Laboratory Exercise 4

Arithmetic and Logical operation

Goals

After this laboratory exercise, you should know how to use arithmetic, logical and shift instructions. In addition, you should also understand overflow in arithmetic operation and how to detect it.

Literature

Behrooz Parhami (CAMS): Section 5.3

Preparation

Before you start the exercise, you should review the textbook, section 5.3 and read this laboratory carefully. You should also review the Laboratory Exercise 2.

Assignments at Home and at Lab

Home Assignment 1

The sum of two 32-bit integers may not be representable in 32 bits. In this case, we say that an overflow has occurred. Overflow is possible only with operands of the same sign. For two nonnegative (negative) operands, if the sum obtained is less (greater) than eitheir operand, overflow has occurred. The following program dectects overflow based on this rule. Two operands are stored in register $s1 and $s2, the sum is stored in register $s3. If overflow occur, $t0 register is set to 1 and clear to 0 in otherwise.

```
#Laboratory Exercise 4, Home Assignment 1
.text
start:
      li    $t0,0             #No Overflow is default status
      addu  $s3,$s1,$s2       # s3 = s1 + s2
      xor   $t1,$s1,$s2       #Test if $s1 and $s2 have the same sign

      bltz  $t1,EXIT          #If not, exit
      slt   $t2,$s3,$s1
      bltz  $s1,NEGATIVE      #Test if $s1 and $s2 is negative?
      beq   $t2,$zero,EXIT    #s1 and $s2 are positive
           # if $s3 > $s1 then the result is not overflow
      j     OVERFLOW
NEGATIVE:
      bne   $t2,$zero,EXIT    #s1 and $s2 are negative
           # if $s3 < $s1 then the result is not overflow
OVERFLOW:
      li    $t0,1             #the result is overflow
EXIT:
```

Home Assignment 2

The following program demonstrates how to use logical instructions to extract information from one register. We can extract one bit or more according to the mask we use. Read this example carefully and explain each lines of code.

```
#Laboratory Exercise 4, Home Assignment 2
.text
      li    $s0, 0x0563       #load test value for these function
      andi  $t0, $s0, 0xff    #Extract the LSB of $s0
      andi  $t1, $s0, 0x0400  #Extract bit 10 of $s0
```

Home Assignment 3

This example show how the shift operations used to implement other instructions, such as multiply by a small power of 2.

```
#Laboratory Exercise 4, Home Assignment 3
.text
      li    $s0,1             #s0=1
      sll   $s1,$s0,2         #s1=s0*4
```

Assignment 1

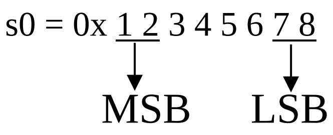
Create a new project to implement the Home Assigment 1. Compile and upload to simulator. Initialize two operands (register $s1 and $s2), run this program step by step, observe memory and registers value.

Assignment 2

Write a program to do the following tasks:

- Extract MSB of $s0
- Clear LSB of $s0
- Set LSB of $s0 (bits 7 to 0 are set to 1)
- Clear $s0 (s0=0, must use logical instructions)

MSB: Most Significant Byte
LSB: Least Significant Byte



Assignment 3

Pseudo instructions in MIPS are not-directly-run-on-MIPS-processor instructions which need to be converted to real-instructions of MIPS. Re-write the following pseudo instructions using real-instructions understood by MIPS processors:

```
a. abs    $s0,s1
       s0 <= | $s1 |
b. move   $s0,s1
       s0 <= $s1
c. not    $s0
       s0 <= bit invert (s0)
d. ble    $s1,s2,L
```

```
if (s1 <= $s2)
     j L
```

Assignment 4

To dectect overflow in additional operation, we also use other rule than the one in Assignment 1. This rule is: when add two operands that have the same sign, overflow will occur if the sum doesn’t have the same sign with either operands. You need to use this rule to write another overflow detection program.

Assignment 5

Write a program that implement multiply by a small power of 2. (2, 4, 8, 16, etc for example).

Conclusions

Before you pass the laboratory exercise, think about the questions below:

- What is the difference between SLLV and SLL instructions?
- What is the difference between SRLV and SRL instructions?

