1070@0000424c: *00000f7c <= 00000000
1078@00004250: \$26 <= 00000000
1078@00004254: *00000f80 <= 00000000
1086@00004258: \$26 <= 00000000
1086@0000425c: *00000f84 <= 00000000
1102@000041a0: \$26 <= 00000010
1106@000041a4: \$27 <= 0000007c
1110@000041a8: \$26 <= 00000010
1126@000041b4: \$26 <= 0000301c
1130@000041b8: \$ 1 <= 00000000
1134@000041bc: \$ 1 <= 00000004
1138@000041c0: \$26 <= 00003020
1154@00004268: \$ 1 <= 00000000

1158@0000426c: \$ 2 <= 00000000
1162@00004270: \$ 3 <= 00000000
1166@00004274: \$ 4 <= 00000000
1170@00004278: \$ 5 <= 00000000
1174@0000427c: \$ 6 <= 00000000
1178@00004280: \$ 7 <= 00000000
1182@00004284: \$ 8 <= 00000000
1186@00004288: \$ 9 <= 00000000
1190@0000428c: \$10 <= 00000000
1194@00004290: \$11 <= 00000000
1198@00004294: \$12 <= 00000000
1202@00004298: \$13 <= 00000000
1206@0000429c: \$14 <= 00000000
1210@000042a0: \$15 <= 00000000
1214@000042a4: \$16 <= 00000003
1218@000042a8: \$17 <= 00000000
1222@000042ac: \$18 <= 00000000
1226@000042b0: \$19 <= 00000000
1230@000042b4: \$20 <= 00000000
1234@000042b8: \$21 <= 00000000
1238@000042bc: \$22 <= 00000000
1242@000042c0: \$23 <= 00000000
1246@000042c4: \$24 <= 00000000
1250@000042c8: \$25 <= 00000000
1254@000042cc: \$26 <= 00000f00
1258@000042d0: \$27 <= 00000010
1262@000042d4: \$28 <= 00000000
1266@000042d8: \$29 <= 00000f00
1274@000042dc: \$30 <= 00000000
1278@000042e0: \$31 <= 00000000
1282@000042e4: \$26 <= 00000000
1294@000042ec: \$26 <= 00000000
1330@00003020: \$16 <= 00000004

1350@00004180: \$26 <= 00003024
1354@00004184: \$27 <= 00000010
1358@00004188: \$26 <= 00001000
1358@0000418c: *00000ffc <= 00000f00
1366@00004190: \$26 <= 00000f00
1370@00004194: \$29 <= 00000f00
1378@000041d4: *00000f04 <= 00000000
1382@000041d8: *00000f08 <= 00000000
1386@000041dc: *00000f0c <= 00000000
1390@000041e0: *00000f10 <= 00000000
1394@000041e4: *00000f14 <= 00000000
1398@000041e8: *00000f18 <= 00000000
1402@000041ec: *00000f1c <= 00000000
1406@000041f0: *00000f20 <= 00000000
1410@000041f4: *00000f24 <= 00000000
1414@000041f8: *00000f28 <= 00000000
1418@000041fc: *00000f2c <= 00000000
1422@00004200: *00000f30 <= 00000000
1426@00004204: *00000f34 <= 00000000
1430@00004208: *00000f38 <= 00000000
1434@0000420c: *00000f3c <= 00000000
1438@00004210: *00000f40 <= 00000004
1442@00004214: *00000f44 <= 00000000
1446@00004218: *00000f48 <= 00000000
1450@0000421c: *00000f4c <= 00000000
1454@00004220: *00000f50 <= 00000000
1458@00004224: *00000f54 <= 00000000
1462@00004228: *00000f58 <= 00000000
1466@0000422c: *00000f5c <= 00000000
1470@00004230: *00000f60 <= 00000000
1474@00004234: *00000f64 <= 00000000
1478@00004238: *00000f68 <= 00000f00
1482@0000423c: *00000f6c <= 00000010

1486@00004240: *00000f70 <= 00000000
1490@00004244: *00000f74 <= 00000f00
1494@00004248: *00000f78 <= 00000000
1498@0000424c: *00000f7c <= 00000000
1506@00004250: \$26 <= 00000000
1506@00004254: *00000f80 <= 00000000
1514@00004258: \$26 <= 00000000
1514@0000425c: *00000f84 <= 00000000
1530@000041a0: \$26 <= 00000010
1534@000041a4: \$27 <= 0000007c
1538@000041a8: \$26 <= 00000010
1554@000041b4: \$26 <= 00003024
1558@000041b8: \$ 1 <= 00000000
1562@000041bc: \$ 1 <= 00000004
1566@000041c0: \$26 <= 00003028
1582@00004268: \$ 1 <= 00000000
1586@0000426c: \$ 2 <= 00000000
1590@00004270: \$ 3 <= 00000000
1594@00004274: \$ 4 <= 00000000
1598@00004278: \$ 5 <= 00000000
1602@0000427c: \$ 6 <= 00000000
1606@00004280: \$ 7 <= 00000000
1610@00004284: \$ 8 <= 00000000
1614@00004288: \$ 9 <= 00000000
1618@0000428c: \$10 <= 00000000
1622@00004290: \$11 <= 00000000
1626@00004294: \$12 <= 00000000
1630@00004298: \$13 <= 00000000
1634@0000429c: \$14 <= 00000000
1638@000042a0: \$15 <= 00000000
1642@000042a4: \$16 <= 00000004
1646@000042a8: \$17 <= 00000000
1650@000042ac: \$18 <= 00000000

