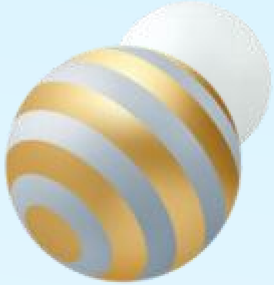
Computer Organization

Lab7 Floating-Point Processing

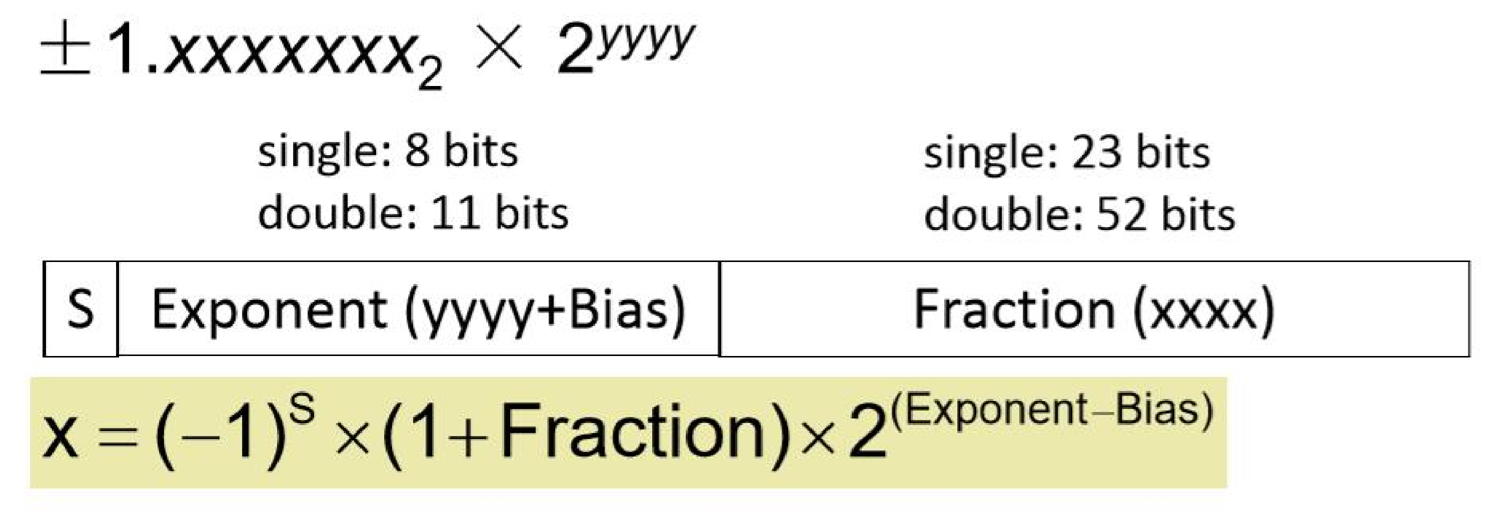
MIPS(4)
Floating-Point



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**

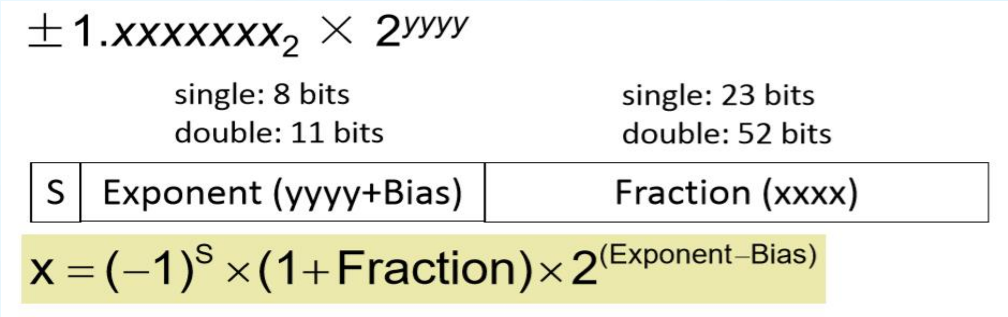
For double-precision float data:

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



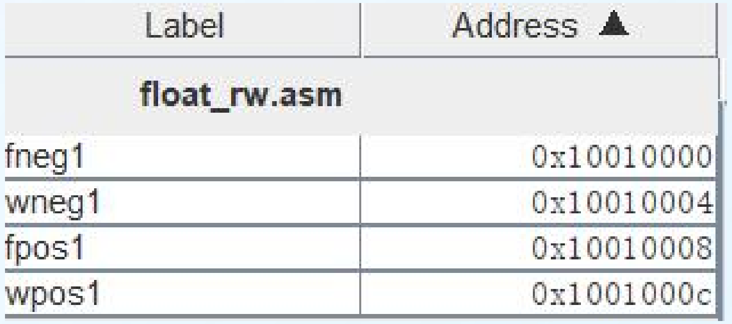
$\pm 1.xxxxxxx_2 \times 2^{yyyy}$

single: 8 bits
double: 11 bits

single: 23 bits
double: 52 bits

S	Exponent (yyyy+Bias)	Fraction (xxxx)

