Computer Organization

Lab1 Introduction

2021 Spring term

wangw6@sustech.edu.cn

contact

- Sakai site:
  - CS202- spring2021
- QQ group:
  - 389296479

Assignments Submission Rules

- All assignments must **be submitted to Sakai** site, any other forms of submission are not accepted.
- If the submission is **delayed for one day**, **20% discount** on the total score. If it is **delayed for more than a week**, any submission is **NOT ACCEPTABLE**! **This assignment is 0 point**.
- In the case of plagiarism:

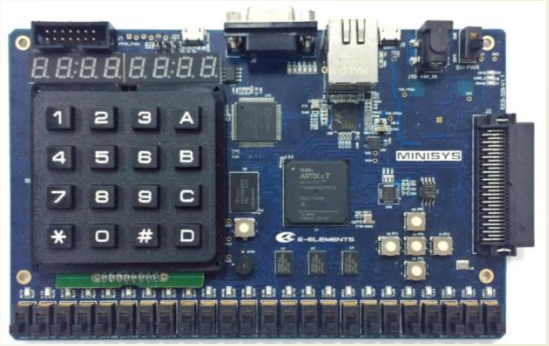
  at the 1st time, the assignment was 0 for all concerned students and at the 2nd time, the grade of the experimental course is 0 for all concerned students.
- Reminder:
  - Assignment scoring and the score publication would be completed within two weeks after the publication of assignment. **If you have any question about the score, please email the relevant reviewer in one week after the score publication**.

Experimental Suite

QtSpim /Mars, vivado & minisys board

- Learn and practice **MIPS** (QtSpim / Mars)