1654@000042b0: \$19 <= 00000000
1658@000042b4: \$20 <= 00000000
1662@000042b8: \$21 <= 00000000
1666@000042bc: \$22 <= 00000000
1670@000042c0: \$23 <= 00000000
1674@000042c4: \$24 <= 00000000
1678@000042c8: \$25 <= 00000000
1682@000042cc: \$26 <= 00000f00
1686@000042d0: \$27 <= 00000010
1690@000042d4: \$28 <= 00000000
1694@000042d8: \$29 <= 00000f00
1702@000042dc: \$30 <= 00000000
1706@000042e0: \$31 <= 00000000
1710@000042e4: \$26 <= 00000000
1722@000042ec: \$26 <= 00000000
1758@00003028: \$16 <= 00000005
1762@0000302c: \$ 1 <= 7fff0000
1766@00003030: \$ 9 <= 7ffffffc
1786@00004180: \$26 <= 00003034
1790@00004184: \$27 <= 00000010
1794@00004188: \$26 <= 00001000
1794@0000418c: *0000ffc <= 00000f00
1802@00004190: \$26 <= 00000f00
1806@00004194: \$29 <= 00000f00
1814@000041d4: *0000f04 <= 7fff0000
1818@000041d8: *0000f08 <= 00000000
1822@000041dc: *0000f0c <= 00000000
1826@000041e0: *0000f10 <= 00000000
1830@000041e4: *0000f14 <= 00000000
1834@000041e8: *0000f18 <= 00000000
1838@000041ec: *0000f1c <= 00000000
1842@000041f0: *0000f20 <= 00000000
1846@000041f4: *0000f24 <= 7ffffffc

1850@000041f8: *00000f28 <= 00000000
1854@000041fc: *00000f2c <= 00000000
1858@00004200: *00000f30 <= 00000000
1862@00004204: *00000f34 <= 00000000
1866@00004208: *00000f38 <= 00000000
1870@0000420c: *00000f3c <= 00000000
1874@00004210: *00000f40 <= 00000005
1878@00004214: *00000f44 <= 00000000
1882@00004218: *00000f48 <= 00000000
1886@0000421c: *00000f4c <= 00000000
1890@00004220: *00000f50 <= 00000000
1894@00004224: *00000f54 <= 00000000
1898@00004228: *00000f58 <= 00000000
1902@0000422c: *00000f5c <= 00000000
1906@00004230: *00000f60 <= 00000000
1910@00004234: *00000f64 <= 00000000
1914@00004238: *00000f68 <= 00000f00
1918@0000423c: *00000f6c <= 00000010
1922@00004240: *00000f70 <= 00000000
1926@00004244: *00000f74 <= 00000f00
1930@00004248: *00000f78 <= 00000000
1934@0000424c: *00000f7c <= 00000000
1942@00004250: \$26 <= 00000000
1942@00004254: *00000f80 <= 00000000
1950@00004258: \$26 <= 00000000
1950@0000425c: *00000f84 <= 00000000
1966@000041a0: \$26 <= 00000010
1970@000041a4: \$27 <= 0000007c
1974@000041a8: \$26 <= 00000010
1990@000041b4: \$26 <= 00003034
1994@000041b8: \$ 1 <= 00000000
1998@000041bc: \$ 1 <= 00000004
2002@000041c0: \$26 <= 00003038

2018@00004268: \$ 1 <= 7fff0000
2022@0000426c: \$ 2 <= 00000000
2026@00004270: \$ 3 <= 00000000
2030@00004274: \$ 4 <= 00000000
2034@00004278: \$ 5 <= 00000000
2038@0000427c: \$ 6 <= 00000000
2042@00004280: \$ 7 <= 00000000
2046@00004284: \$ 8 <= 00000000
2050@00004288: \$ 9 <= 7fffffc
2054@0000428c: \$10 <= 00000000
2058@00004290: \$11 <= 00000000
2062@00004294: \$12 <= 00000000
2066@00004298: \$13 <= 00000000
2070@0000429c: \$14 <= 00000000
2074@000042a0: \$15 <= 00000000
2078@000042a4: \$16 <= 00000005
2082@000042a8: \$17 <= 00000000
2086@000042ac: \$18 <= 00000000
2090@000042b0: \$19 <= 00000000
2094@000042b4: \$20 <= 00000000
2098@000042b8: \$21 <= 00000000
2102@000042bc: \$22 <= 00000000
2106@000042c0: \$23 <= 00000000
2110@000042c4: \$24 <= 00000000
2114@000042c8: \$25 <= 00000000
2118@000042cc: \$26 <= 00000f00
2122@000042d0: \$27 <= 00000010
2126@000042d4: \$28 <= 00000000
2130@000042d8: \$29 <= 00000f00
2138@000042dc: \$30 <= 00000000
2142@000042e0: \$31 <= 00000000
2146@000042e4: \$26 <= 00000000
2158@000042ec: \$26 <= 00000000

2194@00003038: \$16 <= 00000006
2214@00004180: \$26 <= 0000303c
2218@00004184: \$27 <= 00000014
2222@00004188: \$26 <= 00001000
2222@0000418c: *0000ffc <= 00000f00
2230@00004190: \$26 <= 00000f00
2234@00004194: \$29 <= 00000f00
2242@000041d4: *0000f04 <= 7fff0000
2246@000041d8: *0000f08 <= 00000000
2250@000041dc: *0000f0c <= 00000000
2254@000041e0: *0000f10 <= 00000000
2258@000041e4: *0000f14 <= 00000000
2262@000041e8: *0000f18 <= 00000000
2266@000041ec: *0000f1c <= 00000000
2270@000041f0: *0000f20 <= 00000000
2274@000041f4: *0000f24 <= 7fffffc
2278@000041f8: *0000f28 <= 00000000
2282@000041fc: *0000f2c <= 00000000
2286@00004200: *0000f30 <= 00000000
2290@00004204: *0000f34 <= 00000000
2294@00004208: *0000f38 <= 00000000
2298@0000420c: *0000f3c <= 00000000
2302@00004210: *0000f40 <= 00000006
2306@00004214: *0000f44 <= 00000000
2310@00004218: *0000f48 <= 00000000
2314@0000421c: *0000f4c <= 00000000
2318@00004220: *0000f50 <= 00000000
2322@00004224: *0000f54 <= 00000000
2326@00004228: *0000f58 <= 00000000
2330@0000422c: *0000f5c <= 00000000
2334@00004230: *0000f60 <= 00000000
2338@00004234: *0000f64 <= 00000000
2342@00004238: *0000f68 <= 00000f00

