Computer Organization

Lab7 MIPS(6) - Floating-Point Processing

Topics

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

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

S	Exponent (yyyy+Bias)	Fraction (xxxx)
	single: 8 bits double: 11 bits	single: 23 bits double: 52 bits

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

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

- **-1** = $(-1)^1 \times (1+\mathbf{0}) \times 2^0$

  s: 1; exponent: 0 + 0111_1111; fraction: 0
- **1** = $(-1)^0 \times (1+\mathbf{0}) \times 2^0$

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

Data Segment

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

5 Infinite vs NaN (Floating-Point)

Which one will get an infinite value?

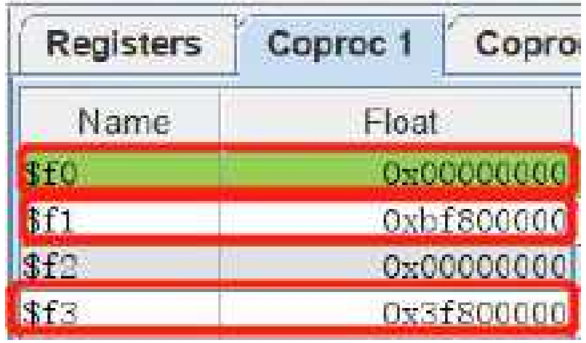
Which one will get the NaN?

	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

```
.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
```

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?

```
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

Type	Description	Instructions
Load and Store	**Load** values and move data **between memory and coprocessor registers**	**lwc1**,**ldc1**; **swc1**,**sdc1**; …
Move	**Move** data between registers	**mtcl**, **mfc1**; **mov.s**,**mov.d**;
Computational	Do **arithmetic** operations on values 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; …
Conditional jumping	**Conditional jump** while **conditional flag** is 0(**f**alse)/1(**t**rue)	**bc1f**, **bc1t**
Convert	**Convert** the **data type**	**floor**.w.d,floor.w.s; **ceil**.w.d, ceil.w.s; **cvt**.d.s

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
```

Q1. What's the output of current demo after running? Why?
Q2. 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 --
```

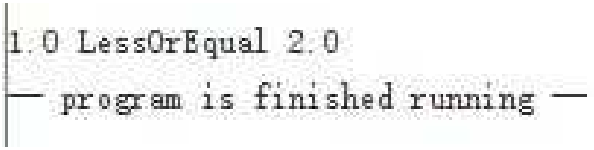
```
orignal float: 12.625
after floor:12
after ceil:13
after round:13
-- program is finished running --
```

9 Demo2

```
##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.



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:

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 31	30 – 20	19 – 0, Low-order word 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

☑ 0	☐ 1	☐ 2	☐ 3
☐ 4	☐ 5	☐ 6	☐ 7

registers and flags in coprocessor 1

12 **Tips:**

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