- Design and implement an **CPU**

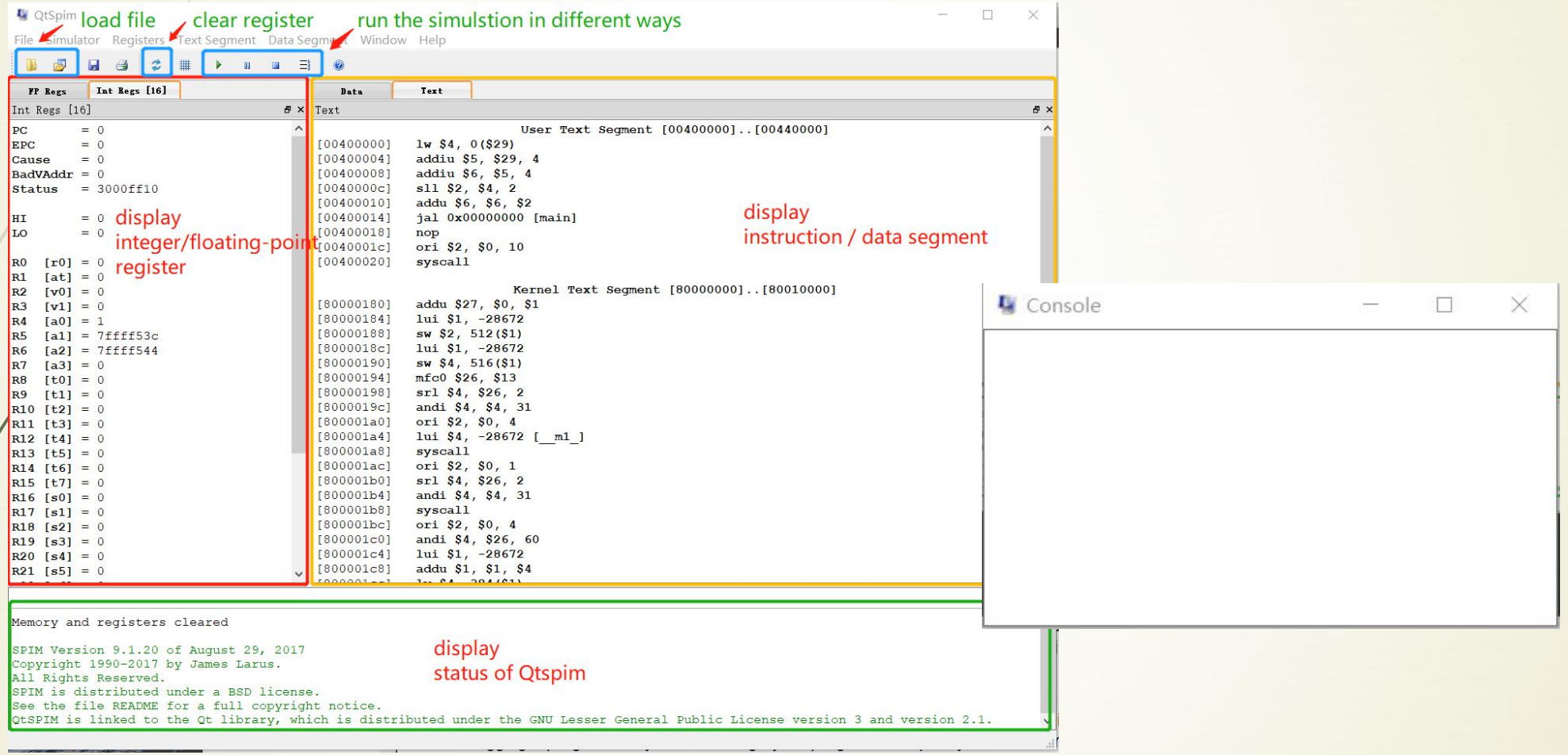


QtSpim（1）

- QtSpim http://spimsimulator.sourceforge.net/
  - **QtSpim** is the newest version of *Spim* that currently being actively maintained, runs on **Microsoft Windows, Mac OS X, and Linux**.
    - Spim , A self-contained simulator that runs MIPS32 program developed by Prof. James Larus from University of Wisconsin-Madison
  - *QtSpim* reads and executes programs written in **assembly language** for a **MIPS** computer. *QtSpim* **does not execute binary (compiled) programs**. To simplify programming, *QtSpim* provides a simple **debugger** and small set of **operating system services**
  - *QtSpim* implements **most of the MIPS32** assembler-extended instruction set. (It omits the floating point comparisons and rounding modes and the memory system page tables.) which means that *QtSpim* will not run programs for all MIPS processors.

Name	Modified	Size
qtspim_9.1.20_linux64.deb	2017-08-29	19.8 MB
QtSpim_9.1.20_mac.mpkg.zip	2017-08-29	12.4 MB
QtSpim_9.1.20_Windows.msi	2017-08-29	13.8 MB

QtSpim (2)


load file
clear register
run the simulstion in different ways
File Simulator Registers Text Segment Data Segment Window Help
FP Regs
Int Regs [16]
Int Regs [16]
PC = 0
EPC = 0
Cause = 0
BadVAddr = 0
Status = 3000ff10
HI = 0
LO = 0
R0 [r0] = 0
R1 [at] = 0
R2 [v0] = 0
R3 [v1] = 0
R4 [a0] = 1
R5 [a1] = 7ffff53c
R6 [a2] = 7ffff544
R7 [a3] = 0
R8 [t0] = 0
R9 [t1] = 0
R10 [t2] = 0
R11 [t3] = 0
R12 [t4] = 0
R13 [t5] = 0
R14 [t6] = 0
R15 [t7] = 0
R16 [s0] = 0
R17 [s1] = 0
R18 [s2] = 0
R19 [s3] = 0
R20 [s4] = 0
R21 [s5] = 0
display
integer/floating-point
register
Data
Text
Text
User Text Segment [00400000]..[00440000]
[00400000] lw $4, 0($29)
[00400004] addiu $5, $29, 4
[00400008] addiu $6, $5, 4
[0040000c] sll $2, $4, 2
[00400010] addu $6, $6, $2
[00400014] jal 0x00000000 [main]
[00400018] nop
[0040001c] ori $2, $0, 10
[00400020] syscall
Kernel Text Segment [80000000]..[80010000]
[80000180] addu $27, $0, $1
[80000184] lui $1, -28672
[80000188] sw $2, 512($1)
[8000018c] lui $1, -28672
[80000190] sw $4, 516($1)
[80000194] mfc0 $26, $13
[80000198] srl $4, $26, 2
[8000019c] andi $4, $4, 31
[800001a0] ori $2, $0, 4
[800001a4] lui $4, -28672 [__m1_]
[800001a8] syscall
[800001ac] ori $2, $0, 1
[800001b0] srl $4, $26, 2
[800001b4] andi $4, $4, 31
[800001b8] syscall
[800001bc] ori $2, $0, 4
[800001c0] andi $4, $26, 60
[800001c4] lui $1, -28672
[800001c8] addu $1, $1, $4
display
instruction / data segment
Console
Memory and registers cleared
SPIM Version 9.1.20 of August 29, 2017
Copyright 1990-2017 by James Larus.
All Rights Reserved.
SPIM is distributed under a BSD license.
See the file README for a full copyright notice.
QtSPIM is linked to the Qt library, which is distributed under the GNU Lesser General Public License version 3 and version 2.1.
display
status of Qtspim