2346@0000423c: *00000f6c <= 00000014
2350@00004240: *00000f70 <= 00000000
2354@00004244: *00000f74 <= 00000f00
2358@00004248: *00000f78 <= 00000000
2362@0000424c: *00000f7c <= 00000000
2370@00004250: \$26 <= 00000000
2370@00004254: *00000f80 <= 00000000
2378@00004258: \$26 <= 00000000
2378@0000425c: *00000f84 <= 00000000
2394@000041a0: \$26 <= 00000014
2398@000041a4: \$27 <= 0000007c
2402@000041a8: \$26 <= 00000014
2418@000041b4: \$26 <= 0000303c
2422@000041b8: \$ 1 <= 00000000
2426@000041bc: \$ 1 <= 00000004
2430@000041c0: \$26 <= 00003040
2446@00004268: \$ 1 <= 7fff0000
2450@0000426c: \$ 2 <= 00000000
2454@00004270: \$ 3 <= 00000000
2458@00004274: \$ 4 <= 00000000
2462@00004278: \$ 5 <= 00000000
2466@0000427c: \$ 6 <= 00000000
2470@00004280: \$ 7 <= 00000000
2474@00004284: \$ 8 <= 00000000
2478@00004288: \$ 9 <= 7fffffc
2482@0000428c: \$10 <= 00000000
2486@00004290: \$11 <= 00000000
2490@00004294: \$12 <= 00000000
2494@00004298: \$13 <= 00000000
2498@0000429c: \$14 <= 00000000
2502@000042a0: \$15 <= 00000000
2506@000042a4: \$16 <= 00000006
2510@000042a8: \$17 <= 00000000

2514@000042ac: \$18 <= 00000000
2518@000042b0: \$19 <= 00000000
2522@000042b4: \$20 <= 00000000
2526@000042b8: \$21 <= 00000000
2530@000042bc: \$22 <= 00000000
2534@000042c0: \$23 <= 00000000
2538@000042c4: \$24 <= 00000000
2542@000042c8: \$25 <= 00000000
2546@000042cc: \$26 <= 00000f00
2550@000042d0: \$27 <= 00000014
2554@000042d4: \$28 <= 00000000
2558@000042d8: \$29 <= 00000f00
2566@000042dc: \$30 <= 00000000
2570@000042e0: \$31 <= 00000000
2574@000042e4: \$26 <= 00000000
2586@000042ec: \$26 <= 00000000
2622@00003040: \$16 <= 00000007
2642@00004180: \$26 <= 00003044
2646@00004184: \$27 <= 00000014
2650@00004188: \$26 <= 00001000
2650@0000418c: *0000ffc <= 00000f00
2658@00004190: \$26 <= 00000f00
2662@00004194: \$29 <= 00000f00
2670@000041d4: *0000f04 <= 7fff0000
2674@000041d8: *0000f08 <= 00000000
2678@000041dc: *0000f0c <= 00000000
2682@000041e0: *0000f10 <= 00000000
2686@000041e4: *0000f14 <= 00000000
2690@000041e8: *0000f18 <= 00000000
2694@000041ec: *0000f1c <= 00000000
2698@000041f0: *0000f20 <= 00000000
2702@000041f4: *0000f24 <= 7fffffc
2706@000041f8: *0000f28 <= 00000000

2710@000041fc: *00000f2c <= 00000000
2714@00004200: *00000f30 <= 00000000
2718@00004204: *00000f34 <= 00000000
2722@00004208: *00000f38 <= 00000000
2726@0000420c: *00000f3c <= 00000000
2730@00004210: *00000f40 <= 00000007
2734@00004214: *00000f44 <= 00000000
2738@00004218: *00000f48 <= 00000000
2742@0000421c: *00000f4c <= 00000000
2746@00004220: *00000f50 <= 00000000
2750@00004224: *00000f54 <= 00000000
2754@00004228: *00000f58 <= 00000000
2758@0000422c: *00000f5c <= 00000000
2762@00004230: *00000f60 <= 00000000
2766@00004234: *00000f64 <= 00000000
2770@00004238: *00000f68 <= 00000f00
2774@0000423c: *00000f6c <= 00000014
2778@00004240: *00000f70 <= 00000000
2782@00004244: *00000f74 <= 00000f00
2786@00004248: *00000f78 <= 00000000
2790@0000424c: *00000f7c <= 00000000
2798@00004250: \$26 <= 00000000
2798@00004254: *00000f80 <= 00000000
2806@00004258: \$26 <= 00000000
2806@0000425c: *00000f84 <= 00000000
2822@000041a0: \$26 <= 00000014
2826@000041a4: \$27 <= 0000007c
2830@000041a8: \$26 <= 00000014
2846@000041b4: \$26 <= 00003044
2850@000041b8: \$ 1 <= 00000000
2854@000041bc: \$ 1 <= 00000004
2858@000041c0: \$26 <= 00003048
2874@00004268: \$ 1 <= 7fff0000

2878@0000426c: \$ 2 <= 00000000
2882@00004270: \$ 3 <= 00000000
2886@00004274: \$ 4 <= 00000000
2890@00004278: \$ 5 <= 00000000
2894@0000427c: \$ 6 <= 00000000
2898@00004280: \$ 7 <= 00000000
2902@00004284: \$ 8 <= 00000000
2906@00004288: \$ 9 <= 7ffffffc
2910@0000428c: \$10 <= 00000000
2914@00004290: \$11 <= 00000000
2918@00004294: \$12 <= 00000000
2922@00004298: \$13 <= 00000000
2926@0000429c: \$14 <= 00000000
2930@000042a0: \$15 <= 00000000
2934@000042a4: \$16 <= 00000007
2938@000042a8: \$17 <= 00000000
2942@000042ac: \$18 <= 00000000
2946@000042b0: \$19 <= 00000000
2950@000042b4: \$20 <= 00000000
2954@000042b8: \$21 <= 00000000
2958@000042bc: \$22 <= 00000000
2962@000042c0: \$23 <= 00000000
2966@000042c4: \$24 <= 00000000
2970@000042c8: \$25 <= 00000000
2974@000042cc: \$26 <= 00000f00
2978@000042d0: \$27 <= 00000014
2982@000042d4: \$28 <= 00000000
2986@000042d8: \$29 <= 00000f00
2994@000042dc: \$30 <= 00000000
2998@000042e0: \$31 <= 00000000
3002@000042e4: \$26 <= 00000000
3014@000042ec: \$26 <= 00000000
3050@00003048: \$16 <= 00000008

