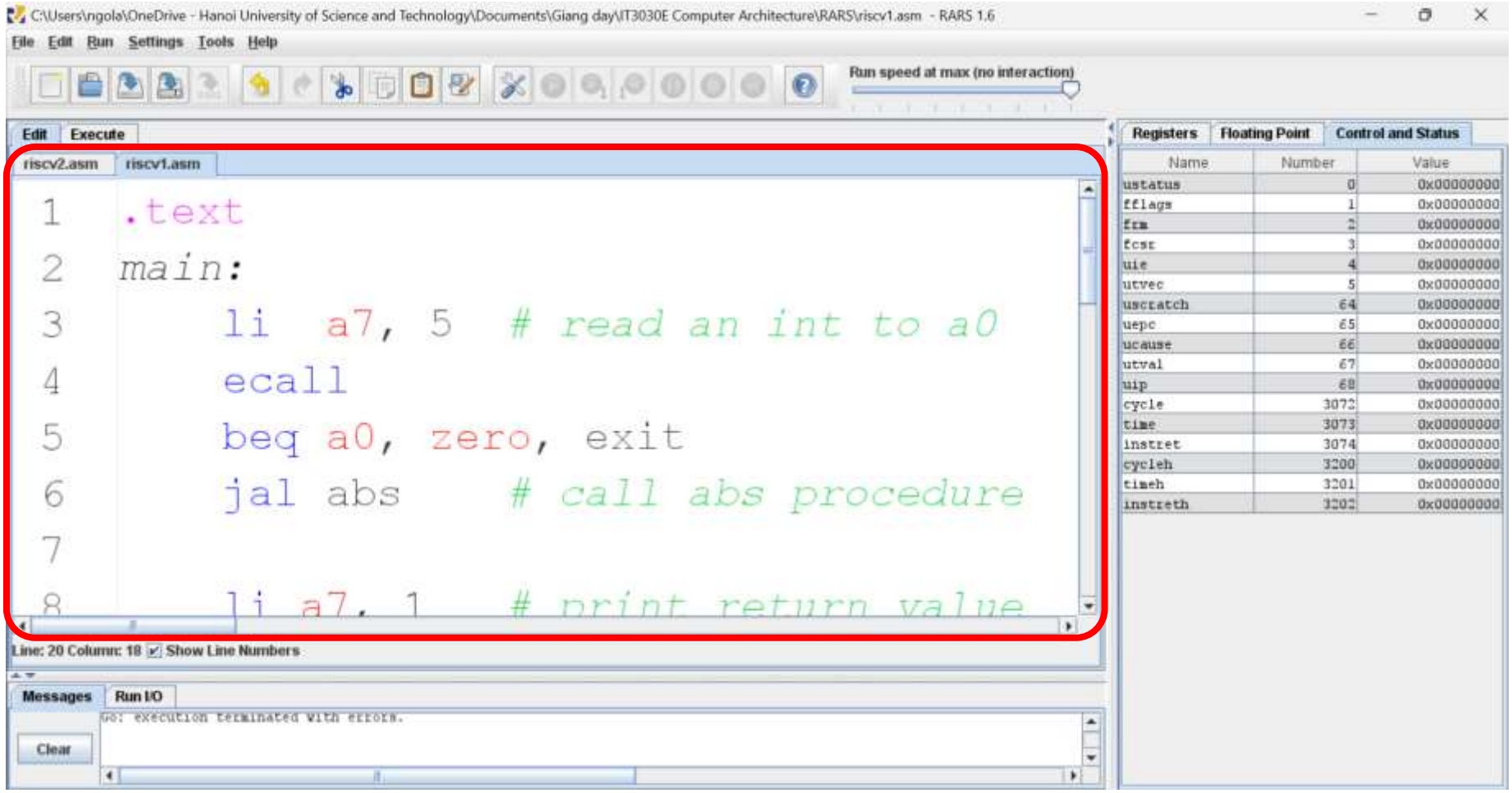
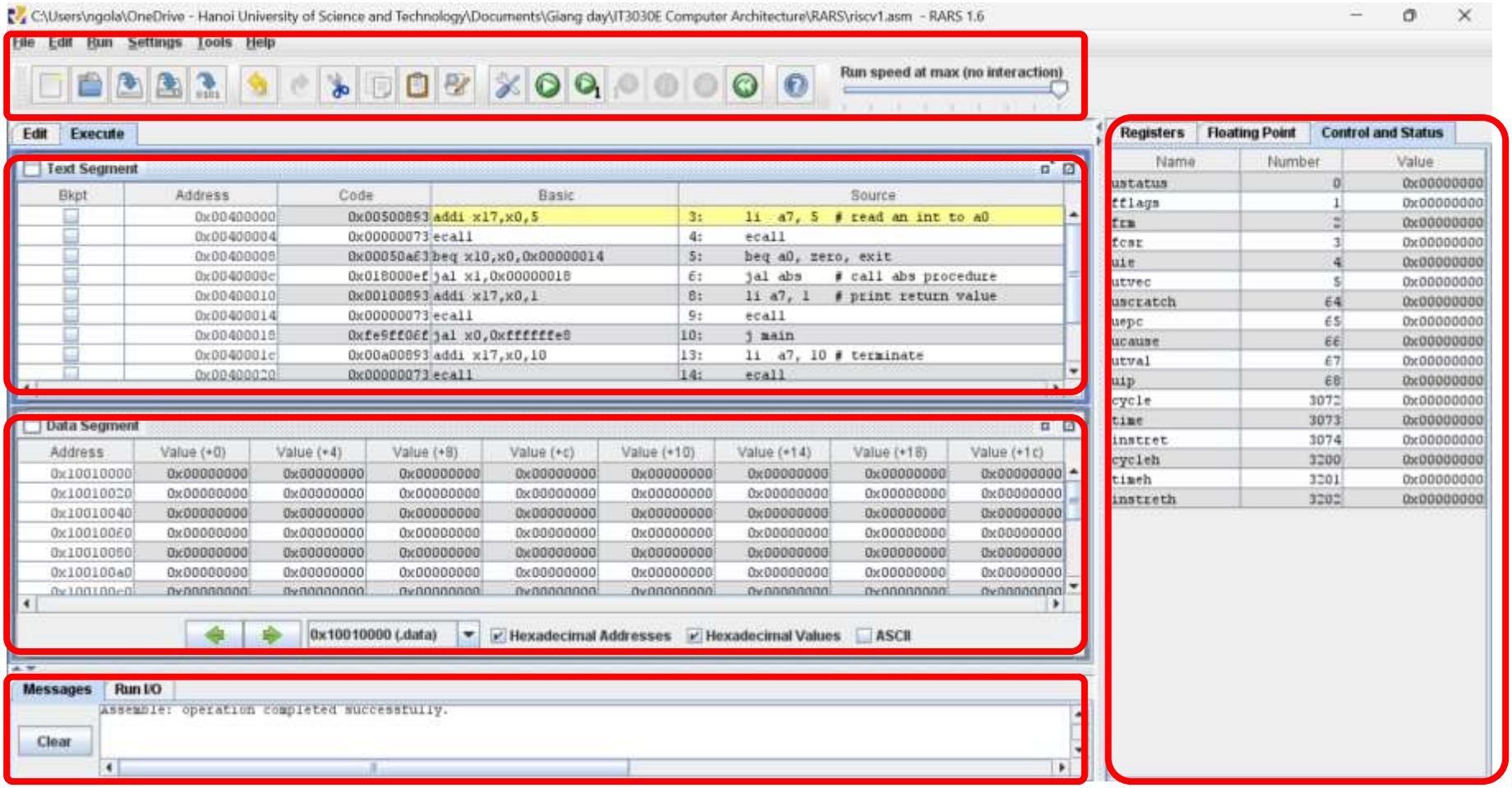
Exercise
Chapter 3. Instruction Set Architecture