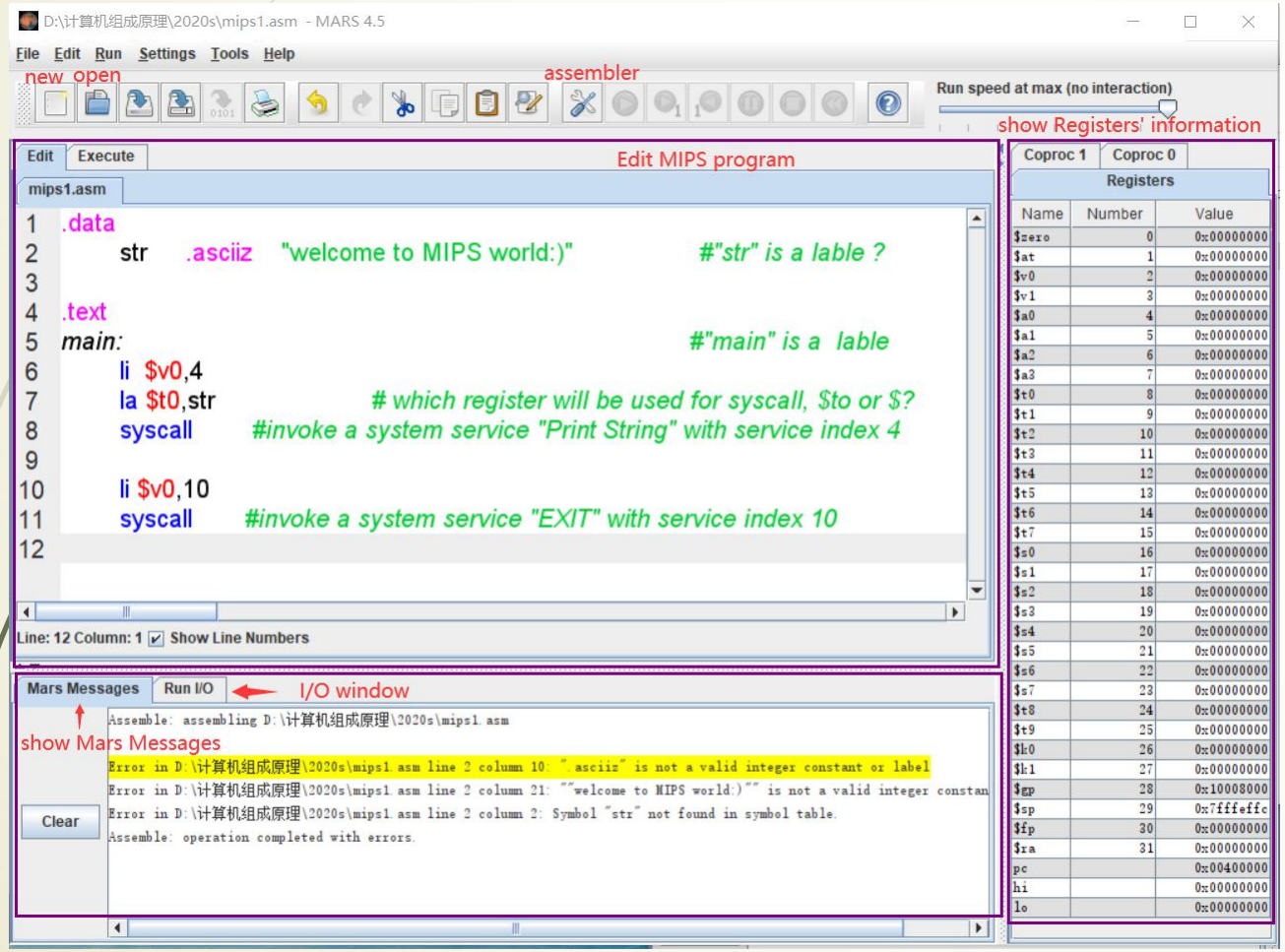
QtSpim（3）

Load file and Do the simulation

- Step1: loading a file (assembly code file usually have the extension ".s")
  - Open file : **File->Load File** or **File ->Reinitialize and Load File**
  - Tips:
    - Reinitialize and Load File : Clears all the changes made by a program, deleting all of its instructions, then reload the last file
    - Before doing the simulation, make sure clear registers ,you can do it by : Simulator->Clear Registers or tools
- Step2:
  - Run file : **Simulator->Run / Continue**