3070@00004180: \$26 <= 0000304c
3074@00004184: \$27 <= 00000014
3078@00004188: \$26 <= 00001000
3078@0000418c: *00000ffc <= 00000f00
3086@00004190: \$26 <= 00000f00
3090@00004194: \$29 <= 00000f00
3098@000041d4: *00000f04 <= 7fff0000
3102@000041d8: *00000f08 <= 00000000
3106@000041dc: *00000f0c <= 00000000
3110@000041e0: *00000f10 <= 00000000
3114@000041e4: *00000f14 <= 00000000
3118@000041e8: *00000f18 <= 00000000
3122@000041ec: *00000f1c <= 00000000
3126@000041f0: *00000f20 <= 00000000
3130@000041f4: *00000f24 <= 7fffffc
3134@000041f8: *00000f28 <= 00000000
3138@000041fc: *00000f2c <= 00000000
3142@00004200: *00000f30 <= 00000000
3146@00004204: *00000f34 <= 00000000
3150@00004208: *00000f38 <= 00000000
3154@0000420c: *00000f3c <= 00000000
3158@00004210: *00000f40 <= 00000008
3162@00004214: *00000f44 <= 00000000
3166@00004218: *00000f48 <= 00000000
3170@0000421c: *00000f4c <= 00000000
3174@00004220: *00000f50 <= 00000000
3178@00004224: *00000f54 <= 00000000
3182@00004228: *00000f58 <= 00000000
3186@0000422c: *00000f5c <= 00000000
3190@00004230: *00000f60 <= 00000000
3194@00004234: *00000f64 <= 00000000
3198@00004238: *00000f68 <= 00000f00
3202@0000423c: *00000f6c <= 00000014

3206@00004240: *00000f70 <= 00000000
3210@00004244: *00000f74 <= 00000f00
3214@00004248: *00000f78 <= 00000000
3218@0000424c: *00000f7c <= 00000000
3226@00004250: \$26 <= 00000000
3226@00004254: *00000f80 <= 00000000
3234@00004258: \$26 <= 00000000
3234@0000425c: *00000f84 <= 00000000
3250@000041a0: \$26 <= 00000014
3254@000041a4: \$27 <= 0000007c
3258@000041a8: \$26 <= 00000014
3274@000041b4: \$26 <= 0000304c
3278@000041b8: \$ 1 <= 00000000
3282@000041bc: \$ 1 <= 00000004
3286@000041c0: \$26 <= 00003050
3302@00004268: \$ 1 <= 7fff0000
3306@0000426c: \$ 2 <= 00000000
3310@00004270: \$ 3 <= 00000000
3314@00004274: \$ 4 <= 00000000
3318@00004278: \$ 5 <= 00000000
3322@0000427c: \$ 6 <= 00000000
3326@00004280: \$ 7 <= 00000000
3330@00004284: \$ 8 <= 00000000
3334@00004288: \$ 9 <= 7fffffc
3338@0000428c: \$10 <= 00000000
3342@00004290: \$11 <= 00000000
3346@00004294: \$12 <= 00000000
3350@00004298: \$13 <= 00000000
3354@0000429c: \$14 <= 00000000
3358@000042a0: \$15 <= 00000000
3362@000042a4: \$16 <= 00000008
3366@000042a8: \$17 <= 00000000
3370@000042ac: \$18 <= 00000000

3374@000042b0: \$19 <= 00000000
3378@000042b4: \$20 <= 00000000
3382@000042b8: \$21 <= 00000000
3386@000042bc: \$22 <= 00000000
3390@000042c0: \$23 <= 00000000
3394@000042c4: \$24 <= 00000000
3398@000042c8: \$25 <= 00000000
3402@000042cc: \$26 <= 00000f00
3406@000042d0: \$27 <= 00000014
3410@000042d4: \$28 <= 00000000
3414@000042d8: \$29 <= 00000f00
3422@000042dc: \$30 <= 00000000
3426@000042e0: \$31 <= 00000000
3430@000042e4: \$26 <= 00000000
3442@000042ec: \$26 <= 00000000
3478@00003050: \$16 <= 00000009
3498@00004180: \$26 <= 00003054
3502@00004184: \$27 <= 00000014
3506@00004188: \$26 <= 00001000
3506@0000418c: *00000ffc <= 00000f00
3514@00004190: \$26 <= 00000f00
3518@00004194: \$29 <= 00000f00
3526@000041d4: *00000f04 <= 7fff0000
3530@000041d8: *00000f08 <= 00000000
3534@000041dc: *00000f0c <= 00000000
3538@000041e0: *00000f10 <= 00000000
3542@000041e4: *00000f14 <= 00000000
3546@000041e8: *00000f18 <= 00000000
3550@000041ec: *00000f1c <= 00000000
3554@000041f0: *00000f20 <= 00000000
3558@000041f4: *00000f24 <= 7fffffc
3562@000041f8: *00000f28 <= 00000000
3566@000041fc: *00000f2c <= 00000000

