# Lab 5

## Character string with SYSCALL function, and sorting

### *Goals*

- Know how to store a string in memory.
- Know how to print out a string on the console.
- Know how to use some algorithms to sort elements in a string.

### *Preparation*

Before doing this lab, you should review your lectures and textbooks in computer architecture (e.g., *Computer Organisation and Design by Patterson & Henessy*, Section 2.8, 2.13, and 6.1).

### *About SYSCALL*

The following table shows a number of system services available for the user mode, mainly for input and output. Contents in MIPS registers are not affected by a system call, except for several specified registers, which store the returned results.

## How to use SYSCALL system services

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

**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 | $a0 = address of input buffer<br>$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 | $a0 = address of null-terminated string containing filename<br>$a1 = flags<br>$a2 = mode | $v0 contains file descriptor (negative if error). *See note below table* |
| **read from file** | 14 | $a0 = file descriptor<br>$a1 = address of input buffer<br>$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 | $a0 = file descriptor<br>$a1 = address of output buffer<br>$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 | | $a0 = low order 32 bits of system time<br>$a1 = high order 32 bits of system time. *See note below table* |
| **MIDI out** | 31 | $a0 = pitch (0-127)<br>$a1 = duration in milliseconds<br>$a2 = instrument (0-127)<br>$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 | $a0 = pitch (0-127)<br>$a1 = duration in milliseconds<br>$a2 = instrument (0-127)<br>$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 | $a0 = i.d. of pseudorandom number generator (any int).<br>$a1 = seed for corresponding pseudorandom number generator. | No values are returned. Sets the seed of the corresponding underlying Java 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 | $a0 contains pseudorandom, uniformly distributed int value in the range 0 = [int] [upper bound], drawn from this random |

| | | | |
|---|---|---|---|
| | | (any int).<br>$a1 = upper bound of range of returned values. | 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<br>0: Yes<br>1: No<br>2: Cancel |
| **InputDialogInt** | 51 | $a0 = address of null-terminated string that is the message to user | $a0 contains int read<br>$a1 contains status value<br>0: OK status<br>-1: input data cannot be correctly parsed<br>-2: Cancel was chosen<br>-3: OK was chosen but no data had been input into field |
| **InputDialogString** | 54 | $a0 = address of null-terminated string that is the message to user<br>$a1 = address of input buffer<br>$a2 = maximum number of characters to read | *See Service 8 note below table*<br>$a1 contains status value<br>0: OK status. Buffer contains the input string.<br>-2: Cancel was chosen. No change to buffer.<br>-3: OK was chosen but no data had been input into field. No change to buffer.<br>-4: length of the input string exceeded the specified maximum. Buffer contains the maximum allowable input string plus a terminating null. |
| **MessageDialog** | 55 | $a0 = address of null-terminated string that is the message to user<br>$a1 = the type of message to be displayed:<br>0: error message, indicated by Error icon<br>1: information message, indicated by Information icon<br>2: warning message, indicated by Warning icon<br>3: question message, indicated by Question icon<br>other: plain message (no icon displayed) | N/A |
| **MessageDialogInt** | 56 | $a0 = address of null-terminated string that is an information-type message to user<br>$a1 = int value to display in string form after the first string | N/A |
| **MessageDialogString** | 59 | $a0 = address of null-terminated string that is an information-type message to user<br>$a1 = address of null-terminated string to display after the first string | N/A |