RARS 1.6 Introduction

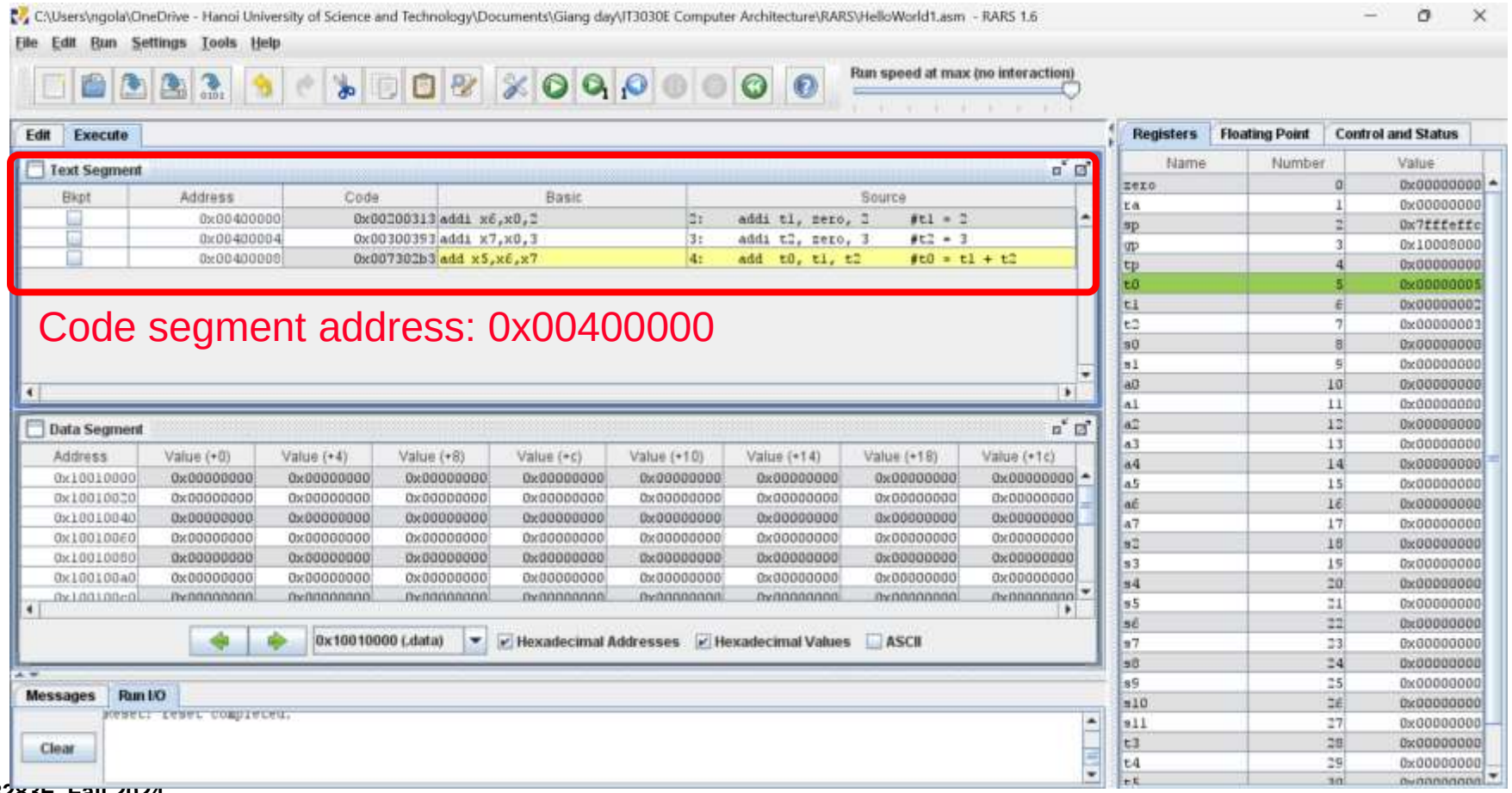


RARS 1.6 Introduction



Hello World 1

```
.text  #Code segment to store instructions
   addi t1, zero, 2     # t1 = 2
   addi t2, zero, 3     # t2 = 3
   add  t0, t1, t2      # t0 = t1 + t2
```