3570@00004200: *00000f30 <= 00000000
3574@00004204: *00000f34 <= 00000000
3578@00004208: *00000f38 <= 00000000
3582@0000420c: *00000f3c <= 00000000
3586@00004210: *00000f40 <= 00000009
3590@00004214: *00000f44 <= 00000000
3594@00004218: *00000f48 <= 00000000
3598@0000421c: *00000f4c <= 00000000
3602@00004220: *00000f50 <= 00000000
3606@00004224: *00000f54 <= 00000000
3610@00004228: *00000f58 <= 00000000
3614@0000422c: *00000f5c <= 00000000
3618@00004230: *00000f60 <= 00000000
3622@00004234: *00000f64 <= 00000000
3626@00004238: *00000f68 <= 00000f00
3630@0000423c: *00000f6c <= 00000014
3634@00004240: *00000f70 <= 00000000
3638@00004244: *00000f74 <= 00000f00
3642@00004248: *00000f78 <= 00000000
3646@0000424c: *00000f7c <= 00000000
3654@00004250: \$26 <= 00000000
3654@00004254: *00000f80 <= 00000000
3662@00004258: \$26 <= 00000000
3662@0000425c: *00000f84 <= 00000000
3678@000041a0: \$26 <= 00000014
3682@000041a4: \$27 <= 0000007c
3686@000041a8: \$26 <= 00000014
3702@000041b4: \$26 <= 00003054
3706@000041b8: \$ 1 <= 00000000
3710@000041bc: \$ 1 <= 00000004
3714@000041c0: \$26 <= 00003058
3730@00004268: \$ 1 <= 7fff0000
3734@0000426c: \$ 2 <= 00000000

3738@00004270: \$ 3 <= 00000000
3742@00004274: \$ 4 <= 00000000
3746@00004278: \$ 5 <= 00000000
3750@0000427c: \$ 6 <= 00000000
3754@00004280: \$ 7 <= 00000000
3758@00004284: \$ 8 <= 00000000
3762@00004288: \$ 9 <= 7ffffffc
3766@0000428c: \$10 <= 00000000
3770@00004290: \$11 <= 00000000
3774@00004294: \$12 <= 00000000
3778@00004298: \$13 <= 00000000
3782@0000429c: \$14 <= 00000000
3786@000042a0: \$15 <= 00000000
3790@000042a4: \$16 <= 00000009
3794@000042a8: \$17 <= 00000000
3798@000042ac: \$18 <= 00000000
3802@000042b0: \$19 <= 00000000
3806@000042b4: \$20 <= 00000000
3810@000042b8: \$21 <= 00000000
3814@000042bc: \$22 <= 00000000
3818@000042c0: \$23 <= 00000000
3822@000042c4: \$24 <= 00000000
3826@000042c8: \$25 <= 00000000
3830@000042cc: \$26 <= 00000f00
3834@000042d0: \$27 <= 00000014
3838@000042d4: \$28 <= 00000000
3842@000042d8: \$29 <= 00000f00
3850@000042dc: \$30 <= 00000000
3854@000042e0: \$31 <= 00000000
3858@000042e4: \$26 <= 00000000
3870@000042ec: \$26 <= 00000000
3906@00003058: \$16 <= 0000000a
3910@0000305c: \$ 1 <= 7fff0000

3914@00003060: \$ 9 <= 7ffffffc
3934@00004180: \$26 <= 00003064
3938@00004184: \$27 <= 00000014
3942@00004188: \$26 <= 00001000
3942@0000418c: *0000ffc <= 00000f00
3950@00004190: \$26 <= 00000f00
3954@00004194: \$29 <= 00000f00
3962@000041d4: *0000f04 <= 7fff0000
3966@000041d8: *0000f08 <= 00000000
3970@000041dc: *0000f0c <= 00000000
3974@000041e0: *0000f10 <= 00000000
3978@000041e4: *0000f14 <= 00000000
3982@000041e8: *0000f18 <= 00000000
3986@000041ec: *0000f1c <= 00000000
3990@000041f0: *0000f20 <= 00000000
3994@000041f4: *0000f24 <= 7ffffffc
3998@000041f8: *0000f28 <= 00000000
4002@000041fc: *0000f2c <= 00000000
4006@00004200: *0000f30 <= 00000000
4010@00004204: *0000f34 <= 00000000
4014@00004208: *0000f38 <= 00000000
4018@0000420c: *0000f3c <= 00000000
4022@00004210: *0000f40 <= 0000000a
4026@00004214: *0000f44 <= 00000000
4030@00004218: *0000f48 <= 00000000
4034@0000421c: *0000f4c <= 00000000
4038@00004220: *0000f50 <= 00000000
4042@00004224: *0000f54 <= 00000000
4046@00004228: *0000f58 <= 00000000
4050@0000422c: *0000f5c <= 00000000
4054@00004230: *0000f60 <= 00000000
4058@00004234: *0000f64 <= 00000000
4062@00004238: *0000f68 <= 00000f00

4066@0000423c: *00000f6c <= 00000014
4070@00004240: *00000f70 <= 00000000
4074@00004244: *00000f74 <= 00000f00
4078@00004248: *00000f78 <= 00000000
4082@0000424c: *00000f7c <= 00000000
4090@00004250: \$26 <= 00000000
4090@00004254: *00000f80 <= 00000000
4098@00004258: \$26 <= 00000000
4098@0000425c: *00000f84 <= 00000000
4114@000041a0: \$26 <= 00000014
4118@000041a4: \$27 <= 0000007c
4122@000041a8: \$26 <= 00000014
4138@000041b4: \$26 <= 00003064
4142@000041b8: \$ 1 <= 00000000
4146@000041bc: \$ 1 <= 00000004
4150@000041c0: \$26 <= 00003068
4166@00004268: \$ 1 <= 7fff0000
4170@0000426c: \$ 2 <= 00000000
4174@00004270: \$ 3 <= 00000000
4178@00004274: \$ 4 <= 00000000
4182@00004278: \$ 5 <= 00000000
4186@0000427c: \$ 6 <= 00000000
4190@00004280: \$ 7 <= 00000000
4194@00004284: \$ 8 <= 00000000
4198@00004288: \$ 9 <= 7fffffc
4202@0000428c: \$10 <= 00000000
4206@00004290: \$11 <= 00000000
4210@00004294: \$12 <= 00000000
4214@00004298: \$13 <= 00000000
4218@0000429c: \$14 <= 00000000
4222@000042a0: \$15 <= 00000000
4226@000042a4: \$16 <= 0000000a
4230@000042a8: \$17 <= 00000000