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



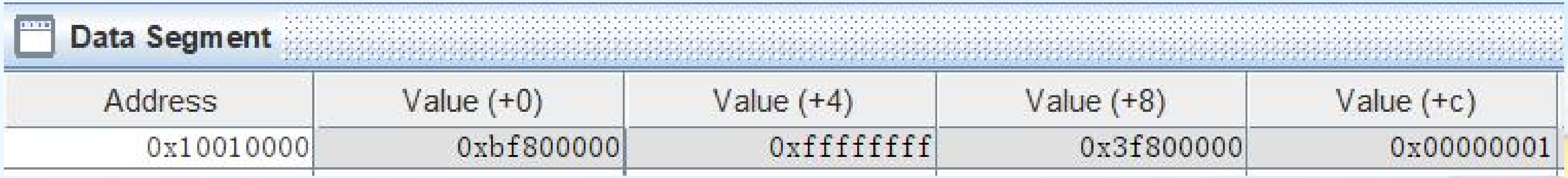
Label	Address ▲
float_rw.asm	
fneg1	0x10010000
wneg1	0x10010004
fpos1	0x10010008
wpos1	0x1001000c

- **-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}

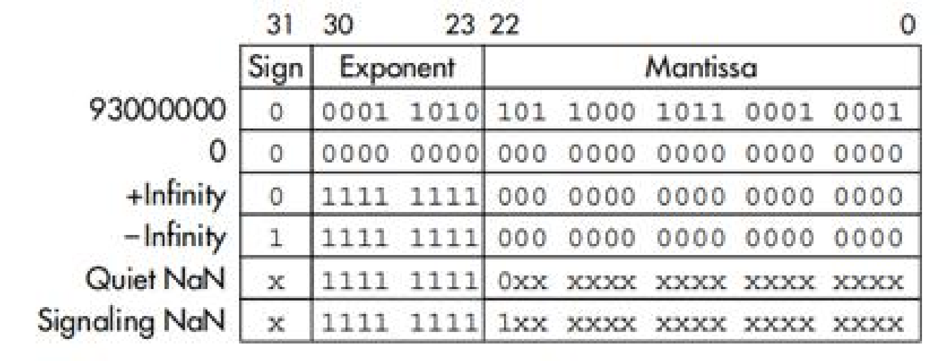
  s: 0; exponent: **0** + 0111_1111; fraction: **0**



Data Segment

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

Infinite vs NaN (Floating-Point)



	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

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

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

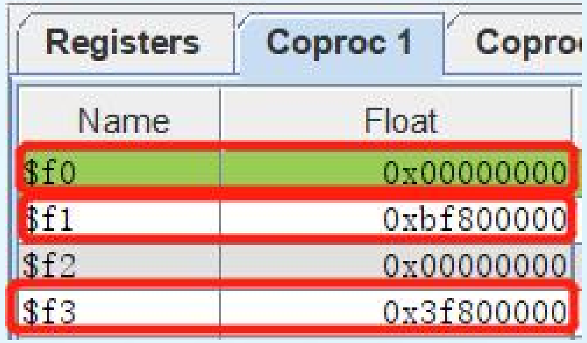
Tips:
lwc1 : load word from memory to the register in coprocessor 1
mtc1: move a word from nomal register to the register in coprocessor 1
mul.s: floating point multiplication single precision
div.s : floating point division single precision

```
.data           #A
        sdata: .word 0xFF7F7FFF
        fneg1: .float -1
.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
```

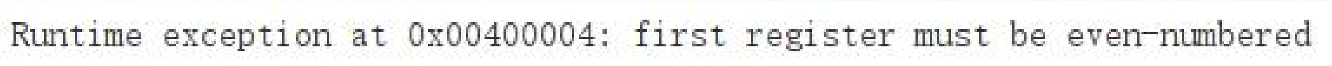
```
.data           #B
        sdata: .word 0xffff7fff
        fneg1: .float -1
.text
        lw $t0,sdata
        mtc1 $t0,$f1
        mul.s $f12,$f1,$f1

        li $v0,2
        syscall

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

        li $v0,2
        syscall

        li $v0,10
        syscall
```

Coprocessor 1 in MIPS

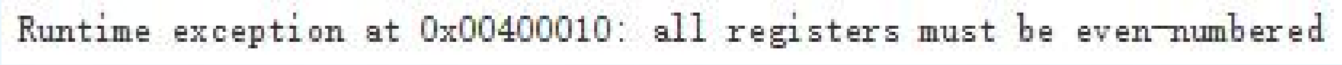
Q1. What's the difference between ‘lwc1’ and ‘ ldc1’ ?
Q2. Which demo would trigger the exception?
Q3. Which demo would get the right answer?



