CPU设计文档

1. 数据通路设计
   1. pc（程序计数器）

模块端口说明如下：

表1 pc端口说明



模块功能定义如下：

表2 pc功能定义



* 1. im（指令存储器）

模块端口说明如下：

表3 im端口说明



模块功能定义如下：

表4 im功能定义



（2）grf（通用寄存器组）

模块端口说明如下：

表5 grf端口说明



模块功能定义如下：

表6 grf功能定义



（3）alu（算术逻辑单元）

模块端口说明如下：

表7 alu端口说明



模块功能定义如下：

表8 alu功能定义



1. dm（数据存储器）

模块端口说明如下：

表9 dm端口说明

模块功能定义如下：

表10 dm功能定义



1. EXT（数据扩展单元）

模块端口说明如下：

表11 ext端口说明



模块功能定义如下：

表12 ext功能定义



1. NPC

模块端口定义如下：

表13 NPC端口说明



模块功能定义如下：

表14 NPC功能定义



1. 控制器设计
   1. 控制器

ctrl\_D端口说明如下：



ctrl\_E端口说明如下：



ctrl\_M端口说明如下：



ctrl\_W端口说明如下：



控制信号真值表如下：



控制信号意义如下：



* 1. 阻塞控制器

阻塞控制器端口说明如下：



阻塞发生条件如下:



(3) 转发控制器

转发控制器端口定义如下：



转发条件如下：



三、测试程序

#cal\_r - cal\_r

lui $s0, 0x5432

ori $s0, $s0, 0x9843

lui $s1, 0x5843

ori $s1, $s1, 0x6543

addu $s2, $s1, $s0

subu $s3, $s1, $s0

addu $s4, $s3, $s0

addu $s5, $s0, $s4

subu $s6, $s5, $s0

subu $s7, $s0, $s6

addu $t0, $s6, $s7

addu $t1, $t0, $s7

subu $t2, $t1, $t1

addu $t3, $t2, $t2

addu $0, $t2, $t3

subu $t4, $t3, $0

addu $t5, $0, $t4

subu $0, $t5, $0

addu $t6, $0, $0

#cal\_r - cal\_i

lui $s0, 0x4325

ori $s0, $s0, 0x5432

lui $s1, 0x8954

ori $s1, $s1, 0x3459

addu $s2, $s1, $s0

subu $s3, $s1, $s0

ori $s4, $s3, 0x8932

subu $s5, $s0, $s4

addu $s6, $s0, $s4

ori $s7, $s5, 0x8954

ori $t0, $s6, 0x5894

addu $t1, $s7, $t0

lui $t2, 0x8594

subu $t3, $t2, $s0

lui $t4, 0x8594

addu $t5, $t4, $s0

lui $t4, 0x3498

lui $t5, 0x8265

addu $t6, $t4, $t5

lui $0, 0x8943

addu $t7, $s0, $0

ori $0, $0, 0x8594

ori $t8, $0, $t7

addu $t9, $t8, $0

#cal\_r - load

lui $s0, 0x8694

ori $s1, $s0, 0x8754

lui $s2, 0x8954

ori $s3, $s3, 0x5437

lui $s4, 0x2349

ori $s5, $0, 0x8954

lui $s6, 0x8954

ori $s7, $0, 0x7843

sw $s0, 0($0)

sw $s1, 4($0)

sw $s2, 8($0)

sw $s3, 12($0)

sw $s4, 16($0)

sw $s5, 20($0)

sw $s6, 24($0)

sw $s7, 28($0)

lw $t0, 0($0)

addu $t1, $t0, $s0

addu $t2, $t0, $t1

lw $t2, 4($0)

subu $t3, $t2, $t1

subu $t4, $t3, $t2

lw $t3, 8($0)

lw $t4, 8($0)

addu $t5, $t3, $t4

addu $t6, $t3, $t4

subu $t7, $t6, $t6

lw $t8, 12($t7)

ori $t9, $0, 0x0010

addu $t0, $t9, $0

lw $t0, 0($t0)

addu $t1, $t0, $t9

ori $t2, $0, 0x0002

addu $t3, $t2, $t9

addu $t4, $t1, $t0

lw $t4, 0($t3)

subu $t5, $t3, $t4

addu $t6, $t3, $t2

addu $t7, $t6, $t2

lw $t8, 0($t6)

lw $t8, 0($t7)

addu $t9, $t8, $t7

subu $t9, $t8, $t8

#cal\_r - jal

ori $s0, $0, 0x8593

ori $ra, $0, 0x5439

jal next1

addu $s2, $s0, $ra

next1:

addu $s3, $ra, $s0

addu $ra, $s3, $s0

jal next2

next2:

subu $s4, $ra, $s0

subu $s5, $s4, $ra

addu $ra, $ra, $s0

jal next3

addu $s6, $s5, $ra

subu $s6, $s5, $ra

nop

next3:

subu $s7, $s6, $ra

addu $ra, $ra, $ra

jal next4

nop

addu $t0, $ra, $s0

next4:

addu $t1, $ra, $ra

subu $t2, $ra, $ra

#cal\_i - cal\_i

lui $s0, 0x5493

ori $s1, $s0, 0x8954

ori $s2, $s1, 0x6543

ori $s3, $s1, 0x2345

lui $s4, 0x8954

ori $s5, $s4, 0x3555

ori $s6, $s4, 0x8592

ori $s6, $s6, 0x3478

ori $s7, $s6, 0x8594

lui $0, 0x5439

ori $t0, $0, 0x8954

ori $0, $t0, 0x5432

lui $t1, 0x5342

ori $t2, $0, 0x2345

#cal\_i - load

lui $s0, 0x8954

ori $s1, $s0, 0x7854

lui $s2, 0x2345

ori $s3, $0, 0x8954

ori $s4, $2, 0x8432

sw $s0, 0($0)

sw $s1, 4($0)

sw $s2, 8($0)

sw $s3, 12($0)

sw $s4, 16($0)

lw $t0, 0($0)

ori $t1, $t0, 0x8954

ori $t1, $t0, 0x2345

lw $t1, 4($0)

lw $t1, 8($0)

ori $t2, $t1, 0x4352

ori $t3, $t1, 0x5435

lw $0, 4($0)

ori $t4, $0, 0x8594

ori $t4, $0, 0x000c

lw $t5, 0($t4)

ori $t5, $t5, 0x5432

ori $t6, $t5, 0x3543

ori $t6, $0, 0x0010

nop

lw $t7, 0($t6)

ori $t8, $t7, 0x8943

lui $t9, 0x0000

lw $t9, 0($t9)

ori $t0, $t9, 0x8943

ori $t1, $t9, 0x7548

#cal\_i - jal

lui $s0, 0x8954

ori $s0, $s0, 0x5432

ori $ra, $s0, 0x8943

jal next1

ori $s1, $ra, 0x8594

next1:

ori $s2, $ra, 0x2345

ori $ra, $ra, 0x8943

jal next2

next2:

ori $s3, $ra, 0x5483

ori $s4, $ra, 0x3456

lui $ra, 0x5843

jal next3

ori $ra, $ra, 0x5438

ori $s6, $ra, 0x8954

nop

next3:

ori $s6, $ra, 0x8965

ori $ra, $ra, 0x3453

jal next4

next4:

ori $ra, $ra, 0x1453

ori $s7, $ra, 0x5436

#load - load

ori $s0, $0, 0x0000

ori $s1, $0, 0x0004

ori $s2, $0, 0x0008

ori $s3, $0, 0x000c

sw $s0, 0($0)

sw $s1, 4($0)

sw $s2, 8($0)

sw $s3, 12($0)

lw $t0, 0($0)

lw $t1, 0($t0)

lw $t2, 4($t0)

lw $t2, 0($t2)

lw $t3, 4($t2)

lw $t4, 8($t2)

lw $0, 0($t4)

lw $t5, 8($0)

lw $t6, 0($t5)

lw $t6, 0($t6)

lw $t6, 4($t6)

lw $t6, 8($0)

#load - jal

ori $s0, $0, 0x0004

ori $s1, $0, 0x0008

la $s2, next1

sw $s0, 4($0)

sw $s1, 0($s2)

ori $ra, $0, 0x0004

jal next1

nop

next1:

lw $t0, 0($ra)

la $s3, next2

sw $s1, 0($s3)

ori $ra, $0, 0x0004

jal next2

lw $t1, 0($ra)

next2:

lw $t2, 0($ra)

la $s4, next3

sw $s1, 0($s4)

ori $ra, $0, 0x0008

jal next3

next3:

lw $t3, -4($ra)

lw $t4, -4($ra)

#store - cal\_r

lui $s0, 0x8953

ori $s1, $s0, 0x2354

ori $s2, $0, 0x0004

lui $s3, 0x8955

addu $s3, $s0, $s1

sw $s3, 0($0)

sw $s3, 4($0)

lui $s4, 0x2364

subu $s4, $s3, $s1

sw $s4, 0($0)

sw $s4, 4($0)

ori $s5, $0, 0x0008

addu $s5, $s2, $0

sw $s4, 0($s5)

sw $s4, 4($s5)

lui $s6, 0x0004

subu $s6, $s4, $s4

sw $s3, 0($s6)

sw $s3, 4($s6)