  - The value of register in left window will be refreshed, the program's output will appear in the Console window.

Mars(1)

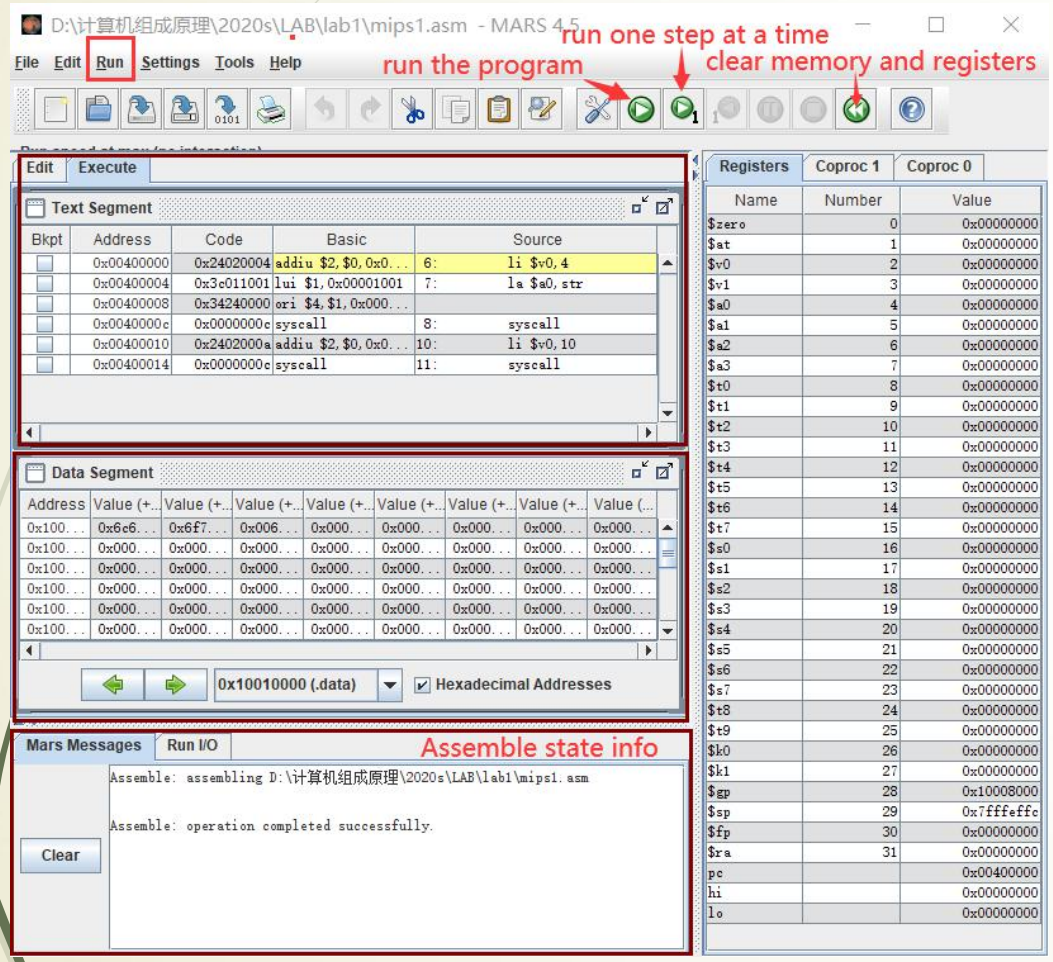
http://courses.missouristate.edu/kenvollmar/mars/download.htm

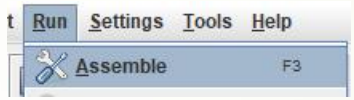


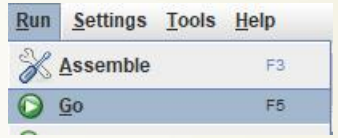
MARS is a **lightweight** interactive development environment (**IDE**) for programming in **MIPS** assembly language, intended for educational-level use with Patterson and Hennessy's Computer Organization and Design.

