Computer Organization

Lab7 MIPS(6) - Floating-Point Processing

2021 Spring term

wangw6@sustech.edu.cn

Topics

- **Floating-Point Number**
  - IEEE 745 On Floating-point Number
- **Registers of Coprocessor 1**
- **Floating-point Instructions**
  - Load & Store, Move
  - Computational
  - Relational and Branch ...
- **Practices**

IEEE 745 On Floating-Point Number

$$\pm 1.xxxxxxx_2 \times 2^{yyyy}$$

single: 8 bits
double: 11 bits

single: 23 bits
double: 52 bits

S	Exponent (yyyy+Bias)	Fraction (xxxx)

$$x = (-1)^S \times (1 + \text{Fraction}) \times 2^{(\text{Exponent} - \text{Bias})}$$

For single-precision float data:

Exponents 0000_0000 and 1111_1111 reserved

Bias in Exponent is: 0111_1111

For double-precision float data:

Exponents 000_0000_0000 and 111_1111_1111 reserved

Bias in Exponent is: 011_1111_1111

IEEE 745 On Floating-Point Number continued

```
.data
fneg1:    .float  -1
wneg1:    .word -1
fpos1:    .float   1
wpos1:    .word  1
```

$\pm 1.xxxxxxx_2 \times 2^{yyyy}$

single: 8 bits
double: 11 bits

single: 23 bits
double: 52 bits

S	Exponent (yyyy+Bias)	Fraction (xxxx)

$$x = (-1)^S \times (1 + \text{Fraction}) \times 2^{(\text{Exponent} - \text{Bias})}$$

Label	Address ▲
float_rw.asm	
fneg1	0x10010000
wneg1	0x10010004
fpos1	0x10010008
wpos1	0x1001000c

- **-1** = $(-1)^{1}$ x $(1+0)$ x 2^{0}
  s: 1, exponent: 0 + 0111_1111, fraction: 0
- **1** = $(-1)^{0}$ x $(1+0)$ x 2^{0}
  s: 0, exponent: 0 + 0111_1111, fraction: 0

Data Segment

Address	Value (+0)	Value (+4)	Value (+8)	Value (+c)
0x10010000	0xbf800000	0xffffffff	0x3f800000	0x00000001

Coprocessor 1 in MIPS

What's the difference between lwc1and ldc1?
Which demo would trigger the exception?
Which demo would get the right answer?

Registers	Coproc 1	Copro

Name	Float
$f0	0x00000000
$f1	0xbf800000
$f2	0x00000000
$f3	0x3f800000

```
Runtime exception at 0x00400004: first register must be even-numbered
```

```
Runtime exception at 0x00400010: all registers must be even-numbered
```

```
.data              #demo1
        fneg1:     .float -1
        fpos1:     .float 1
.text
        lwc1 $f1,fneg1
        lwc1 $f3,fpos1
        add.s $f12,$f1,$f3

        li $v0,2
        syscall
        li $v0,10
        syscall
```

```
.data              #demo2
        fneg1:     .double -1
        fpos1:     .double 1
.text
        ldc1 $f1,fneg1
        ldc1 $f3,fpos1
        add.d $f12,$f1,$f3

        li $v0,3
        syscall
        li $v0,10
        syscall
```

```
.data              #demo3
        fneg1:     .double -1
        fpos1:     .double 1
.text
        ldc1 $f0,fneg1
        ldc1 $f2,fpos1
        add.d $f11,$f0,$f2

        li $v0,3
        syscall
        li $v0,10
        syscall
```

Floating-Point Instructions

The **floating-point coprocessor** has these classes of **instructions**:

• **Load and Store** Instructions: Load values and move data between memory and coprocessor registers.

lwc1,**ldc1**; **swc1**,**sdc1**; ...etc

• **Move** Instructions: Move data between registers.

