Computer Organization

Lab7 Floating-Point Processing

MIPS(4)
Floating-Point

Topic

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

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(8bit): **0000_0000** and **1111_1111** reserved
Bias in Exponent: **0111_1111**

For double-precision float data:

Exponents(11bit): **000_0000_0000** and **111_1111_1111** reserved
Bias in Exponent : **011_1111_1111**

IEEE 745 On Floating-Point Number continued

```
.data
fneg1:      .float    -1     32 bit
wneg1: 整数 .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

- $-1 = (-1)^1 \times (1 + 0) \times 2^0$

  s: 1; exponent: 0 + 0111_1111; fraction: 0

- $1 = (-1)^0 \times (1 + 0) \times 2^0$

  s: 0; exponent: 0 + 0111_1111; fraction: 0

Data Segment

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

$$-\underbrace{1011\ 1111\ 1}_{127-127=0}000\ 0000\ 0000\ 0000\ 0000\ 0000$$

$- 2^0 \times 1 = -1$

Infinite vs NaN (Floating-Point)

	Sign (31)	Exponent (30–23)	Mantissa (22–0)
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

Q1. Which one will get an infinite value, A or B? 拥问

Q2. Which one will get the NaN, A or B?

Tips:
lwc1 : load word from memory to the register in coprocessor 1
mtc1: move a word from nomal register to the register in coprocessor 1
mul.s: floating point multiplication single precision
div.s : floating point division single precision

```
.data            #A
    sdata: .word 0xFF7F7FFF
    fneg1: .float -1      如何使用 由指令决定
.text
    lw $t0,sdata
    mtc1 $t0,$f1
    mul.s $f12,$f1,$f1

    li $v0,2              Infinity
    syscall

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

    li $v0,2              -Infinity
    syscall

    li $v0,10
    syscall
```

```
.data            #B
    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
```

Coprocessor 1 in MIPS

Q1. What's the difference between 'lwc1' and 'ldc1'?
Q2. Which demo would trigger the exception?
Q3. 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                 #A
      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
```

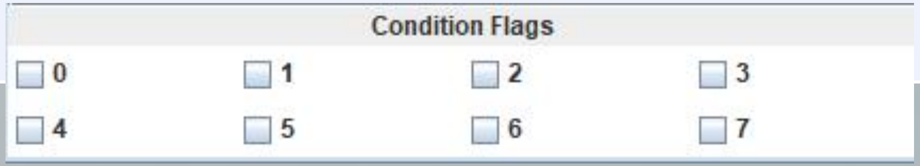
```
.data                 #B
      fneg1:   .double  -1
      fpos1:   .double   1
.text
      ldc1 $f1, fneg1      f0
      ldc1 $f3, fpos1      f2
      add.d $f12, $f1, $f3

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

```
.data                 #C
      fneg1:   .double  -1
      fpos1:   .double   1
.text
      ldc1 $f0, fneg1
      ldc1 $f2, fpos1
      add.d $f11, $f0, $f2
                f12
      li $v0,3
      syscall
      li $v0,10
      syscall
```

Floating-Point Instructions

Type	Description	Instructions
Load and Store	**Move** data **between memory and coprocessor1 register**	单 双 **lwc1**,**ldc1**; **swc1**,**sdc1**; ...
Move	**Move** data between **nomal register** and **coprocessor1 register** **Move** data between **coprocessor1 registers**	**mtc1**, **mfc1**; **mov.s**,**mov.d**;
Computational	Do **arithmetic** operations on data in coprocessor 1 registers	add.**s**, add.**d**; sub.s, sub.d; mul.s, mul.d; div.s,div.d; ...
Relational	**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; ...
Convert	**Convert** the **data type**	**floor**.w.d,floor.w.s; **ceil**.w.d, ceil.w.s; round.w.d, round.w.s; **cvt**.d.s, cvt.d.w, cvt.w.s ......
Conditional jumping	**Conditional jump** while **conditional flag** is 0(**f**alse)/1(**t**rue)	**bc1f**, **bc1t**



Demo(1)

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

        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
```

```
#add the content to  "macro_print_str.asm"

.macro print_float(%fr)

        addi $sp,$sp,-8
        swc1 $f12,4($sp)   #B
        sw $v0,0($sp)

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

        lw $v0,0($sp)
        lwc1 $f12,4($sp)
        addi $sp,$sp,8     #D

.end_macro
```

Here is a demo which is supposed to get the following output:

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

While running the demo, another result is got as the following snap:

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

Find the reason, and correct the demo. *(The tips are marked by A,B,C,D)*

Demo(2)

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

	##complete code here##

	li $v0, 2
	syscall

	##complete code here##

	bc1t printLe
	j printGt
```

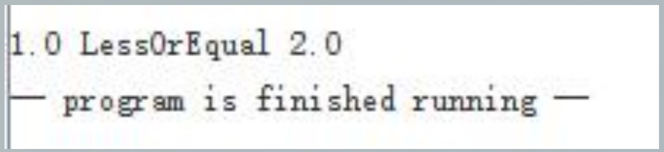
```
##piece 2/2 of code##
printLe:
	print_string( " LessOrEqual ")
	j printSecondData

printGt:
	print_string(" LargerThan ")

printSecondData:
	li $v0,3
	syscall

	end
```

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


1.0 LessOrEqual 2.0
-- program is finished running --

Practices

1. Calculate the value of e from the infinite series: $$\sum_{n=0}^{\infty}\frac{1}{n!}=\frac{1}{0!}+\frac{1}{1!}+\frac{1}{2!}+\frac{1}{3!}+\frac{1}{4!}+\frac{1}{5!}+\cdots$$

- 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 e (as double-precision float).

2. Complete the code on page 9

3. 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(1)

	31	30 23	22 0
Single	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

High-order word   Low-order word

	31	30 20	19 0 31 0
Double	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

Tips(2)

Service	Code in $v0	Arguments	Result
print float	2	**$f12** = float to print	
print double	3	**$f12** = double to print	
read float	6		**$f0** contains float read
read double	7		**$f0** contains double read

#the content of "macro_print_str.asm"

```
.macro print_string(%str)
	.data
		pstr:	.asciiz	%str
	.text
		la $a0,pstr
		li $v0,4
		syscall
.end_macro

.macro end
	li $v0,10
	syscall
.end_macro
```