Laboratory Exercise 5

Character string with SYSCALL function, and sorting

Goals

After this laboratory exercise, you should understand the mechanism of storing ASCII and Unicode string. You will be able to program to process string and put string to console. In addition, you should know how to sort a list of elements.

Literature

Patterson, Henessy (COD): section 2.8, 2.13

Preparation

Before you start the exercise, you should review the textbook, section 6.1 and read this laboratory carefully. You should also read the Mips Lab Environment Reference to find the usage of printf, putchar procedures … and so on.

About SYSCALL

A number of system services, mainly for input and output, are available for use by your MIPS program. They are described in the table below.

MIPS register contents are not affected by a system call, except for result registers as specified in the table below.

How to use SYSCALL system services

1. Load the service number in register $v0.
2. Load argument values, if any, in $a0, $a1, $a2, or $f12 as specified.
3. Issue the SYSCALL instruction.
4. Retrieve return values, if any, from result registers as specified.

Example: display the value stored in $t0 on the console

```
    li   $v0, 1              # service 1 is print integer
    li   $a0, 0x307          # the interger to be printed is 0x307
    syscall                  # execute
```

Table of Frequently Available Services

Service	Code in $v0	Arguments	Result
print decimal integer	1	$a0 = integer to print	

print string	4	$a0 = address of null-terminated string to print	
read integer	5		$v0 contains integer read
read string	8	$a0 = address of input buffer $a1 = maximum number of characters to read	*See note below table*
exit	10	(terminate execution)	
print character	11	$a0 = character to print	*See note below table*
read character	12		$v0 contains character read
open file	13	$a0 = address of null-terminated string containing filename $a1 = flags $a2 = mode	$v0 contains file descriptor (negative if error). *See note below table*
read from file	14	$a0 = file descriptor $a1 = address of input buffer $a2 = maximum number of characters to read	$v0 contains number of characters read (0 if end-of-file, negative if error). *See note below table*
write to file	15	$a0 = file descriptor $a1 = address of output buffer $a2 = number of characters to write	$v0 contains number of characters written (negative if error). *See note below table*
close file	16	$a0 = file descriptor	
exit2 (terminate with value)	17	$a0 = termination result	*See note below table*
time (system time)	30		$a0 = low order 32 bits of system time $a1 = high order 32 bits of system time. *See note below table*
MIDI out	31	$a0 = pitch (0-127) $a1 = duration in milliseconds $a2 = instrument (0-127) $a3 = volume (0-127)	Generate tone and return immediately. *See note below table*
sleep	32	$a0 = the length of time to sleep in milliseconds.	Causes the MARS Java thread to sleep for (at least) the specified number of milliseconds. This timing will not be precise, as the Java implementation will add some overhead.
MIDI out synchronous	33	$a0 = pitch (0-127) $a1 = duration in milliseconds $a2 = instrument (0-127) $a3 = volume (0-127)	Generate tone and return upon tone completion. *See note below table*
print integer in hexadecimal	34	$a0 = integer to print	Displayed value is 8 hexadecimal digits, left-padding with zeroes if necessary.
print integer in binary	35	$a0 = integer to print	Displayed value is 32 bits, left-padding with zeroes if necessary.
print integer as unsigned	36	$a0 = integer to print	Displayed as unsigned decimal value.
(not used)	37-39		
set seed	40	$a0 = i.d. of pseudorandom	No values are returned. Sets the seed of the corresponding underlying Java