Directives

- Instruct assembler to allocate program objects.
- Program structure

  .text: store objects in the code segment (instructions)

  .data: store objects in data segment (static variables)
- Variable declaration (allocation)

  .byte/.half/.word: store listed values as bytes/halfs/words

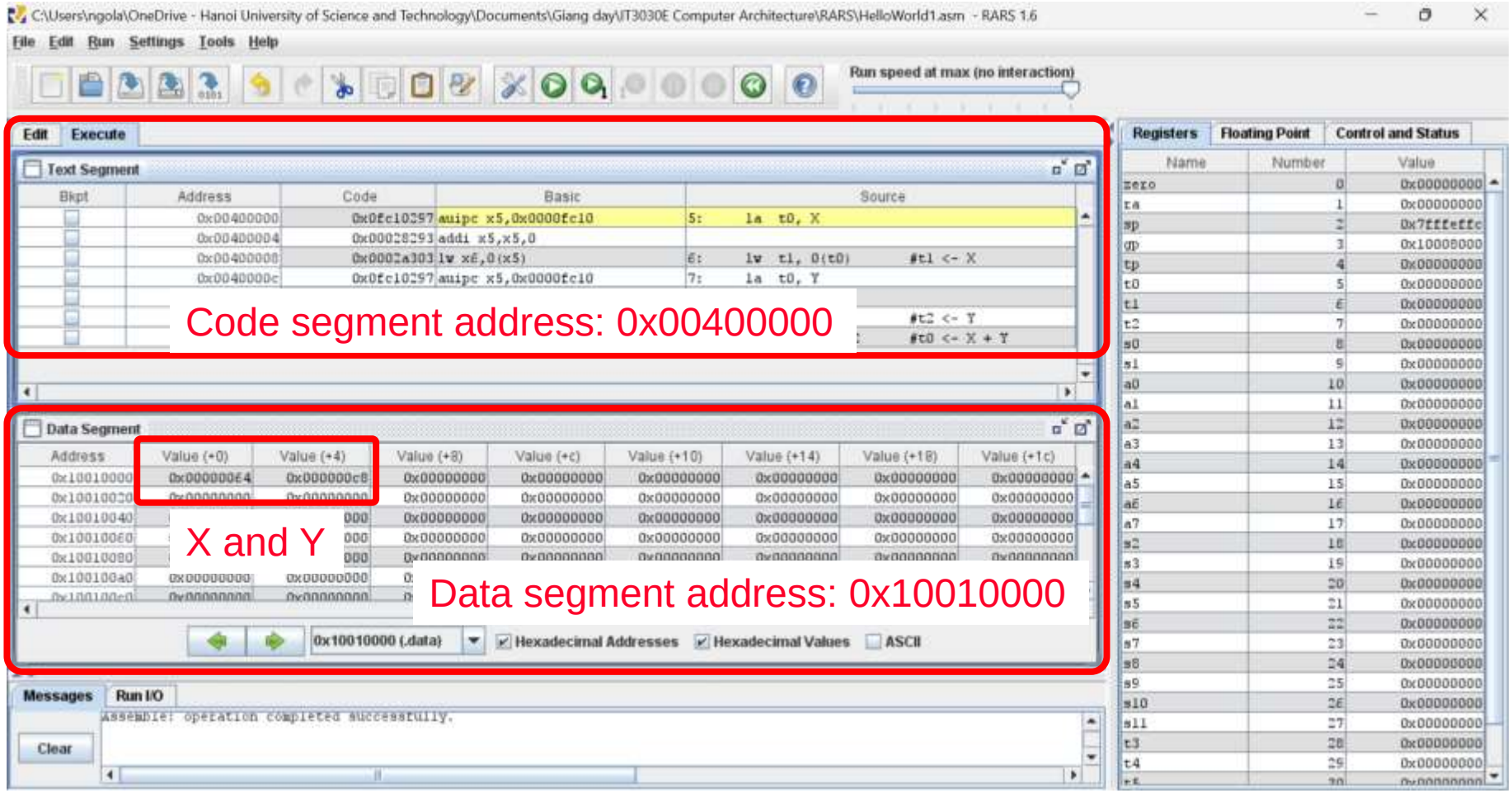
  .ascii/.asciz: string and null-terminated string