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
```

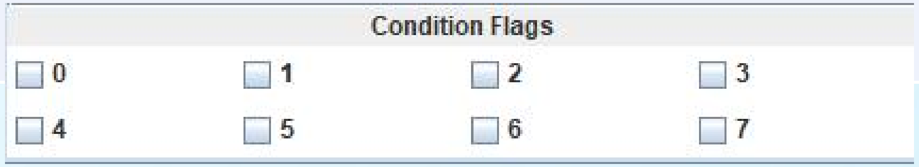
```
.data               #B
        fneg1:      .double  -1
        fpos1:      .double   1
.text
        ldc1 $f1, fneg1
        ldc1 $f3, fpos1
        add.d $f12, $f1, $f3

        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

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

Floating-Point Instructions

Type	Description	Instructions
Load and Store	**Move** data **between memory and coprocessor1 register**	**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 ……

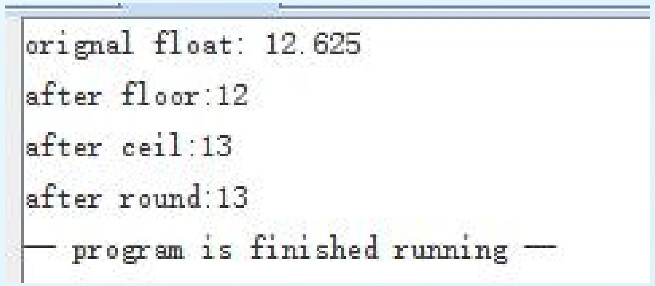
Conditional jumping	**Conditional jump** while **conditional flag** is 0(**f**alse)/1(**t**rue)  Condition Flags □ 0 □ 1 □ 2 □ 3 □ 4 □ 5 □ 6 □ 7	**bc1f**, **bc1t**

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
```

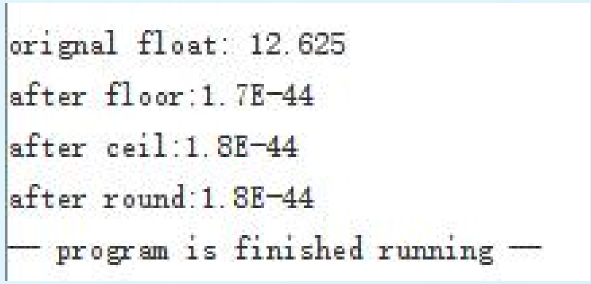
```
#add the content to   "macro_print_str.asm"