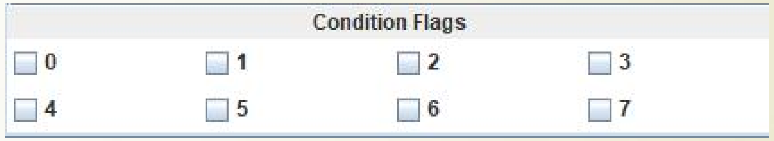
mtcl, **mfc1**; VS **mov.s**,**mov.d**; ...etc

• **Computational** Instructions: Do arithmetic and logical operations on values in coprocessor registers.

add.s,add.d; sub.s,sub.d; mul.s,mul.d; div.s,div.d; ...etc

• **Relational** Instructions: **Compare** two floating-point values and set conditional flag

c.eq.s, c.eq.d; c.le.s,c.le.d; c.lt.s,c.lt.d; ...etc



• **Conditional jumping** instructions :

bc1f # conditional jump while conditional flag is 0(false)

bc1t; # conditional jump while conditional flag is 1(true)

• **Convert Instructions: floor.w.d, floor.w.s; ceil.w.d, ceil.w.d; cvt.d.s**

Infinite vs NaN (floating-point)

Which one will get an infinite value?

Which one will get the NaN?

	31 Sign	30–23 Exponent	22–0 Mantissa
93000000	0	0001 1010	101 1000 1011 0001 0001
0	0	0000 0000	000 0000 0000 0000 0000
+Infinity	0	1111 1111	000 0000 0000 0000 0000
−Infinity	1	1111 1111	000 0000 0000 0000 0000
Quiet NaN	x	1111 1111	0xx xxxx xxxx xxxx xxxx
Signaling NaN	x	1111 1111	1xx xxxx xxxx xxxx xxxx

```
.data
	sdata: .word 0xff7f7fff
	fneg1: .float -1
.text
	lw $t0,sdata
	mtc1 $t0,$f1
	mul.s $f12,$f1,$f1

	li $v0,2
	syscall

	lwc1 $f2,fneg1
	mul.s $f12,$f12,$f2

	li $v0,2
	syscall

	li $v0,10
	syscall
```

```
.data
	sdata: .word 0xffff7fff
	fneg1: .float -1
.text
	lw $t0,sdata
	mtc1 $t0,$f1
	mul.s $f12,$f1,$f1

	li $v0,2
	syscall

	lwc1 $f2,fneg1
	div.s $f12,$f12,$f2

	li $v0,2
	syscall

	li $v0,10
	syscall
```

Demo 1

```
.include "macro_print_str.asm"
.data
	f1: .float 12.625
.text
	lwc1 $f0,f1
	floor.w.s $f1,$f0
	ceil.w.s $f2,$f0
	round.w.s $f3,$f0

	print_string("orignal float: ")
	print_float($f0)

	print_string("\nafter floor:")
	print_float($f1)

	print_string("\nafter ceil:")
	print_float($f2)

	print_string("\nafter round:")
	print_float($f3)

	end
```

What's the output of current demo after running?
Why?
How to change the code to get correct output?

```
.macro print_float(%fr)
	addi $sp,$sp,-8
	swc1 $f12,4($sp)
	sw $v0,0($sp)

	mov.s $f12,%fr
	li $v0,2
	syscall

	lw $v0,0($sp)
	lwc1 $f12,4($sp)
	addi $sp,$sp,8
.end_macro
```

```
orignal float: 12.625
after floor:1.7E-44
after ceil:1.8E-44
after round:1.8E-44
-- program is finished running --
```

```
orignal float: 12.625
after floor:12
after ceil:13
after round:13
-- program is finished running --
```

Demo2

```
##piece 1/2 of code##
.include "macro_print_str.asm"
.data
        str1: .asciiz   "str1:"
        fd1:  .float     1.0
        dd1:.double 2.0
.text

        li $v0 2
        syscall



        bc1t printLe
        j printGt
```

```
##piece 2/2 of code##
printLe:
        print_string(  “is less or equal than ")
        j printSecondData
printGt:
        print_string(" is larger than")
printSecondData:
        li $v0,3
        syscall

        end
```