  .space: reserved specified number of bytes
- List of directives: see **RARS 1.6 Help**

Hello World 2

```
.data #Data segment to store variables
      X: .word 100
      Y: .word 200
.text #Code segment to store instructions
      la   t0, X
      lw   t1, 0(t0)        #t1 <- X
      la   t0, Y
      lw   t2, 0(t0)        #t2 <- Y
      add t0, t1, t2        #t0 <- X + Y
```

Hello World 1



Exercise

- Draw the map of this data segment

```
.data
        arr16: .space 16
        arr: .byte 'a','b','c'
        st1: .asciz "abcd"
        X1: .word 0xFFFFFFFF
        st2: .ascii "efgh"
        X2: .word 0xFFFFFFFF
        st3: .asciz "1234"
        X3: .word 0xFFFFFFFF
        st4: .asciz "5678"
        X4: .word 0xFFFFFFFF
```

Data segment map

Data Segment

Address	Value (+0)	Value (+4)	Value (+8)	Value (+c)	Value (+10)	Value (+14)	Value (+18)	Value (+1c)
0x10010000	0x00000000	0x00000000	0x00000000	0x00000000	0x61636261	0x00646362	0xffffffff	0x68676665
0x10010020	0xffffffff	0x34333231	0x00000000	0xffffffff	0x38373635	0x00000000	0xffffffff	0x00000000
0x10010040	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000
0x10010060	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000
0x10010080	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000
0x100100a0	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000
0x100100c0	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000	0x00000000

0x10010000 (.data) ☑ Hexadecimal Addresses ☑ Hexadecimal Values ☐ ASCII

Data Segment

Address	Value (+0)	Value (+4)	Value (+8)	Value (+c)	Value (+10)	Value (+14)	Value (+18)	Value (+1c)
0x10010000	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	a c b a	\0 d c b	. . . .	h g f e
0x10010020	. . . .	4 3 2 1	\0 \0 \0 \0	. . . .	8 7 6 5	\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	\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	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0
0x10010080	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0
0x100100a0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0
0x100100c0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0	\0 \0 \0 \0

0x10010000 (.data) ☑ Hexadecimal Addresses ☑ Hexadecimal Values ☑ ASCII

Exercise 3.1

- 1.1: Write the RISC-V assembly code equivalent to the following C statement.

f = g + (h − 5);

- Assume that the variables f, g, and h, have already been placed/allocated in registers x5, x6, and x7 respectively.
- Note: a minimal number of RISC-V instructions should be used.
- 1.2: Write a complete assembly program that
  - Declares integer variables f, g, h.
  - Initialize values for f, g, h.
  - Calculate and do the assignment: f = g + (h – 5)

```
.data
      f:.word 0
      g:.word 100
      h:.word 300
.text
      la x8, h
      lw x7, 0(x8)     #load h to x7
      la x8, g
      lw x6, 0(x8)     #load g to x6
      addi x7, x7, -5
      add x5, x6, x7   #calculate
      la x8, f
      sw x5, 0(x8)     #store to f
```

Exercise 3.2

- 2.1 Write the RISC-V assembly code equivalent to the below C statement.