.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 --
```

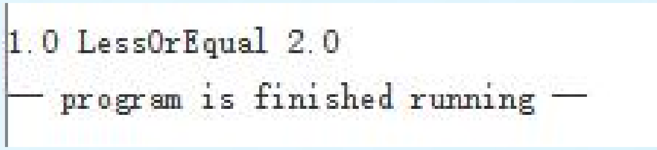
Find the reason, and correct the demo. *(The tips are marked by A,B,C,D)*

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).

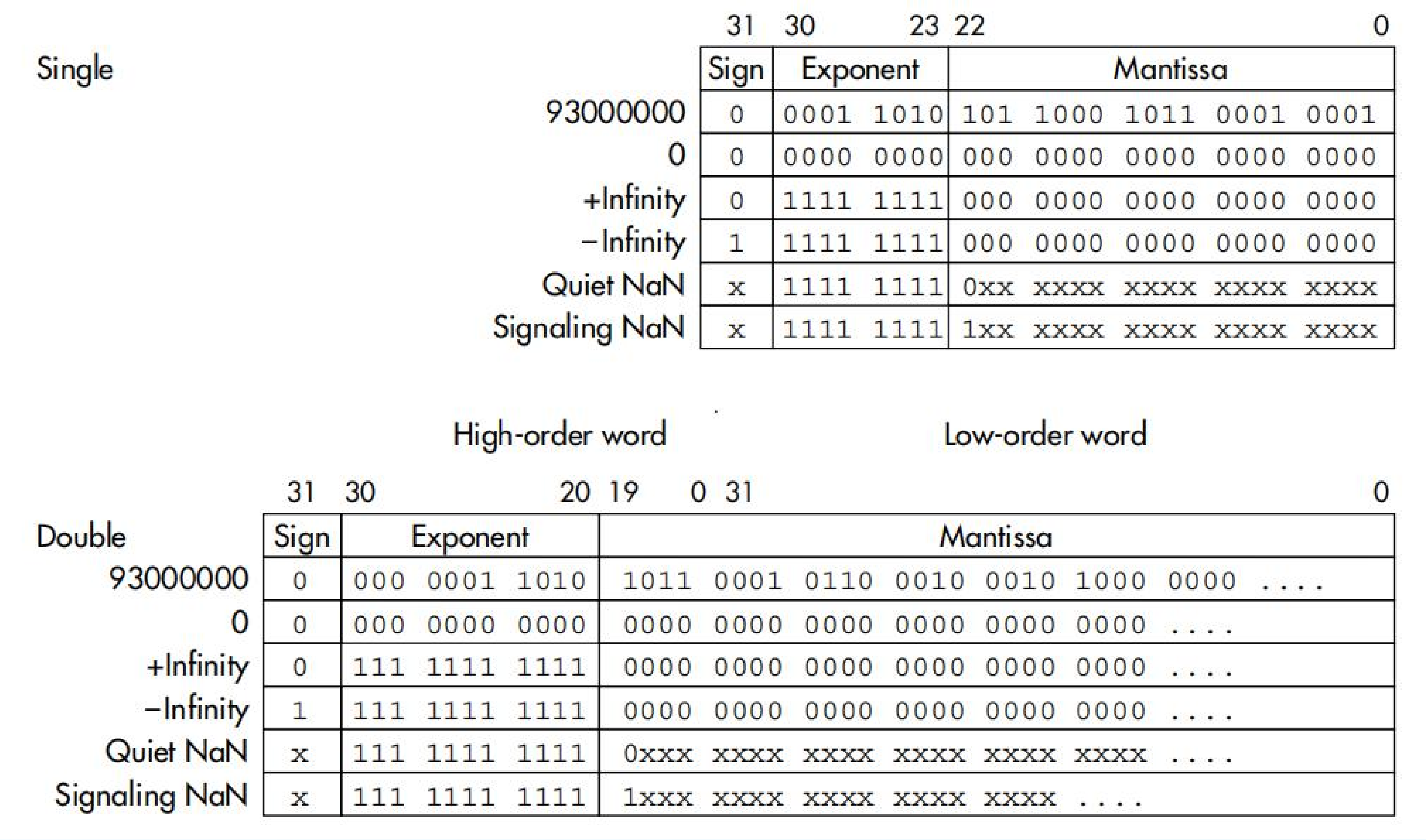
2. Complete the code on page 9

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;

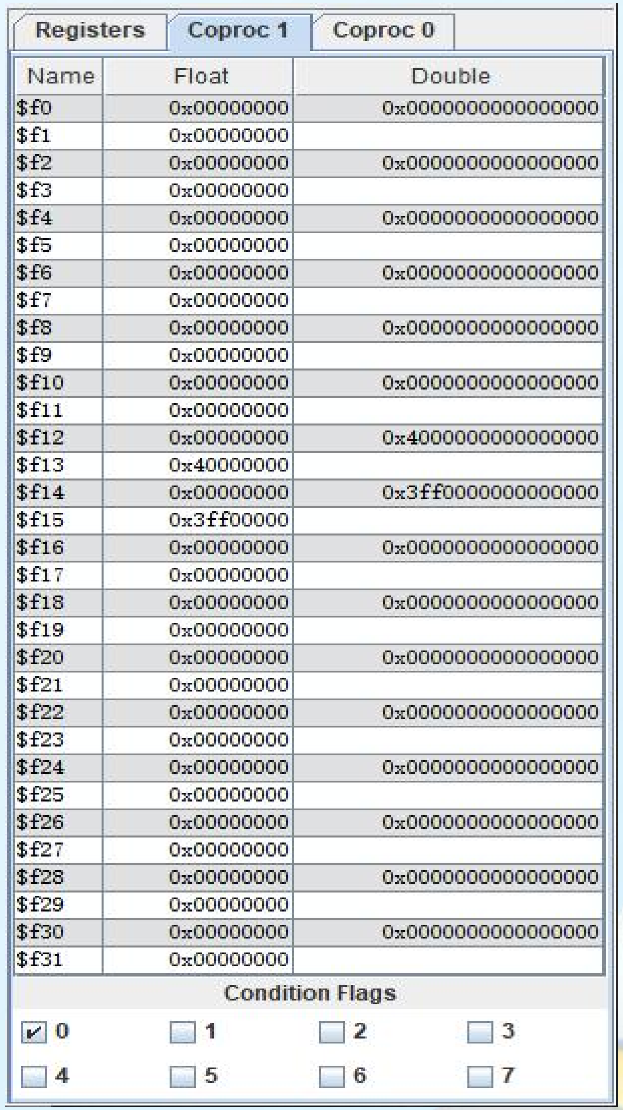
Tips(1)



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

	High-order word		Low-order word
Double	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"



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

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
```