MARS requires Java J2SE 1.5 (or later) SDK installed on your computer.

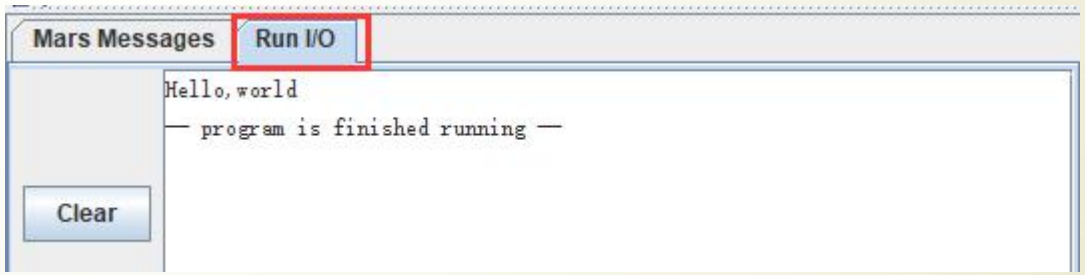
Mars(2)


D:\计算机组成原理\2020s\LAB\lab1\mips1.asm - MARS 4.5
File Edit Run Settings Tools Help
run one step at a time
run the program
clear memory and registers
Edit Execute
Text Segment
Bkpt Address Code Basic Source
0x00400000 0x24020004 addiu $2, $0, 0x0... 6: li $v0, 4
0x00400004 0x3c011001 lui $1, 0x00001001 7: la $a0, str
0x00400008 0x34240000 ori $4, $1, 0x000...
0x0040000c 0x0000000c syscall 8: syscall
0x00400010 0x2402000a addiu $2, $0, 0x0... 10: li $v0, 10
0x00400014 0x0000000c syscall 11: syscall
Data Segment
Address Value (+... Value (+... Value (+... Value (+... Value (+... Value (+... Value (+... Value (...
0x100... 0x6c6... 0x6f7... 0x006... 0x000... 0x000... 0x000... 0x000... 0x000...
0x10010000 (.data)
Hexadecimal Addresses
Mars Messages Run I/O
Assemble state info
Assemble: assembling D:\计算机组成原理\2020s\LAB\lab1\mips1.asm
Assemble: operation completed successfully.
Clear
Registers Coproc 1 Coproc 0
Name Number Value
$zero 0 0x00000000
$at 1 0x00000000
$v0 2 0x00000000
$v1 3 0x00000000
$a0 4 0x00000000
$a1 5 0x00000000
$a2 6 0x00000000
$a3 7 0x00000000
$t0 8 0x00000000
$t1 9 0x00000000
$t2 10 0x00000000
$t3 11 0x00000000
$t4 12 0x00000000
$t5 13 0x00000000
$t6 14 0x00000000
$t7 15 0x00000000
$s0 16 0x00000000
$s1 17 0x00000000
$s2 18 0x00000000
$s3 19 0x00000000
$s4 20 0x00000000
$s5 21 0x00000000
$s6 22 0x00000000
$s7 23 0x00000000
$t8 24 0x00000000
$t9 25 0x00000000
$k0 26 0x00000000
$k1 27 0x00000000
$gp 28 0x10008000
$sp 29 0x7fffeffc
$fp 30 0x00000000
$ra 31 0x00000000
pc 0x00400000
hi 0x00000000
lo 0x00000000


Run Settings Tools Help
Assemble F3


Run Settings Tools Help
Assemble F3
Go F5


Mars Messages Run I/O
Assemble: assembling D:\计算机组成原理\2020s\LAB\lab1\mips1.asm
Assemble: operation completed successfully.
Go: running mips1.asm
Go: execution completed successfully.
Clear