## 1. print decimal integer

To print an integer to standard output (the console).
*Argument(s):*

$v0 = 1
$a0 = number to be printed

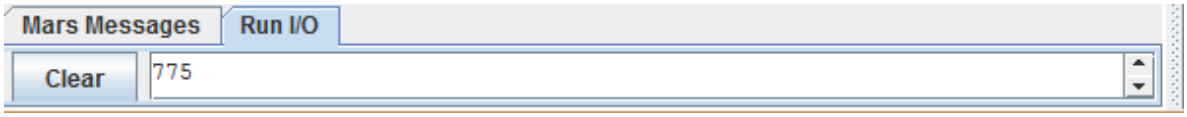
*Return value:*

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*




## 2. MessageDialogInt

To show an integer to an 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

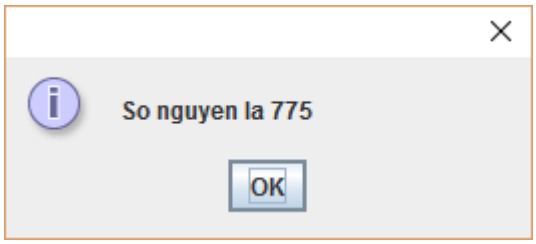
*Return value:*

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*




## 3. print string

To print a string to standard output (the console).
*Argument(s):*

$v0 = 4
$a0 = value to be printed

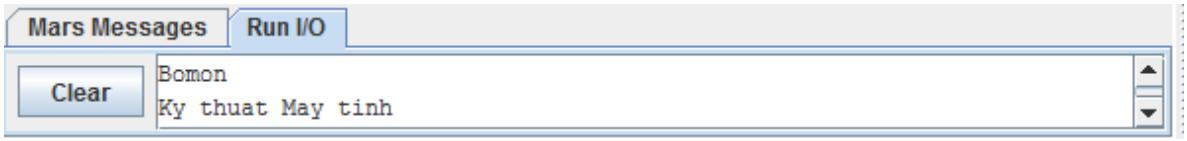
*Return value:*

none

*Example:*

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

*and result is*




## 4. MessageDialogString

To show a string to an information-type message dialog

*Argument(s):*

$v0 = 59
$a0 = address of the null-terminated message string
$a1 = address of null-terminated string to display

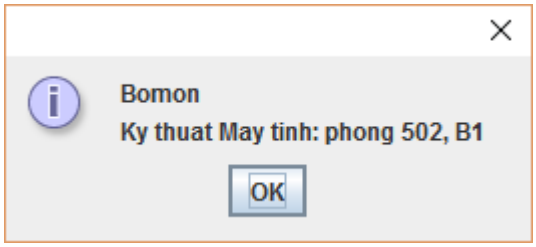
*Return value:*

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*




## 5. read integer

To get an integer from standard input (the keyboard).

*Argument(s):*

$v0 = 5

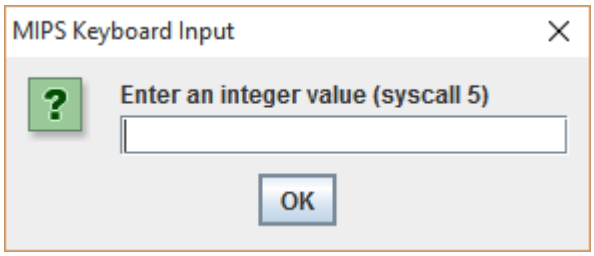
*Return value:*

$v0 = contains integer to be read

*Example:*

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

*and result is*




## 6. InputDialogInt

To show a message dialog to read an integer with content parser

*Argument(s):*

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

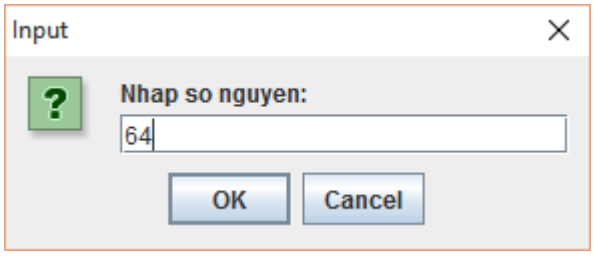
*Return value:*

$a0 = contains integer to 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*




## 7. read string

To 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 length cannot be longer than n-1.

