Lab Sheet 4 for CS F342 Computer Architecture
Semester 1 – 2020-2021

Goals for the Lab: To understand and use (1) the branch instructions and jump instructions, and (2) logical and shift operations.

MIPS does not have if statements, nor does it have for or while statements. To create conditional processing and loops it is necessary to build the control structure with branch statements. Normally, the execution of a statement is followed by the execution of the next statement in the code. A branch instruction causes execution to jump to a different statement. Some branches are conditional -- they only branch if a specified condition is met. Others are unconditional -- they always cause a branch to occur.

I) Branch Instructions: branch if a specified condition is met. All branch instructions use the I-format.

Name	Format	Meaning	Example
Branch If Equal	`beq Rs,Rt,label`	if Rs == Rt branch to label	`beq $t1,$t2,next`
Branch If Not Equal	`bne Rs,Rt,label`	if Rs != Rt branch to label	`bne $t1,$t2,else`
Branch If Greater Than	`bgt Rs,Rt,label`	if Rs > Rt branch to label	`bgt $t1,$t2,top`
Branch If Less Than	`blt Rs,Rt,label`	if Rs < Rt branch to label	`blt $t1,$t2,two`
Branch If Greater Than or Equal	`bge Rs,Rt,label`	if Rs >= Rt branch to label	`bge $t1,$t2,done`
Branch If Less Than or Equal	`ble Rs,Rt,label`	if Rs <= Rt branch to label	`ble $t1,$t2,three`
Branch If Equal To Zero	`beqz Rs,label`	if Rs == 0 branch to label	`beqz $t1,after`
Branch If Not Equal To Zero	`bnez Rs,label`	if Rs != 0 branch to label	`bnez $t1,second`
Branch If Greater Than Zero	`bgtz Rs,label`	if Rs > 0 branch to label	`bgtz $t1,high`
Branch If Less Than Zero	`bltz Rs,label`	if Rs < 0 branch to label	`bltz $t1,low`
Branch If Greater Than or Equal To Zero	`bgez Rs,label`	if Rs >= 0 branch to label	`bgez $t1,somehi`
Branch If Less Than or Equal To Zero	`blez Rs,label`	if Rs <= 0 branch to label	`blez $t1,somelo`
Branch	`b label`	branch to label	`b loop`

The if-else construct :

```
if (var1 == var2) {
      ....        /* block of code #1 */
}
else {
      ....        /* block of code #2 */
}
```

Let's assume that the values of variables *var1* and *var2* are in registers **`$t0`** and **`$t1`**. Then, this piece of C code would be translated as:

```
            bne $t0, $t1, Else      # go to Else if $t0 != $t1
            ....                    # code for block #1
            beq $0, $0, Exit        # go to Exit (skip code for block #2)
Else:
            ....                    # code for block #2
Exit:                               # exit the if-else
```

Instructions like, *SLT -- Set on less than (signed), SLTI – Set on less than immediate (signed), and SLTU -- Set on less than (unsigned)* uses R-format.

Instruction	Example	Meaning	Comments
set on less than	`slt $1,$2,$3`	if($2<$3)$1=1; else $1=0	Test if less than. If true, set $1 to 1. Otherwise, set $1 to 0.
set on less than immediate	`slti $1,$2,100`	if($2<100)$1=1; else $1=0	Test if less than. If true, set $1 to 1. Otherwise, set $1 to 0.

The sltu instruction is used with unsigned integers: sltu d,s,t # if ($s < $t) d = 1 else d=0.

Exercise 1: Write MIPS code to find the minimum and maximum of two integer numbers.

```
# Find max $t0 and $t1
bge $t0,$t1,ifblock     # Check if $t0>=$t1, $t0 is maximum, then go to ifblock (label)
move $t2,$t1            # Else, $t1 is maximum
blt $t0,$t1,exit

ifblock:
move $t2,$t0

exit:

# Display the Max
la $a0,output_msg1
li $v0,4
syscall
move $a0,$t2
li $v0,1
syscall
#################################################################
# Find min $t0 and $t1
ble $t0,$t1,ifblock1     # Check if $t0<=$t1, $t0 is min, then go to ifblock (label)
move $t2,$t1            # Else, $t1 is min
bgt $t0,$t1,exit1

ifblock1:
move $t2,$t0

exit1:

# Display the Min
la $a0,output_msg2
li $v0,4
syscall
move $a0,$t2
li $v0,1
syscall
```

Exercise 2: Write MIPS code to find the input integer is even or odd.

```
li $t1,2
div $t0,$t1
mfhi $t0

# Find max $t0 and $t1
beqz $t0,ifblock     # if($t0%2==0) goto ifblock and print even

la $a0,output_msg1   # Else, print odd
li $v0,4
syscall
bnez $t0,exit

ifblock:
la $a0,output_msg   # Else, print even
li $v0,4
syscall

exit:
```

II) Jump Instructions: an instruction which unconditionally branches to a labeled instruction. We use jump instructions.