4234@000042ac: \$18 <= 00000000
4238@000042b0: \$19 <= 00000000
4242@000042b4: \$20 <= 00000000
4246@000042b8: \$21 <= 00000000
4250@000042bc: \$22 <= 00000000
4254@000042c0: \$23 <= 00000000
4258@000042c4: \$24 <= 00000000
4262@000042c8: \$25 <= 00000000
4266@000042cc: \$26 <= 00000f00
4270@000042d0: \$27 <= 00000014
4274@000042d4: \$28 <= 00000000
4278@000042d8: \$29 <= 00000f00
4286@000042dc: \$30 <= 00000000
4290@000042e0: \$31 <= 00000000
4294@000042e4: \$26 <= 00000000
4306@000042ec: \$26 <= 00000000
4342@00003068: \$16 <= 0000000b
4362@00004180: \$26 <= 0000306c
4366@00004184: \$27 <= 00000014
4370@00004188: \$26 <= 00001000
4370@0000418c: *0000ffc <= 00000f00
4378@00004190: \$26 <= 00000f00
4382@00004194: \$29 <= 00000f00
4390@000041d4: *0000f04 <= 7fff0000
4394@000041d8: *0000f08 <= 00000000
4398@000041dc: *0000f0c <= 00000000
4402@000041e0: *0000f10 <= 00000000
4406@000041e4: *0000f14 <= 00000000
4410@000041e8: *0000f18 <= 00000000
4414@000041ec: *0000f1c <= 00000000
4418@000041f0: *0000f20 <= 00000000
4422@000041f4: *0000f24 <= 7fffffc
4426@000041f8: *0000f28 <= 00000000

4430@000041fc: *00000f2c <= 00000000
4434@00004200: *00000f30 <= 00000000
4438@00004204: *00000f34 <= 00000000
4442@00004208: *00000f38 <= 00000000
4446@0000420c: *00000f3c <= 00000000
4450@00004210: *00000f40 <= 0000000b
4454@00004214: *00000f44 <= 00000000
4458@00004218: *00000f48 <= 00000000
4462@0000421c: *00000f4c <= 00000000
4466@00004220: *00000f50 <= 00000000
4470@00004224: *00000f54 <= 00000000
4474@00004228: *00000f58 <= 00000000
4478@0000422c: *00000f5c <= 00000000
4482@00004230: *00000f60 <= 00000000
4486@00004234: *00000f64 <= 00000000
4490@00004238: *00000f68 <= 00000f00
4494@0000423c: *00000f6c <= 00000014
4498@00004240: *00000f70 <= 00000000
4502@00004244: *00000f74 <= 00000f00
4506@00004248: *00000f78 <= 00000000
4510@0000424c: *00000f7c <= 00000000
4518@00004250: \$26 <= 00000000
4518@00004254: *00000f80 <= 00000000
4526@00004258: \$26 <= 00000000
4526@0000425c: *00000f84 <= 00000000
4542@000041a0: \$26 <= 00000014
4546@000041a4: \$27 <= 0000007c
4550@000041a8: \$26 <= 00000014
4566@000041b4: \$26 <= 0000306c
4570@000041b8: \$ 1 <= 00000000
4574@000041bc: \$ 1 <= 00000004
4578@000041c0: \$26 <= 00003070
4594@00004268: \$ 1 <= 7fff0000

4598@0000426c: \$ 2 <= 00000000
4602@00004270: \$ 3 <= 00000000
4606@00004274: \$ 4 <= 00000000
4610@00004278: \$ 5 <= 00000000
4614@0000427c: \$ 6 <= 00000000
4618@00004280: \$ 7 <= 00000000
4622@00004284: \$ 8 <= 00000000
4626@00004288: \$ 9 <= 7ffffffc
4630@0000428c: \$10 <= 00000000
4634@00004290: \$11 <= 00000000
4638@00004294: \$12 <= 00000000
4642@00004298: \$13 <= 00000000
4646@0000429c: \$14 <= 00000000
4650@000042a0: \$15 <= 00000000
4654@000042a4: \$16 <= 0000000b
4658@000042a8: \$17 <= 00000000
4662@000042ac: \$18 <= 00000000
4666@000042b0: \$19 <= 00000000
4670@000042b4: \$20 <= 00000000
4674@000042b8: \$21 <= 00000000
4678@000042bc: \$22 <= 00000000
4682@000042c0: \$23 <= 00000000
4686@000042c4: \$24 <= 00000000
4690@000042c8: \$25 <= 00000000
4694@000042cc: \$26 <= 00000f00
4698@000042d0: \$27 <= 00000014
4702@000042d4: \$28 <= 00000000
4706@000042d8: \$29 <= 00000f00
4714@000042dc: \$30 <= 00000000
4718@000042e0: \$31 <= 00000000
4722@000042e4: \$26 <= 00000000
4734@000042ec: \$26 <= 00000000
4770@00003070: \$16 <= 0000000c

4790@00004180: \$26 <= 00003074
4794@00004184: \$27 <= 00000028
4798@00004188: \$26 <= 00001000
4798@0000418c: *00000ffc <= 00000f00
4806@00004190: \$26 <= 00000f00
4810@00004194: \$29 <= 00000f00
4818@000041d4: *00000f04 <= 7fff0000
4822@000041d8: *00000f08 <= 00000000
4826@000041dc: *00000f0c <= 00000000
4830@000041e0: *00000f10 <= 00000000
4834@000041e4: *00000f14 <= 00000000
4838@000041e8: *00000f18 <= 00000000
4842@000041ec: *00000f1c <= 00000000
4846@000041f0: *00000f20 <= 00000000
4850@000041f4: *00000f24 <= 7fffffc
4854@000041f8: *00000f28 <= 00000000
4858@000041fc: *00000f2c <= 00000000
4862@00004200: *00000f30 <= 00000000
4866@00004204: *00000f34 <= 00000000
4870@00004208: *00000f38 <= 00000000
4874@0000420c: *00000f3c <= 00000000
4878@00004210: *00000f40 <= 0000000c
4882@00004214: *00000f44 <= 00000000
4886@00004218: *00000f48 <= 00000000
4890@0000421c: *00000f4c <= 00000000
4894@00004220: *00000f50 <= 00000000
4898@00004224: *00000f54 <= 00000000
4902@00004228: *00000f58 <= 00000000
4906@0000422c: *00000f5c <= 00000000
4910@00004230: *00000f60 <= 00000000
4914@00004234: *00000f64 <= 00000000
4918@00004238: *00000f68 <= 00000f00
4922@0000423c: *00000f6c <= 00000028