		number generator (any int). $a1 = seed for corresponding pseudorandom number generator.	pseudorandom number generator (`java.util.Random`). *See note below table*
random int	41	$a0 = i.d. of pseudorandom number generator (any int).	$a0 contains the next pseudorandom, uniformly distributed int value from this random number generator's sequence. *See note below table*
random int range	42	$a0 = i.d. of pseudorandom number generator (any int). $a1 = upper bound of range of returned values.	$a0 contains pseudorandom, uniformly distributed int value in the range 0 = [int] [upper bound], drawn from this random number generator's sequence. *See note below table*
ConfirmDialog	50	$a0 = address of null-terminated string that is the message to user	$a0 contains value of user-chosen option 0: Yes 1: No 2: Cancel
InputDialogInt	51	$a0 = address of null-terminated string that is the message to user	$a0 contains int read $a1 contains status value 0: OK status -1: input data cannot be correctly parsed -2: Cancel was chosen -3: OK was chosen but no data had been input into field
InputDialogString	54	$a0 = address of null-terminated string that is the message to user $a1 = address of input buffer $a2 = maximum number of characters to read	*See Service 8 note below table* $a1 contains status value 0: OK status. Buffer contains the input string. -2: Cancel was chosen. No change to buffer. -3: OK was chosen but no data had been input into field. No change to buffer. -4: length of the input string exceeded the specified maximum. Buffer contains the maximum allowable input string plus a terminating null.
MessageDialog	55	$a0 = address of null-terminated string that is the message to user $a1 = the type of message to be displayed: 0: error message, indicated by Error icon 1: information message, indicated by Information icon 2: warning message, indicated by Warning icon 3: question message, indicated by Question icon other: plain message (no icon displayed)	N/A

MessageDialogInt	56	$a0 = address of null-terminated string that is an information-type message to user $a1 = int value to display in string form after the first string	N/A
MessageDialogString	59	$a0 = address of null-terminated string that is an information-type message to user $a1 = address of null-terminated string to display after the first string	N/A

1. print decimal integer

print an integer to standard output (the console).

Argument(s):

$v0 = 1
$a0 = number to be printed

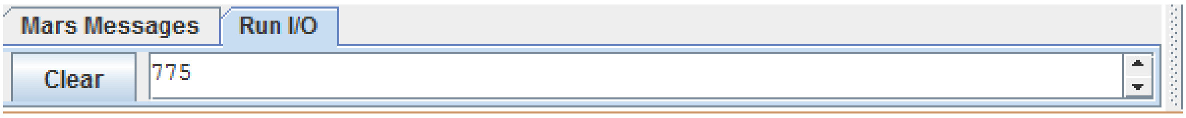
Return value:

none

Example:

```
   li   $v0, 1            # service 1 is print integer
   li   $a0, 0x307        # the interger to be printed is 0x307
   syscall                # execute
```

and result is



```
775
```

2. MessageDialogInt

show an integer to a information-type message dialog.

Argument(s):

$v0 = 56
$a0 = address of the null-terminated message string
$a1 = int value to display in string form after the first

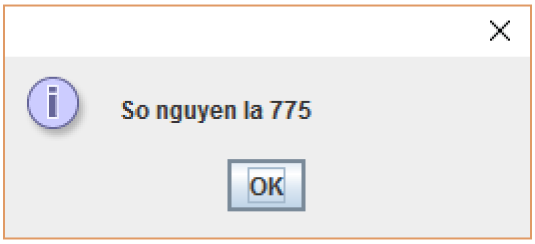
string *Return value:*

none

Example:

```
.data
Message: .asciiz "So nguyen la "
.text
   li   $v0, 56
   la   $a0, Message
   li   $a1, 0x307        # the interger to be printed is 0x307
   syscall                # execute
```

and result is


So nguyen la 775

3. print string

Formatted print to standard output (the console).

Argument(s):

$v0 = 1

$a0 = value to be printed

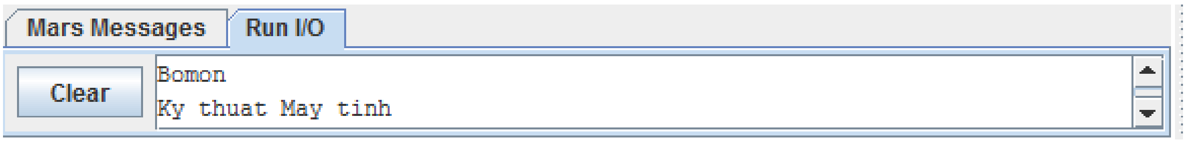
Return value:

none

Example:

```
.data
Message: .asciiz "Bomon \nKy thuat May tinh"
.text
   li  $v0, 4
   la  $a0, Message
   syscall
```

and result is



```
Bomon
Ky thuat May tinh
```

4. MessageDialogString

Show a string to a information-type message dialog

Argument(s):