Instruction	Meaning
j label	Unconditionally jump to the instruction at the label.
jal label	Jump and Link; Typically used in function calls.
jr Rsrc	Unconditionally jump to the instruction whose address is in register Rsrc.

The C *while* and MIPS

The C *while* expression closely resembles the *if* expression. It has a predicate and something that happens continuously as long as the expression returns true.

```
predicate:  slt $t0, $s1, $s2            # while ($s1 < $s2)
            beq $t0, $zero, endwhile     #     {
consequent: addi $s1, $s1, 1             #     $s1++;
            j predicate                  #     }
endwhile:                                #
```

```
predicate:  slt $t0, $s1, $s2            } Predicate ($t0 = 1 if true)
            beq $t0, $zero, endwhile     } Branch Statement to exit loop
consequent: addi $s1, $s1, 1             } Consequent (skipped if not true)
            j predicate                  } Loop Back Statement
endwhile:
```

The C *for* and MIPS

The *for* expression is like the while expression except it has two addition components to it. Not only does it have the *consequent* body which is evaluated continuously as long as the predicate returns a true value, it has *initialization* and *next* statements built into it. It would look as follows:

```
initialize: add $s1, $zero, $zero        # for ($s1 = 0,
            addi $s2, $zero, 10          #      $s2 = 10;
predicate:  slt $t0, $s1, $s2            #      $s1 < $2; $s1++)
            beq $t0, $zero, endfor       #    {
consequent: addi $s1, $s1, 0             #    $s1 += 0;
            addi $s1, $s1, 1             #                /* $s1 ++; */
            j predicate                  #    }
endfor:
```

Notice how it's form doesn't really change that much from the while loop. It's really just a construct in C to make code more compressed and readable. The form in MIPS looks like:

```
initialize: add $s1, $zero, $zero        } Initialization Statements
            addi $s2, $zero, 10
predicate:  slt $t0, $s1, $s2            } Predicate ($t0 = 1 if true)
            beq $t0, $zero, endfor       } Branch Statement to exit loop
consequent: addi $s1, $s1, 0             } Consequent (skipped if not true)
            addi $s1, $s1, 1             } Next Statements
            j predicate                  } Loop Back Statement
endfor:
```

Exercise 3 : Write MIPS code to find the sum of first n natural numbers.

```
.data
input_msg: .asciiz "Enter a number: "
output_msg: .asciiz "The sum "

.text
main:
```

```
# Read integer number n
la $a0,input_msg
li $v0,4
syscall
li $v0,5
syscall
move $t3,$v0  # $t3 contains n

li $t0,0   # intialize sum =0.
li $t1,0   # intialize count =0

loop:
   bgt $t1,$t3,exit   # while count>n, come out of loop
   add $t0,$t0,$t1    # sum=sum+count
   addi $t1,$t1,1     # increment count
   j loop
exit:

# Display the sum
la $a0,output_msg
li $v0,4
syscall
move $a0,$t0
li $v0,1
syscall

# Exit the program
li $v0,10
syscall
```

III) Floating point branch instructions :

Conditional jumps are performed in two stages :

1. Comparison of FP values sets a code in a special register

2. Branch instructions jump depending on the value of the code.

Instruction	Operation
c.eq.d $f0,$f12	set floating point coprocessor flag true if equal double
c.eq.s $f0,$f12	set floating point coprocessor flag true if equal float
c.ge.d $f0,$f12	set floating point coprocessor flag true if greater or equal double
c.ge.s $f0,$f12	**set floating point coprocessor flag true if greater or equal float**
c.gt.d $f0,$f12	set floating point coprocessor flag true if greater than double
c.gt.s $f0,$f12	set floating point coprocessor flag true if greater than float
c.le.d $f0,$f12	set floating point coprocessor flag true if less or equal double
c.le.s $f0,$f12	set floating point coprocessor flag true if less or equal float
c.lt.d $f0,$f12	set floating point coprocessor flag true if less than double
c.lt.s $f0,$f12	set floating point coprocessor flag true if less than float
c.ne.d $f0,$f12	set floating point coprocessor flag true if not equal double
c.ne.s $f0,$f12	set floating point coprocessor flag true if not equal float

The floating point compare instructions set or clear the floating point coprocessor flag. The bc1t (flag true) and bc1f (flag false) instructions can then be used for branching conditioned on the comparison result. [Note : Some of the above instructions are not available in QtSpim.]