4926@00004240: *00000f70 <= 00000000
4930@00004244: *00000f74 <= 00000f00
4934@00004248: *00000f78 <= 00000000
4938@0000424c: *00000f7c <= 00000000
4946@00004250: \$26 <= 00000000
4946@00004254: *00000f80 <= 00000000
4954@00004258: \$26 <= 00000000
4954@0000425c: *00000f84 <= 00000000
4970@000041a0: \$26 <= 00000028
4974@000041a4: \$27 <= 0000007c
4978@000041a8: \$26 <= 00000028
4994@000041b4: \$26 <= 00003074
4998@000041b8: \$ 1 <= 00000000
5002@000041bc: \$ 1 <= 00000004
5006@000041c0: \$26 <= 00003078
5022@00004268: \$ 1 <= 7fff0000
5026@0000426c: \$ 2 <= 00000000
5030@00004270: \$ 3 <= 00000000
5034@00004274: \$ 4 <= 00000000
5038@00004278: \$ 5 <= 00000000
5042@0000427c: \$ 6 <= 00000000
5046@00004280: \$ 7 <= 00000000
5050@00004284: \$ 8 <= 00000000
5054@00004288: \$ 9 <= 7fffffc
5058@0000428c: \$10 <= 00000000
5062@00004290: \$11 <= 00000000
5066@00004294: \$12 <= 00000000
5070@00004298: \$13 <= 00000000
5074@0000429c: \$14 <= 00000000
5078@000042a0: \$15 <= 00000000
5082@000042a4: \$16 <= 0000000c
5086@000042a8: \$17 <= 00000000
5090@000042ac: \$18 <= 00000000

5094@000042b0: \$19 <= 00000000
5098@000042b4: \$20 <= 00000000
5102@000042b8: \$21 <= 00000000
5106@000042bc: \$22 <= 00000000
5110@000042c0: \$23 <= 00000000
5114@000042c4: \$24 <= 00000000
5118@000042c8: \$25 <= 00000000
5122@000042cc: \$26 <= 00000f00
5126@000042d0: \$27 <= 00000028
5130@000042d4: \$28 <= 00000000
5134@000042d8: \$29 <= 00000f00
5142@000042dc: \$30 <= 00000000
5146@000042e0: \$31 <= 00000000
5150@000042e4: \$26 <= 00000000
5162@000042ec: \$26 <= 00000000
5198@00003078: \$16 <= 0000000d
5218@00004180: \$26 <= 0000307c
5222@00004184: \$27 <= 00000030
5226@00004188: \$26 <= 00001000
5226@0000418c: *00000ffc <= 00000f00
5234@00004190: \$26 <= 00000f00
5238@00004194: \$29 <= 00000f00
5246@000041d4: *00000f04 <= 7fff0000
5250@000041d8: *00000f08 <= 00000000
5254@000041dc: *00000f0c <= 00000000
5258@000041e0: *00000f10 <= 00000000
5262@000041e4: *00000f14 <= 00000000
5266@000041e8: *00000f18 <= 00000000
5270@000041ec: *00000f1c <= 00000000
5274@000041f0: *00000f20 <= 00000000
5278@000041f4: *00000f24 <= 7fffffc
5282@000041f8: *00000f28 <= 00000000
5286@000041fc: *00000f2c <= 00000000

5290@00004200: *00000f30 <= 00000000
5294@00004204: *00000f34 <= 00000000
5298@00004208: *00000f38 <= 00000000
5302@0000420c: *00000f3c <= 00000000
5306@00004210: *00000f40 <= 0000000d
5310@00004214: *00000f44 <= 00000000
5314@00004218: *00000f48 <= 00000000
5318@0000421c: *00000f4c <= 00000000
5322@00004220: *00000f50 <= 00000000
5326@00004224: *00000f54 <= 00000000
5330@00004228: *00000f58 <= 00000000
5334@0000422c: *00000f5c <= 00000000
5338@00004230: *00000f60 <= 00000000
5342@00004234: *00000f64 <= 00000000
5346@00004238: *00000f68 <= 00000f00
5350@0000423c: *00000f6c <= 00000030
5354@00004240: *00000f70 <= 00000000
5358@00004244: *00000f74 <= 00000f00
5362@00004248: *00000f78 <= 00000000
5366@0000424c: *00000f7c <= 00000000
5374@00004250: \$26 <= 00000000
5374@00004254: *00000f80 <= 00000000
5382@00004258: \$26 <= 00000000
5382@0000425c: *00000f84 <= 00000000
5398@000041a0: \$26 <= 00000030
5402@000041a4: \$27 <= 0000007c
5406@000041a8: \$26 <= 00000030
5422@000041b4: \$26 <= 0000307c
5426@000041b8: \$ 1 <= 00000000
5430@000041bc: \$ 1 <= 00000004
5434@000041c0: \$26 <= 00003080
5450@00004268: \$ 1 <= 7fff0000
5454@0000426c: \$ 2 <= 00000000