$v0 = 59

$a0 = address of the null-terminated message string

$a1 = address of null-terminated string to display

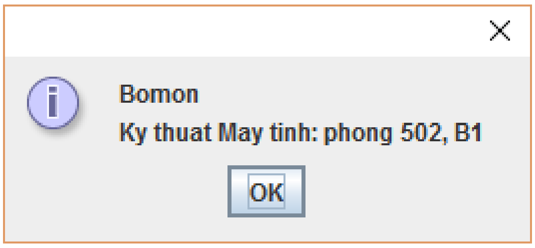
Return value:

none

Example:

```
.data
Message: .asciiz "Bomon \nKy thuat May tinh:"
Address: .asciiz " phong 502, B1"
.text
   li  $v0, 59
   la  $a0, Message
   la  $a1, Address
   syscall
```

and result is



Bomon
Ky thuat May tinh: phong 502, B1

5. read integer

Get a integer from standard input (the keyboard).

Argument(s):

$v0 = 5

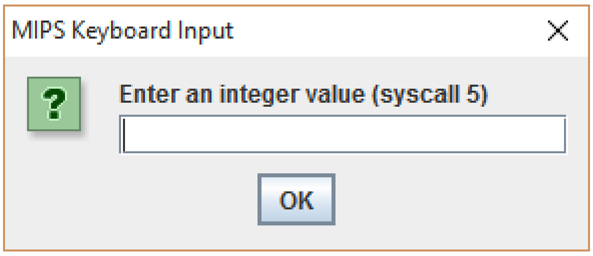
Return value:

$v0 = contains integer read

Example:

```
     li      $v0, 5
     syscall
```

and result is



MIPS Keyboard Input

Enter an integer value (syscall 5)

6. InputDialogInt

Show a message dialog to read a integer with content parser

Argument(s):

$v0 = 51
$a0 = address of the null-terminated message string

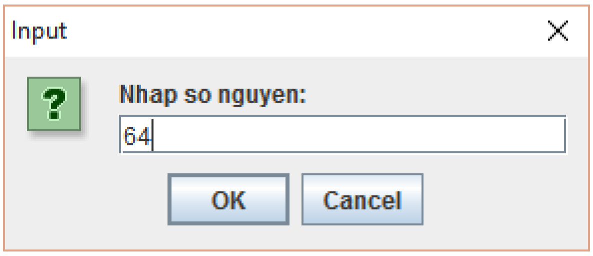
Return value:

$a0 = contains int read
$a1 contains status value
0: OK status
-1: input data cannot be correctly parsed
-2: Cancel was chosen
-3: OK was chosen but no data had been input into field

Example:

```
.data
Message: .asciiz "Nhap so nguyen:”
.text
   li    $v0, 51
   la    $a0, Message
   syscall
```

and result is



Input

Nhap so nguyen:

64

7. read string

Get a string from standard input (the keyboard).

Argument(s):

$v0 = 8
$a0 = address of input buffer
$a1 = maximum number of characters to read

Return value:

none

Remarks:

For specified length n, string can be no longer than n-1.

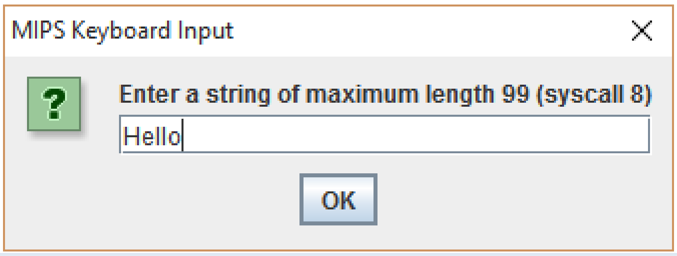
- If less than that, adds newline to end.
- In either case, then pads with null byte

Just in special cases:
If n = 1, input is ignored and null byte placed at buffer address.
If n < 1, input is ignored and nothing is written to the buffer.