Instruction	Example	Meaning
`bc1t`	`bc1t label`	Branch to `label` if condition flag `0` is true
`bc1t`	`bc1t 1, label`	Branch to `label` if condition flag `1` is true
`bc1f`	`bc1f label`	Branch to `label` if condition flag `0` is false
`bc1f`	`bc1f 4, label`	Branch to `label` if condition flag `4` is false

Exercise 4 : Write MIPS code to find the minimum and maximum of two floating point numbers.

```
.data
input_msg1: .asciiz "Enter first number"
input_msg2: .asciiz "Enter second number"
output_msg1: .asciiz "The Maximum is :"
output_msg2: .asciiz "The Minimum is :"
.text

main:
# Read first number
la $a0,input_msg1
li $v0,4
syscall
li $v0,6
syscall
mov.s $f1,$f0

# Read second number
la $a0,input_msg2
li $v0,4
syscall
li $v0,6
syscall
mov.s $f2,$f0

# Find max $f1 and $f2
c.lt.s $f1,$f2     # Check if $f1>=$f2, $f1 is maximum, then go to ifblock (label)
bc1f ifblock
mov.s $f4,$f2           # Else, $f2 is maximum
c.lt.s $f1,$f2
bc1t exit

ifblock:
mov.s $f4,$f1

exit:

# Display the Max
la $a0,output_msg1
li $v0,4
syscall
mov.s $f12,$f4
li $v0,2
syscall


# Find min $f1 and $f2
c.lt.s $f1,$f2     # Check if $f1<=$f2, $f1 is min, then go to ifblock (label)
bc1t ifblock1

c.lt.s $f1,$f2
bc1f else1
```

```
ifblock1:
mov.s $f4,$f1

else1:
mov.s $f4,$f2

# Display the Min
la $a0,output_msg2
li $v0,4
syscall
mov.s $f12,$f4
li $v0,2
syscall


# Exit the program
li $v0,10
syscall
```

IV) Logical and Shift operations : MIPS has two types of bitwise instructions: those that operate on registers, and those that operate on a register and an immediate operand. The register instructions are:
(1) and Rd, Rs, Rt
(2) or Rd, Rs, Rt
(3) nor Rd, Rs, Rt
(4) xor Rd, Rs, Rt

The immediate insructions are:
(1) andi Rt, Rs, immed
(2) ori Rt, Rs, immed
(3) xori Rt, Rs, immed

Example 1 : By ANDing a value with a deliberately designed constant, called a bit mask we can clear specific bits. Any bits that are 0 in the mask will be cleared in the result, and bits that are 1 in the mask with be preserved in the result.

```
value   10010100
mask    00001111
--------------------
        00000100
```

Shift instructions :
• Left shift: Moves bits from a lower position to a higher position.
• Right shift: Moves bits from a higher position to a lower position.

sll $t0,$t1,5 shift left logical
srl $t0,$t1,5 shift right logical
sra $t0,$t1,5 shift right arithmetic
sllv $t0,$t1,$t2 shift left logical value (register)
srlv $t0,$t1,$t2 shift right logical value (register)
srav $t0,$t1,$t2 shift right arithmetic value (register)

Example 1: sll $t0,$t1,5, suppose $t1 is 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 1010
The bits fill in 0s when value moved to the left by number of positions.
0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0001 0100 0000

Example 2: sra $t0,$t1,5, suppose $t1 is 1011 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000

Then fill in MSB value when value moved to the right by number of positions. (preserving sign).
1111 1101 1000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000 0000

Exercise 5 : Give MIPS instruction to perform the following :

(a) Returns in $v0 , 0 and 1 depending on the most significant bit of input stored in $a

[Answer : srl $v0, $a0, 31]

(b) Flip (Replace 0's and 1's)

[Answer : xor $v0, $a0, -1]

(c) To perform NOT operation, using logical operations.