B[4] = A[i-j];

- Assume that the variables i, and j are allocated in registers x28, and x29 respectively. A and B are two integer array, with the base address of A and B are in registers x10 and x11 respectively.
- 2.2 Write the complete program in RARS 1.6 that
  - Declares two integer arrays A and B with at least 6 elements for each array.
  - Do the operation B[4] = A[i-j]; with i and j in x28 and x29.

```
.data
      A:.space 100     #25x4-byte integers each
      B:.space 100

.text
      la a0, A
      la a1, B
      li t0, 100
      sw t0, 0(a0)     #initialize A[0]=100
      sub t3, t3, t4   #i-j, now i and j are both 0
      slli t4, t3, 2   #offset of A[i-j]
      add a0, a0, t4   #a0 hold addr A[i-j]
      lw  t5, 0(a0)    #load A[i-j]
      sw  t5, 32(a1)   #store to B[8]
```

Exercise 3.3

- Reverse-compile the following RISC-V assembly code to the equivalent C code. Assume that the variables f, g, h, i, and j are allocated at registers x5, x6, x7, x28, and x29, respectively, and the base address of the arrays A and B are in registers x10 and x11.

```
        slli x30, x5, 2
        add x30, x10, x30
        slli x31, x6, 2
        add x31, x11, x31
        lw x5, 0(x30)
        addi x12, x30, 8
        lw x30, 0(x12)
    add x30, x30, x5
    lw x30, 0(x31)
```

Exercise 3.4

- Find the format and the machine code of the following instruction:

  sw x5, 32(x30)

RISC-V system services (syscall)

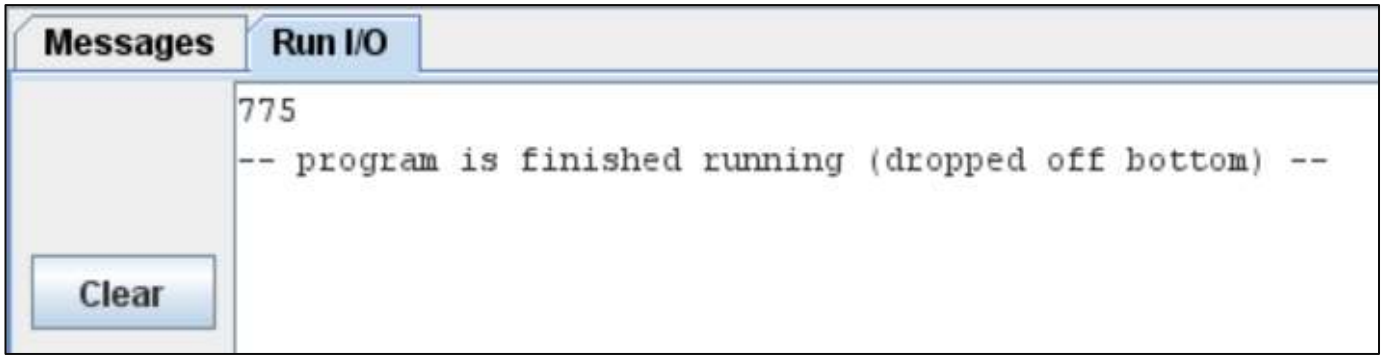
- Basic input/output services provided by RISC-V system.
  - Print string, print character, print integer/floating point to output console.
  - Read string, char, int, float/double from input console.
  - Other function: random, dialog,…
- Usage:
  - Step 1. Load the service number in register a7.
  - Step 2. Load argument values, if any, in a0, a1, a2, a3, fa0, ... as specified.
  - Step 3. Issue the ECALL instruction.
  - Step 4. Retrieve return values, if any, from result registers as specified
- List of system services: see **RARS 1.6 Help**

System service: print integer

- Input params:
  - a7 = 1
  - a0 = [integer value to print].
- Example:

```
li a7, 1
li a0, 0x307
ecall
```

- Result:

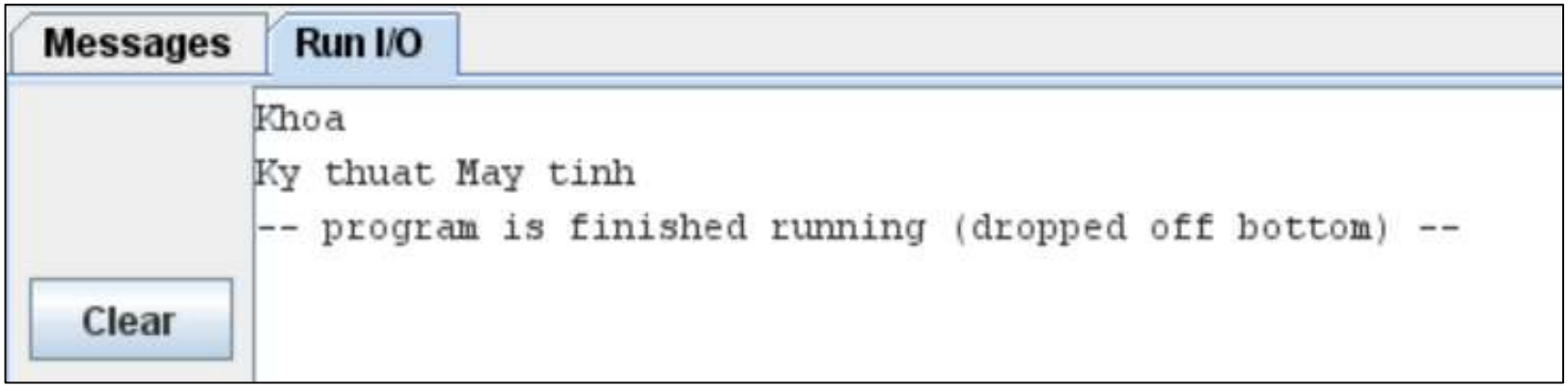


System service: print string

- Input params:
  - a7 = 4
  - a0 = address of the string to print
- Example:

```
.data
message: .asciz "Khoa \nKy thuat May tinh"
.text
   li a7, 4
   la a0, message
   ecall
```

- Result



System service: read integer

- Input params
  - a7 = 5
- Return
  - a0 = integer value read
- Example:

```
li a7, 5
ecall
```

- Result: try run the above code on RARS 1.6
  - The ecall instruction activates the input caret at the in/out console waiting for user input.
  - User types in an integer and press Enter → the integer is loaded to a0.

Hello World 3

- Write a program
  - Print “Hello!” to console
  - Wait for user to press any key
  - Print “Have a good day!”

```
#simple syscall example for input/output
.data
   #this is where we declare variables
   hello: .asciz "Hello!\n"
   goodday: .asciz "Have a good day!\n"
.text
main:
    #this is where our code goes
    #print hello string
    li  a7, 4
    la  a0, hello
    ecall
    #wait for user to press on keyboard
    li  a7, 12
    ecall
    #then say good day
    li  a7, 4
    la  a0, goodday
    ecall
endmain:
```

Exercise 3.5

- Write a program to:
  - Input an integer X from console
  - Output to screen the appropriate string:
    - “odd” if X is an odd number
    - “even” if X is an even number

Exercise 3.6

- 1. Write a subprogram/function to:
  - Get an integer X as input argument
  - Output the absolute value of X
- 2. Use the above function to write a program that reads an input integer from input console, then calculate and display the absolute value of that integer.
- 3. Modify the above program so that it repeats the above process continuously until it reads the value 0 from input console.

```
.text
main:
    li  a7, 5                   # read an int to a0
    ecall
    beq a0, zero, exit          # exit if input = 0
    jal abs                     # call abs procedure
    li a7, 1                    # print return value
    ecall
    j main
exit: li  a7, 10                # terminate, WHY is this necessary?
    ecall                       # see system service 10
end_main:

abs: bge a0, zero, done  # if a0>=0 done
    sub a0, zero, a0          # else negate a0
done:
    jr  ra
```

Exercise 3.7

- Write a program to read a positive value n from console, then calculate and print the sum of all numbers from 1 to n.
- Implement the function of calculate sum as a procedure with below parameters:
  - a7: n (upper boundary)
  - a0: return value of (1+2+..+n)

Exercise 3.8

- Develop a simple implementation of the strlen() function

size_t **strlen**(const char *str)

- Write a program to input a string (max of 255 chars), then print out its length