Example:

```
.data
Message: .space 100    # Buffer 100 byte chua chuoi ki tu can
.text
   li   $v0, 8
   la   $a0, Message
   li   $a1, 100
   syscall
```

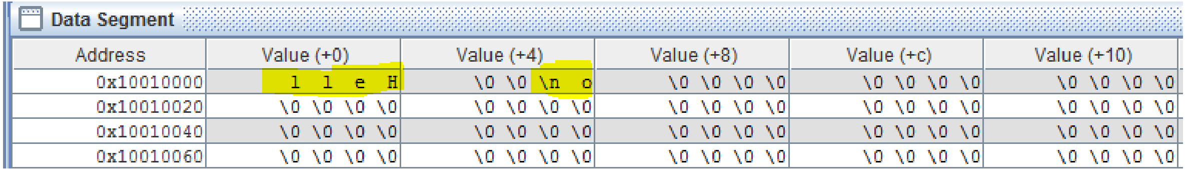
and result is



MIPS Keyboard Input

Enter a string of maximum length 99 (syscall 8)

Hello



Data Segment

Address	Value (+0)	Value (+4)	Value (+8)	Value (+c)	Value (+10)
0x10010000	l l e H	\0 \0 \n o	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0
0x10010020	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0
0x10010040	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0
0x10010060	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0

8. InputDialogString

Show a message dialog to read a string with content parser

Argument(s):

$v0 = 54
$a0 = address of the null-terminated message string
$a1 = address of input buffer
$a2 = maximum number of characters to read

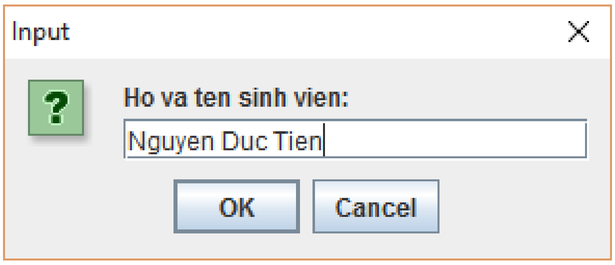
Return value:

$a1 contains status value
0: OK status
-2: OK was chosen but no data had been input into field.
No change to buffer.
-3: OK was chosen but no data had been input into field
-4: length of the input string exceeded the specified maximum. Buffer contains the maximum allowable input string plus a terminating null.

Example:

```
.data
Message: .asciiz "Ho va ten sinh vien:”
string:  .space   100
.text
   li   $v0, 54
   la   $a0, Message
   la   $a1, string
   la   $a2, 100
   syscall
```

and result is



Ho va ten sinh vien:
Nguyen Duc Tien

9. print character

Print a character to standard output (the console).

Argument(s):

$v0 = 11
$a0 = character to print (at the lowest significant byte)

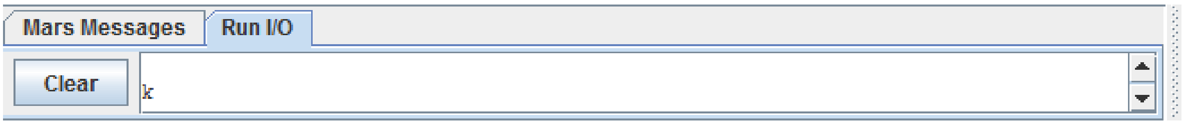
Return value:

none

Example:

```
   li  $v0, 11
   li  $a0, 'k'
   syscall
```

and result is



```
k
```

10. read character

Get a character from standard output (the keyboard).

Argument(s):

$v0 = 12

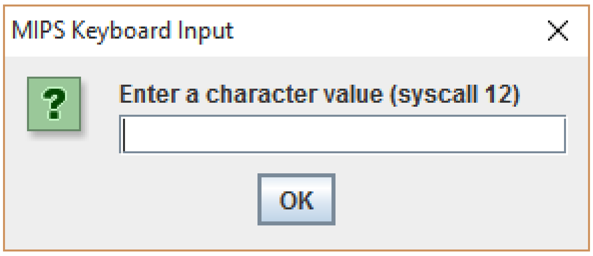
Return value:

$v0 contains character read

Example:

```
   li  $v0, 12
   syscall
```

and result is



Enter a character value (syscall 12)

11. ConfirmDialog

Show a message bog with 3 button: Yes | No | Cancel

Argument(s):