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

Just in special cases:

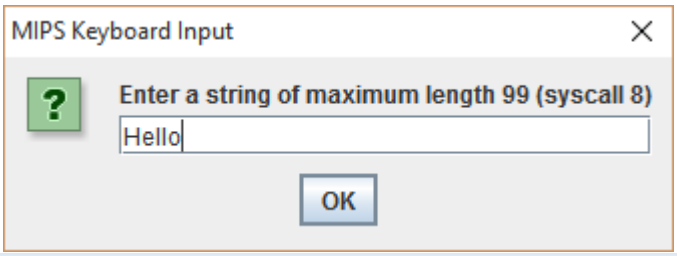
If n = 1, input is ignored and null byte is placed at buffer address.

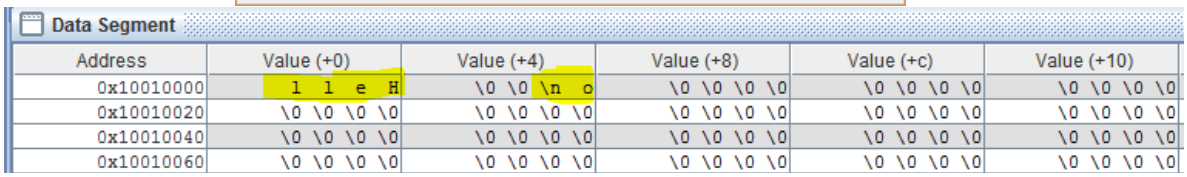
If n < 1, input is ignored and nothing is written to the buffer.

*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*




## 8. InputDialogString

To 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: OKstatus is chosen but no data has been input into field. No change to buffer.

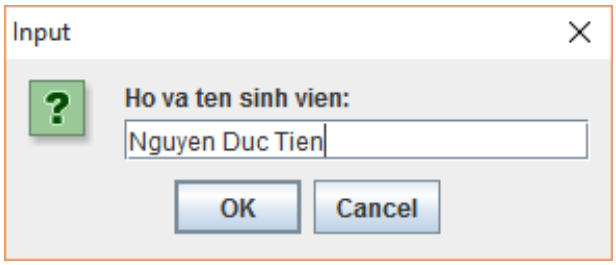
-3: OK status is chosen but no data has been input into field.

-4: length of the input string exceeds 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*




## 9. print character

To print a character to standard output (the console).

*Argument(s):*

$v0 = 11

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

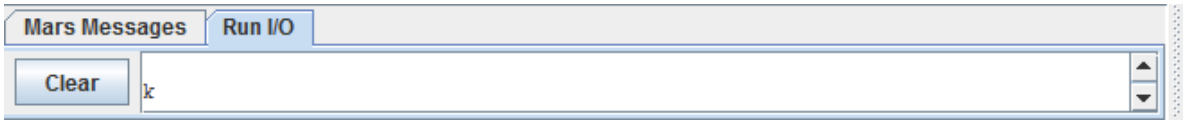
*Return value:*

none

*Example:*

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

*and result is*




## 10. read character

To get a character from standard output (the keyboard).

*Argument(s):*

$v0 = 12

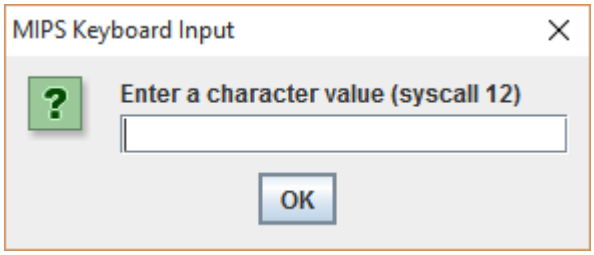
*Return value:*

$v0 contains character read

*Example:*

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

*and result is*



## 11. ConfirmDialog

To show a message box with 3 buttons: Yes | No | Cancel

*Argument(s):*

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

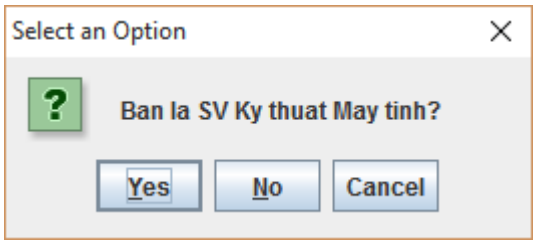
*Return value:*

$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*




## 12. MessageDialog

To show a message box 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)