#store - cal\_i

lui $s0, 0x8954

ori $s1, $s0, 0x5438

lui $s1, 0x7853

sw $s1, 0($0)

sw $s1, 4($0)

ori $s1, $0, 0x5345

ori $s1, $0, 0x3465

sw $s1, 0($0)

sw $s1, 4($0)

ori $s2, $0, 0x0008

ori $s2, $0, 0x0004

sw $s2, 0($s2)

sw $s2, 4($s2)

ori $s3, $0, 0x0004

lui $s3, 0x0000

sw $s0, 0($s3)

sw $s0, 4($s3)

#store - load

ori $s0, $0, 0x0004

ori $s1, $0, 0x0008

ori $s2, $0, 0x000c

ori $s3, $0, 0x0010

sw $s0, 0($0)

sw $s1, 4($0)

sw $s2, 8($0)

sw $s3, 12($0)

ori $t0, $0, 0x8954

nop

lw $t0, 0($0)

sw $t0, 16($0)

sw $t0, 20($0)

ori $t1, $0, 0x2444

lw $t1, 0($0)

sw $t0, 0($t1)

sw $t0, 4($t1)

lw $t2, 4($0)

lw $t3, 8($0)

sw $t2, 0($t3)

sw $t3, 4($t3)

lw $t4, 12($0)

sw $t4, 4($t4)

#store - jal

lui $s0, 0x9823

ori $s0, $s0, 0x4532

ori $ra, 0x5325

jal next1

sw $s0, 0($ra)

next1:

sw $s0, 4($ra)

jal next2

next2:

sw $s0, 0($ra)

sw $s0, 8($ra)

jal next3

sw $ra, 0($0)

sw $ra, 4($0)

nop

next3:

sw $ra, 8($0)

jal next4

sw $ra, 0($ra)

next4:

sw $ra, 4($ra)

#beq - cal\_r

lui $s0, 0x4583

ori $s1, $s0, 0x6542

addu $s2, $s0, $s1

beq $s2, $0, next1

nop

addu $s3, $s2, $s1

next1:

subu $s4, $s3, $s1

beq $s4, $s1, next2

nop

addu $s4, $s3, $s2

next2:

subu $s4, $s3, $s3

beq $s4, $0, next3

nop

lui $t0, 0x3543

next3:

subu $s3, $s1, $s1

nop

beq $s3, $0, next4

nop

lui $t1, 0x4835

next4:

addu $s3, $s0, $s1

addu $s4, $s0, $s1

beq $s3, $s4, next5

nop

lui $t2, 0x9543

next5:

#beq - cal\_i

lui $s0, 0x5342

ori $s1, $s0, 0x5432

ori $s2, $s0, 0x5432

beq $s1, $s2, next1

nop

lui $s0, 0x4533

next1:

lui $s2, 0x5432

lui $s3, 0x5432

beq $s2, $s3, next2

nop

lui $s2, 0x5432

next2:

lui $s4, 0x9543

nop

beq $s4, $0, next3

nop

lui $s0, 0x5432

next3:

#beq - load

lui $s0, 0x8753

ori $s1, $s0, 0x8543

sw $s0, 0($0)

sw $s1, 4($0)

lw $s2, 0($0)

beq $s2, $0, next1

nop

lui $t0, 0x8594

next1:

lw $s3, 0($0)

nop

beq $s3, $0, next2

nop

lui $t2, 0x8954

next2:

lw $s4, 0($0)

lw $s5, 0($0)

beq $s4, $s5, next3

nop

lui $t3, 0x8453

next3:

lui $s7, ox8753

lw $s6, 0($0)

lw $s7, 4($0)

beq $s6, $s7, next4

nop

lui $t4, 0x8754

next4:

#beq - jal

lui $s0, 0x8754

addu $ra, $0, $0

jal next1

nop

next1:

beq $ra, $0, next2

nop

lui $t0, 0x4532

next2:

#jr - cal\_r

la $s0, next1

la $s1, next2

addu $t0, $s0, $0

jr $t0

nop

next1:

addu $t1, $s1, $0

nop

jr $t1

nop

next2:

#jr - cal\_i

addu $s0, $0, $0

lui $s0, 0x3010

jr $s0

nop

addu $s1, $s0, $0

ori $s1, $0, 0x3020

jr $s1

lui $t0, 0x5432

nop

#jr - load

ori $s0, $0, 0x3020

ori $s1, $0, 0x3030

sw $s0, 0($0)

sw $s1, 4($0)

addu $s2, $0, $0

lw $s2, 0($0)

jr $s2

nop

addu $s3, $0, $0

lw $s3, 4($0)

nop

jr $s3

nop

#jr - jal

la $s3, next2

lui $s0, 0x8754

addu $ra, $0, $0

jal next1

nop

next1:

jr $s3

nop

lui $t0, 0x4532

next2:

思考题

1、

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **指令类型** | **前序指令** | **前前序指令** | **冲突寄存器** | **解决方法** | **测试序列** |
| cal\_r | cal\_r / cal\_i |  | rs / rt | 转发 | subu $s3, $s1, $s0 addu $s4, $s3, $s0 |
|  | cal\_r / cal\_i | rs / rt | 转发 | subu $s7, $s0, $s6 addu $t0, $s6, $s7 addu $t1, $t0, $s7 |
| load |  | rs / rt | 阻塞 | lw $t0, 0($0) addu $t1, $t0, $s0 |
|  | load | rs / rt | 转发 | lw $t0, 0($0) addu $t1, $t0, $s0 addu $t2, $t0, $t1 |
| jal |  | 31 | 转发 | jal next1 addu $s2, $s0, $ra next1: |
|  | jal | 31 | 转发 | jal next3 addu $s6, $s5, $ra subu $s6, $s5, $ra |
| cal\_i | cal\_r / cal\_i |  | rs | 转发 | ori $s1, $s0, 0x8954 ori $s2, $s1, 0x6543 |
|  | cal\_r / cal\_i | rs | 转发 | ori $s6, $s4, 0x8592 ori $s6, $s6, 0x3478 ori $s7, $s6, 0x8594 |
| load |  | rs | 阻塞 | lw $t1, 8($0) ori $t2, $t1, 0x4352 |
|  | load | rs | 转发 | lw $t1, 8($0) ori $t2, $t1, 0x4352 ori $t3, $t1, 0x5435 |
| jal |  | 31 | 转发 | jal next1 ori $s1, $ra, 0x8594 next1: |
|  | jal | 31 | 转发 | jal next3 ori $ra, $ra, 0x5438 ori $s6, $ra, 0x8954 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| load | cal\_r / cal\_i |  | rs | 转发 | addu $t2, $t0, $t1 lw $t2, 4($0) |
|  | cal\_r / cal\_i | rs | 转发 | subu $t3, $t2, $t1 subu $t4, $t3, $t2 lw $t3, 8($0) |
| load |  | rs | 阻塞 | lw $t0, 0($0) lw $t1, 0($t0) |
|  | load | rs | 转发 | lw $t2, 4($t0) lw $t2, 0($t2) lw $t3, 4($t2) |
| jal |  | 31 | 转发 | jal next2 lw $t1, 0($ra) |
|  | jal | 31 | 转发 | jal next2 lw $t1, 0($ra) next2: lw $t2, 0($ra) |
| store | cal\_r / cal\_i |  | rs / rt | 转发 | addu $s3, $s0, $s1 sw $s3, 0($0) |
|  | cal\_r / cal\_i | rs / rt | 转发 | addu $s3, $s0, $s1 sw $s3, 0($0) sw $s3, 4($0) |
| load |  | rs | 阻塞 | lw $t1, 0($0) sw $t0, 0($t1) |
| load |  | rt | 转发 | lw $t0, 0($0) sw $t0, 16($0) |
|  | load | rs / rt | 转发 | lw $t0, 0($0) sw $t0, 16($0) sw $t0, 20($0) |
| jal |  | 31 | 转发 | jal next1 sw $s0, 0($ra) |
|  | jal | 31 | 转发 | jal next2 next2: sw $s0, 0($ra) sw $s0, 8($ra) |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| beq | cal\_r / cal\_i |  | rs / rt | 阻塞 | addu $s2, $s0, $s1 beq $s2, $0, next1 |
|  | cal\_r / cal\_i | rs / rt | 转发 | subu $s3, $s1, $s1 nop beq $s3, $0, next4 |
| load |  | rs / rt | 阻塞 | lw $s2, 0($0) beq $s2, $0, next1 |
|  | load | rs / rt | 阻塞 | lw $s3, 0($0) nop beq $s3, $0, next2 |
| jal |  | 31 | 转发 |  |
|  | jal | 31 | 转发 | jal next1 nop next1: beq $ra, $0, next2 |
| jr | cal\_r / cal\_i |  | rs | 阻塞 | addu $t0, $s0, $0 jr $t0 |
|  | cal\_r / cal\_i | rs | 转发 | addu $t1, $s1, $0 nop jr $t1 |
| load |  | rs | 阻塞 | lw $s2, 0($0) jr $s2 |
|  | load | rs | 阻塞 | lw $s3, 4($0) nop jr $s3 |
| jal |  | 31 | 转发 |  |
|  | jal | 31 | 转发 | jal next1 nop next1: jr $s3 |