$v0 = 50
$a0 = address of the null-terminated message string

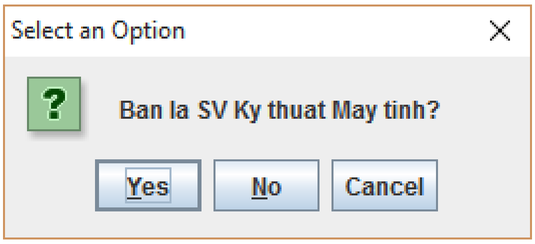
Return value:

$a0 = contains value of user-chosen option
0: Yes
1: No
2: Cancel

Example:

```
.data
Message: .asciiz "Ban la SV Ky thuat May tinh?"
.text
   li   $v0, 50
   la   $a0, Message
   syscall
```

and result is



Ban la SV Ky thuat May tinh?

12. MessageDialog

Show a message bog with icon and button OK only

Argument(s):

$v0 = 55
$a0 = address of the null-terminated message string
$a1 = the type of message to be displayed:
0: error message, indicated by Error icon
1: information message, indicated by Information icon
2: warning message, indicated by Warning icon
3: question message, indicated by Question icon
other: plain message (no icon displayed)

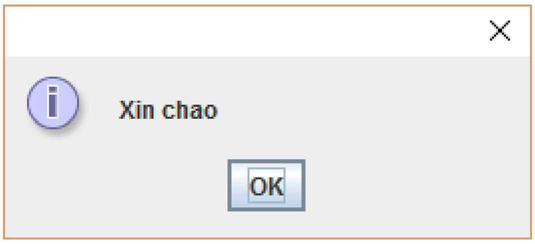
Return value:

none

Example:

```
.data
Message: .asciiz "Xin chao"
.text
   li   $v0, 55
   la   $a0, Message
   syscall
```

and result is



Xin chao

13. MIDI out

Make a sound

Argument(s):

$v0 = 31
$a0 = pitch (0-127)
$a1 = duration in milliseconds
$a2 = instrument (0-127)
$a3 = volume (0-127)

Return value:

Generate tone and return immediately

Example:

```
   li $v0, 33
   li $a0, 42     #pitch
   li $a1, 2000   #time
   li $a2, 0      #musical instrusment
   li $a3, 212    #volume
```

14. MIDI out synchronous

Make a sound

Argument(s):

$v0 = 33

$a0 = pitch (0-127)
$a1 = duration in milliseconds
$a2 = instrument (0-127)
$a3 = volume (0-127)

Return value:

Generate tone and return upon tone completion

Example:

```
   li $v0, 33
   li $a0, 42    #pitch
   li $a1, 2000  #time
   li $a2, 0     #musical instrusment
   li $a3, 212   #volume
   syscall
```

15. Exit

Terminated the software. Make sense that there is no EXIT instruction in the Instruction Set of any processors. Exit is a service belongs to Operating System.

Argument(s):

$v0 = 10

Return value:

none

Example:

```
   li        $v0, 10     #exit
   syscall
```

16. Exit with code

Terminated the software. Make sense that there is no EXIT instruction in the Instruction Set of any processors. Exit is a service belongs to Operating System.

Argument(s):

$v0 = 17
$a0 = termination result

Return value:

none

Example:

```
   li      $v0, 17      # exit
   li      $a0, 3       # with error code = 3
   syscall
```