Mars Messages Run I/O
Hello, world
— program is finished running —
Clear

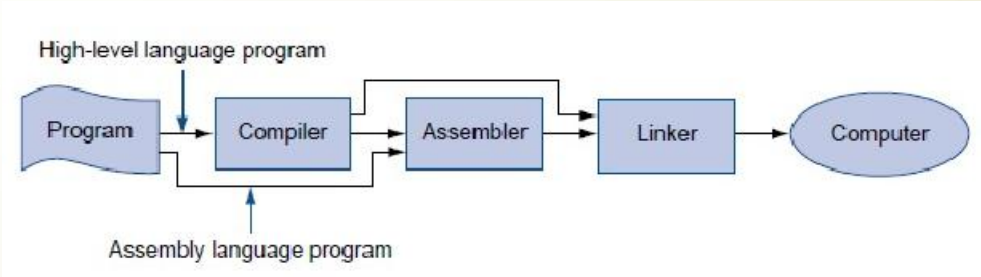
Assembly Language Overview

- Assembly language
  - The main body of assembly language is assembly instruction. Assembly instructions and machine instructions differ in instruction expression. Assembly instruction is a human-friendly writing format of machine instruction. Assembly language is the mnemonic of machine language.
    - For example

      machine instruction "1000100111011000" means that send the contents of register BX to AX.

      The assembly instructions are written as "mov ax, bx".

      Such writing is similar to human language and easy to read and remember.
  - Feature : programs written in assembly language are inherently machine-specific and must be totally rewritten to run on another computer architecture
  - CISC (intel x86) vs RISC (ARM , MIPS)



Assembly Program Structure

- Program Structure
  - data declarations, program code
  - data declaration section followed by program code section
- **Data** Declarations
  - placed in section of program identified with assembler directive .data
  - declare variable names used in program; storage allocated in main memory (RAM)
- **Code**
  - placed in section of text identified with assembler directive .text
  - contains program code (instructions)
  - starting point for code e.g .ecution given label main:
  - ending point of main code should use exit system call (see below in "System Calls" part)
- Comments
  - anything following # on a line
    # This stuff would be consideredd as comment

```
# Comment giving name of program and description of function
# Template.s
# Bare-bones outline of MIPS assembly language program

            .data       # variable declarations follow this line
                        # ...

            .text       # instructions follow this line

main:                   # indicates start of code (first instruction to execute)
                        # ...

# End of program, leave a blank line afterwards to make SPIM happy
```

System Calls

- **System Calls**
  - SPIM provides a small set of operating-system-like services through the system call (syscall) instruction.
  - To request a service, a program loads the system call code into register $v0 and arguments into registers $a0 $a3 (or $f12 for floating-point values).
  - System calls that return values put their results in register $v0 (or $f0 for floating-point results).

Service	System call code	Arguments	Result
print_int	1	$a0 = integer	
print_float	2	$f12 = float	
print_double	3	$f12 = double	
print_string	4	$a0 = string	
read_int	5		integer (in $v0)
read_float	6		float (in $f0)
read_double	7		double (in $f0)
read_string	8	$a0 = buffer, $a1 = length	
sbrk	9	$a0 = amount	address (in $v0)
exit	10		
print_char	11	$a0 = char	
read_char	12		char (in $v0)
open	13	$a0 = filename (string), $a1 = flags, $a2 = mode	file descriptor (in $v0)
read	14	$a0 = file descriptor, $a1 = buffer, $a2 = length	num chars read (in $v0)
write	15	$a0 = file descriptor, $a1 = buffer, $a2 = length	num chars written (in $v0)
close	16	$a0 = file descriptor	
exit2	17	$a0 = result	

Practice & think

- 1. **Install QtSpim/Mars on your PC and refer to the help page to find:**
  - Which version of MIPS does the simulator support?
  - Is the function of 'syscall' in Qtspim the same with Mars?
  - What's the name and ID of the registers used while invoke the "print string" syscall?
- 2. **Make an assembly file, load and run it by QtSpim/Mars:**
  - The assembly code should get your ID and name, and print them out
  - Is there any object file or executable file generated while doing the simulation?
  - (Optional) What's the Machine code of the MIPS instruction "li $v0,4"
- 3. (Optional**) Find an assembler for MIPS from the Internet**, use it to assemble the code of question 2 to generate an executable file, Can the executable file run on your computer and why?

A demo

```
#    text segment
     .text
     .globl main
main:                   # execution starts here
     la $a0,str         # put string address into a0
     li $v0,4           # system call to print
    syscall
     li $v0,10
    syscall             # system call to exit
#data segment
    .data

str:    .asciiz "hello Internet\n"
```