The output is expected to be the following screenshot, please complete the code.

```
1.0 LessOrEqual 2.0
-- program is finished running --
```

Practices

- 1. Calculate the value of π from the infinite series: $\pi = 4 - \frac{4}{3} + \frac{4}{5} - \frac{4}{7} + \frac{4}{9} - \frac{4}{11} + \cdots$

  Input a double-precision float number which represents a precision threshold.

  Your program should terminate when the difference between two successive iterations is smaller than the precision threshold.

  Print the value of π (as double-precision float).

- 2. Given a single-precision float number 'x' and a positive integer 'r'. Round up 'x' to a number which keeps 'r' digits after the decimal point. Print the processing results and the final results.

  For example, suppose 'x' is 1.5671

  - if 'r' is 2, print 1.57;
  - if 'r' is 0, print 2;
  - if 'r' is 3, print 1.567;

Tips:

Single

	31	30 … 23	22 … 0
	Sign	Exponent	Mantissa
93000000	0	0001 1010	101 1000 1011 0001 0001
0	0	0000 0000	000 0000 0000 0000 0000
+Infinity	0	1111 1111	000 0000 0000 0000 0000
−Infinity	1	1111 1111	000 0000 0000 0000 0000
Quiet NaN	x	1111 1111	0xx xxxx xxxx xxxx xxxx
Signaling NaN	x	1111 1111	1xx xxxx xxxx xxxx xxxx

Double

High-order word / Low-order word

	31	30 … 20	19 … 0, 31 … 0
	Sign	Exponent	Mantissa
93000000	0	000 0001 1010	1011 0001 0110 0010 0010 1000 0000 ....
0	0	000 0000 0000	0000 0000 0000 0000 0000 0000 ....
+Infinity	0	111 1111 1111	0000 0000 0000 0000 0000 0000 ....
−Infinity	1	111 1111 1111	0000 0000 0000 0000 0000 0000 ....
Quiet NaN	x	111 1111 1111	0xxx xxxx xxxx xxxx xxxx xxxx ....
Signaling NaN	x	111 1111 1111	1xxx xxxx xxxx xxxx xxxx ....

reference from "see in MIPS"

Registers | Coproc 1 | Coproc 0

Name	Float	Double
$f0	0x00000000	0x0000000000000000
$f1	0x00000000	
$f2	0x00000000	0x0000000000000000
$f3	0x00000000	
$f4	0x00000000	0x0000000000000000
$f5	0x00000000	
$f6	0x00000000	0x0000000000000000
$f7	0x00000000	
$f8	0x00000000	0x0000000000000000
$f9	0x00000000	
$f10	0x00000000	0x0000000000000000
$f11	0x00000000	
$f12	0x00000000	0x4000000000000000
$f13	0x40000000	
$f14	0x00000000	0x3ff0000000000000
$f15	0x3ff00000	
$f16	0x00000000	0x0000000000000000
$f17	0x00000000	
$f18	0x00000000	0x0000000000000000
$f19	0x00000000	
$f20	0x00000000	0x0000000000000000
$f21	0x00000000	
$f22	0x00000000	0x0000000000000000
$f23	0x00000000	
$f24	0x00000000	0x0000000000000000
$f25	0x00000000	
$f26	0x00000000	0x0000000000000000
$f27	0x00000000	
$f28	0x00000000	0x0000000000000000
$f29	0x00000000	
$f30	0x00000000	0x0000000000000000
$f31	0x00000000	

Condition Flags

- [x] 0
- [ ] 1
- [ ] 2
- [ ] 3
- [ ] 4
- [ ] 5
- [ ] 6
- [ ] 7

registers and flags in coprocessor 1