Assignments at Home and at Lab

Home Assignment 1

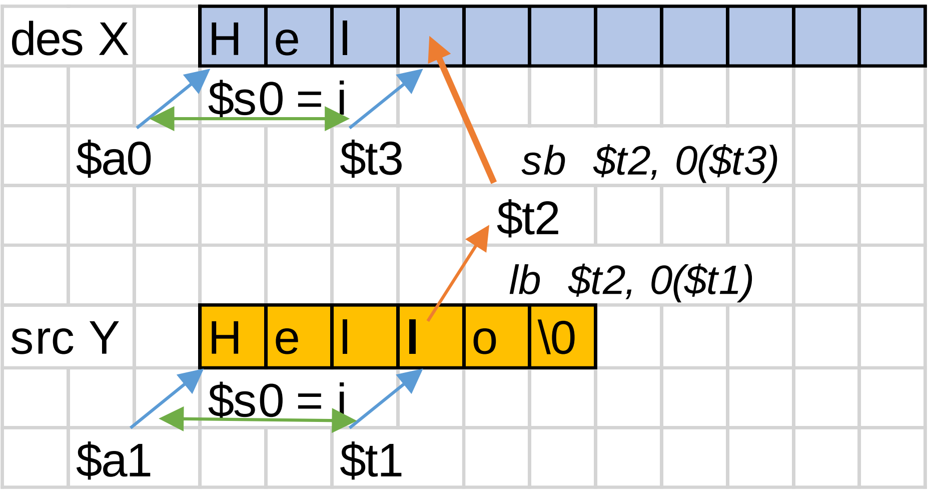
The following simple assembly program will display a welcome string. We use printf function for this purpose. Read this example carefully, pay attention to the way to pass parameters for printf function. Read Mips Lab Enviroment Reference for details.

```
#Laboratory Exercise 5, Home Assignment 1
.data
test: .asciiz "Hello World"
.text
```

```
    li  $v0, 4
    la  $a0, test
    syscall
```

Home Assignment 2

Procedure strcpy copies string y to string x using the null byte termination convention of C. Read this example carefully, try to understand all of this code section.



```
#Laboratory Exercise 5, Home Assignment 2
.data
x: .space 1000                      # destination string x, empty
y: .asciiz "Hello"                  # source string y

.text
strcpy:
      add   $s0,$zero,$zero          #s0 = i=0
L1:
      add   $t1,$s0,$a1              #t1 = s0 + a1 = i + y[0]
                                     #   = address of y[i]
      lb    $t2,0($t1)               #t2 = value at t1 = y[i]
      add   $t3,$s0,$a0              #t3 = s0 + a0 = i + x[0]
                                     #   = address of x[i]
      sb    $t2,0($t3)               #x[i]= t2 = y[i]
      beq   $t2,$zero,end_of_strcpy #if y[i]==0, exit
      nop
      addi  bb$s0,$s0,1                #s0=s0 + 1 <-> i=i+1
      j     L1                       #next character
      nop
end_of_strcpy:
```

Home Assignment 3

The following program count the length of a null-terminated string. Read this example carefully, analyse each line of code.

```
#Laboratory Exercise 5, Home Assignment 3
.data
string:      .space   50
Message1:    .asciiz "Nhap xau:”
Message2:    .asciiz "Do dai la "
.text
main:
get_string:   # TODO
```

```
get_length:   la   $a0, string          # a0 = Address(string[0])
              xor  $v0, $zero, $zero    # v0 = length = 0
              xor  $t0, $zero, $zero    # t0 = i = 0
check_char:   add  $t1, $a0, $t0        # t1 = a0 + t0
                                        #= Address(string[0]+i)
              lb   $t2, 0($t1)          # t2 = string[i]
              beq  $t2,$zero,end_of_str # Is null char?
              addi $v0, $v0, 1          # v0=v0+1->length=length+1
              addi $t0, $t0, 1          # t0=t0+1->i = i + 1
              j    check_char
end_of_str:
end_of_get_length:
print_length: # TODO
```

Assignment 1

Create a new project to implement the program in Home Assignment 1. Compile and upload to simulator. Run and observe the result. Go to data memory section, check how test string are stored and packed in memory.

Assignment 2

Create a new project to print the sum of two register $s0 and $s1 according to this format:

“The sum of (s0) and (s1) is (result)”

Assignment 3

Create a new project to implement the program in Home Assignment 2. Add more instructions to assign a test string for y variable, and implement *strcpy* function. Compile and upload to simulator. Run and observe the result.

Assignment 4

Accomplish the Home Assignment 3 with syscall function to get a string from dialog, and show the length to message dialog.

Assignment 5

Write a program that let user input a string. Input process will be terminated when user press Enter or then length of the string exceed 20 characters. Print the reverse string.

Conclusions

Before you pass the laboratory exercise, think about the questions below:

- What the difference between the string in C and Java?
- In C, with 8 bytes, how many characters that we can store?
- In Java, with 8 bytes, how many characters that we can store?