5458@00004270: \$ 3 <= 00000000
5462@00004274: \$ 4 <= 00000000
5466@00004278: \$ 5 <= 00000000
5470@0000427c: \$ 6 <= 00000000
5474@00004280: \$ 7 <= 00000000
5478@00004284: \$ 8 <= 00000000
5482@00004288: \$ 9 <= 7ffffffc
5486@0000428c: \$10 <= 00000000
5490@00004290: \$11 <= 00000000
5494@00004294: \$12 <= 00000000
5498@00004298: \$13 <= 00000000
5502@0000429c: \$14 <= 00000000
5506@000042a0: \$15 <= 00000000
5510@000042a4: \$16 <= 0000000d
5514@000042a8: \$17 <= 00000000
5518@000042ac: \$18 <= 00000000
5522@000042b0: \$19 <= 00000000
5526@000042b4: \$20 <= 00000000
5530@000042b8: \$21 <= 00000000
5534@000042bc: \$22 <= 00000000
5538@000042c0: \$23 <= 00000000
5542@000042c4: \$24 <= 00000000
5546@000042c8: \$25 <= 00000000
5550@000042cc: \$26 <= 00000f00
5554@000042d0: \$27 <= 00000030
5558@000042d4: \$28 <= 00000000
5562@000042d8: \$29 <= 00000f00
5570@000042dc: \$30 <= 00000000
5574@000042e0: \$31 <= 00000000
5578@000042e4: \$26 <= 00000000
5590@000042ec: \$26 <= 00000000
5626@00003080: \$16 <= 0000000e

3. 中断与 IO 测试

见思考题部分第 5 题。

思考题

1. 我们计组课程一本参考书目标题中有“硬件/软件接口”接口字样，那么到底什么是“硬件/软件接口”？

是硬件与软件的交互方式，是联系硬件与软件的界面。硬件提供给软件一套操作硬件的方法（指令集），而软件根据硬件的结构与功能做出相应的调度。

2. 在我们设计的流水线中，DM 处于 CPU 内部，请你考虑现代计算机中它的位置应该在何处。处于 CPU 外部，通过总线与 CPU 连接。
3. BE 部件对所有的外设都是必要的吗？

不是。Timer 只支持整字读写，故不需要 BE 信号。

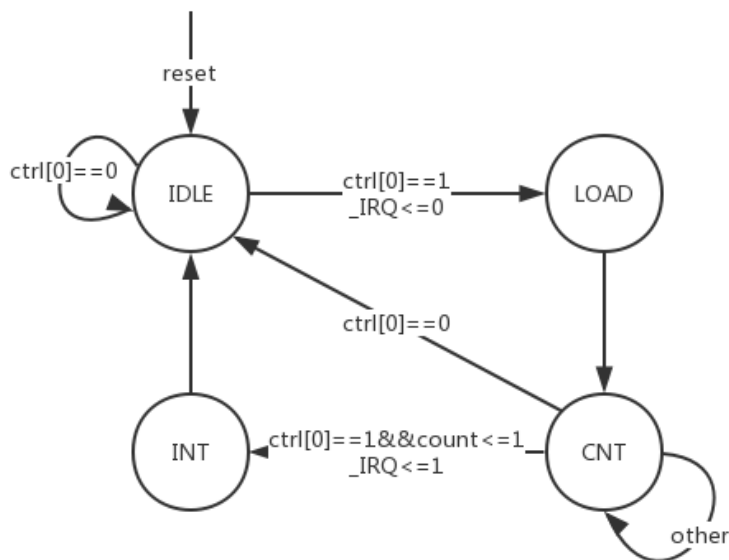
4. 请阅读官方提供的定时器源代码，阐述两种中断模式的异同，并分别针对每一种模式绘制状态转移图

两种中断模式基本相同，仅在 INT 状态返回 IDLE 状态时的行为有所不同。

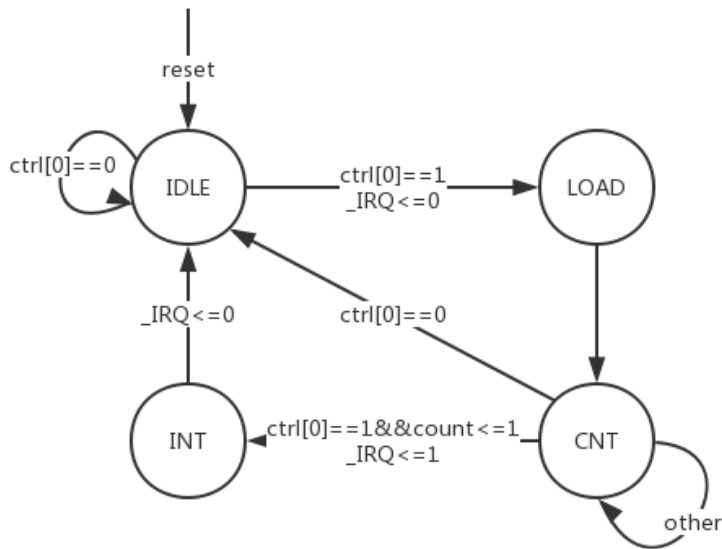
在模式 0 下，当计数器倒计数为 0 后，计数器停止计数，此时 ctrl 寄存器中的使能 Enable 自动变为 0。模式 0 下的中断信号将持续有效，直至控制寄存器中的中断屏蔽位被设置为 0。

在模式 1 下，当计数器倒计数为 0 后，初值寄存器值被自动加载至计数器，计数器继续倒计数。不同于模式 0，模式 1 下计数器每次计数循环中只产生一周期的中断信号。

模式 0:



模式 1:



5. 请开发一个主程序以及定时器的 **exception handler**。整个系统完成如下功能：
1. 定时器在主程序中被初始化为模式 0；
 2. 定时器倒计时至 0 产生中断；
 3. **handler** 设置使能 **Enable** 为 1 从而再次启动定时器的计数器。2 及 3 被无限重复。
 4. 主程序在初始化时将定时器初始化为模式 0，设定初值寄存器的初值为某个值，如 100 或 1000。（注意，主程序可能需要涉及对 **CP0.SR** 的编程，推荐阅读过后文后再进行。）

```

.text
li $t0, 0x7f00
li $t1, 100
li $t2, 9
li $t3, 0x0401
mtc0 $t3, $12
sw $t1, 4($t0)
sw $t2, 0($t0)
End:
beq $0, $0, End
lw $t3, 8($t0)

.ktext 0x4180
sw $t2, 0($t0)
eret

```

6. 请查阅相关资料，说明鼠标和键盘的输入信号是如何被 CPU 知晓的？

鼠标位置移动或按下键盘时，将产生中断信号，从而使 CPU 进入相应的中断处理程序。