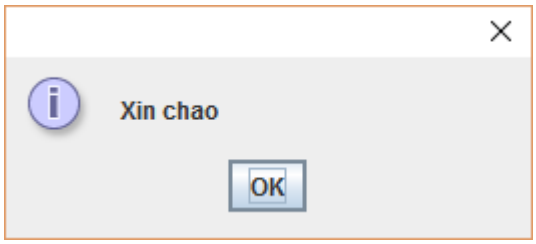
*Return value:*

none

*Example:*

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

*and result is*




## 13. MIDI out

To 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

To 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

Terminate the software. Make sure 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

Terminate the software. Make sure 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
```

## *Inlab Assignments*

### Sample Code 1

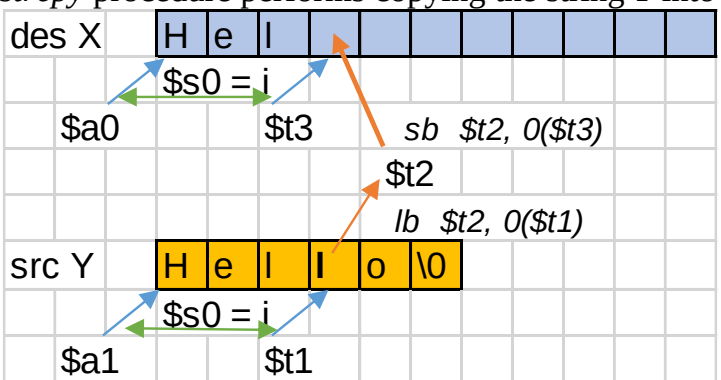
The following simple assembly program displays the string "Hello World" on the console by using the *printf* function.

```
#Laboratory Exercise 5, Sample Code 1
.data
test: .asciiz "Hello World"
.text
   li  $v0, 4
   la  $a0, test
   syscall
```

- Create a new project to execute the Sample Code 1 on MARS.
- Execute the program and observe the results.
- Explain how to pass parameters to the *printf* function and how the *test* string is stored in memory.

### Sample Code 2

The following *strcpy* procedure performs copying the string *Y* into the string *X*.



```
#Laboratory Exercise 5, Sample Code 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:
```

- Create a new project to execute the Sample Code 2 on MARS.
- Assign a different string to variable *y* and execute the program again.
- Observe any change in memory and registers.

## Sample Code 3

The following program measures the length of a null-terminated string.

```
#Laboratory Exercise 5, Sample Code 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
```

- Create a new project to execute the Sample Code 3 on MARS.
- Observe any change in memory and registers.

## Assignment 1

Write an assembly program to print out the sum of two register $s0 and $s1 according to the following format:

“The sum of (*content of $s0*) and (*content of $s1*) is (*result*)”.

## Assignment 2

Write an assembly program that gets a string from the input dialog and then print out the string length to the message dialog.

## Assignment 3

Write an assembly program that lets user input a string and then prints out the string on the console in the reversed order. The input process will be terminated when user presses the *Enter* key or the string length exceeds 15 characters.

## Homework

Write a program that multiplies two 32-bit unsigned integers (**X**, **Y**) and then prints out the 64-bit product (**Z**) on the console. The sample ouput should follow this format:

"The multiplication of **X** (base 10) and **Y** (base 10) is **Z** (base 10)."

"The multiplication of **X'** (base 16) and **Y'** (base 16) is **Z'** (base 16)."