

Assignment 7, Part A

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1

Independent

2

Write a RISC-V assembly function to search a specified integer in an integer array. The function should take the base address of the array, the number of elements in the array, and the specified integer as function arguments. The function should return the index number of the first array entry that holds the specified value. If no array element is the specified value, it should return the value -1.

```
1 # a0 is the base of the array.
2 # a1 is the number of elements in the array.
3 # a2 is the number that the function searches for.
4
5 # The function returns the index in a0 (if found), otherwise
6   -1.
7
8 find_int:
9     addi t0, x0, 1 # t0 is 1.
10    if:
11        blt a1, t0, return_1 # If size < 1 return -1
12    add t0, a0, x0 # t0 is a pointer to a0.
13    slli t3, a1, 2 # t3 is the size of the array in bytes.
14    add t1, a0, t3 # t1 is a pointer to the last element of
15                      the array.
16
17    loop:
18        blt t1, t0, return_1 # t1 < t0
19        lw t2, 0(t0) # t2 = *t0
20        if_equal:
21            beq t2, a2, return_found # If t2 == a2
22                                     return the index.
23        addi t0, t0, 4 # t0++
24        jal x0, loop
25
26    return_found:
27        sub a0, t0, a0 # Calculate the index.
28        srai a0, a0, 2
29        jalr x0, x1, 0
30
31    return_1:
32        addi a0, x0, -1 # Return -1.
33        jalr x0, x1, 0
```

3

Consider a RISC-V assembly function `func1`. `func1` has three passing arguments stored in registers `a0`, `a1` and `a2`, uses temporary registers `t0-t3` and saved registers `s4-s10`. `func1` needs to call `func2` and other functions may call `func1` also. `func2` has two passing arguments stored in registers `a0` and `a1`, respectively. In `func1`, after the program returns to `func1` from `func2`, the code needs the original values stored in registers `t1` and `a0` before it calls `func2`.

- a. Ten words need to be stored in the stack.
- b. `func1` needs to store the values inside `a0`, `t1`, `s4-s10`, `ra` in the stack.

4

Implement the C code snippet in RISC-V assembly language. Use s0 and s1 to hold the variable i, and min_idx in the function selectionSort. Be sure to handle the stack pointer appropriately. Clearly comment on your code.

a)

```
1 # selectionSort takes a0 (base address) and a1 (number of
   elements).
2     selectionSort:
3         # s0 is i
4         # s1 is min_idx
5         # s2 is a0 or arr[]
6         # s3 is a1 or n
7         # s4 is n - 1
8
9         # Save the s and ra registers into the
           stack:
10        addi sp, sp, -24
11        sw s0, 0(sp)
12        sw s1, 4(sp)
13        sw s2, 8(sp)
14        sw s3, 12(sp)
15        sw s4, 16(sp)
16        sw ra, 20(sp)
17
18        # Store a0 and a1:
19        add s2, a0, zero
20        add s3, a1, zero
21
22        # Sort the array:
23        addi s4, a1, -1 # pass n - 1
24        add s0, zero, zero # i = 0
25        for:
26            bge s0, s4, end_loop # i >= n - 1
                goto end_loop
27
28            # Call findMinimum function:
29            slli t0, s0, 2 # i * 4
30            add a0, s2, t0 # pass &array[i] to
                a0
31            sub a1, s3, s0 # pass n - i
32            jal ra, findMinimum
33
34            # Set min_idx to the value in a0:
```

```

35         add s1, a0, zero
36
37     if_swap:
38         beq s1, zero, continue #
39             min_idx == 0 goto continue
40
41         # Call the swap function:
42         add t0, s1, s0 # t0 = min_idx
43             + i
44         slli t0, t0, 2 # (min_idx + i)
45             * 4
46         add a0, s2, t0 # a0 =
47             &array[min_idx + i]
48         slli t0, s0, 2 # i * 4
49         add a1, s2, t0 # a1 = &array[i]
50         jal zero, swap # Call swap
51
52     continue:
53
54         # Increment i:
55         addi s0, s0, 1
56
57         # Jump to Loop:
58         jal zero, for
59
60     end_loop:
61
62         # Restore the s registers:
63         lw s0, 0(sp)
64         lw s1, 4(sp)
65         lw s2, 8(sp)
66         lw s3, 12(sp)
67         lw s4, 16(sp)
68         lw ra, 20(sp)
69
70         # Empty the stack:
71         addi sp, sp, 24
72
73         # Return:
74         jalr zero, ra, 0
75
76     # findMinimum takes a0 (base address) and a1 (number
77         of elements).
78     findMinimum:
79         # t0 is min_idx

```

```

75         # t1 is min_E
76
77     # Initialize min_idx and min_E:
78     add t0, zero, zero # min_idx = 0
79     add t2, a0, t0 # (a0 + min_idx)
80     lw t1, 0(t2) # t1 = array[a0 + min_idx * 4]
81
82     # Loop through the array:
83
84     # t3 is i
85     addi t3, zero, 1
86
87     for_loop_2:
88         # Condition:
89         bge t3, a1, end_loop_2 # i >= a0 goto
90             end_loop_2
91         # Body:
92         slli t4, t3, 2
93         add t4, a0, t4 # t4 = &array[i]
94
95         # t5 = arr[i]
96         lw t5, 0(t4)
97
98         if_2:
99             bge t5, t1, continue_2 # array[i]
100                 >= min_E goto continue_2
101             add t0, t3, zero # min_idx = i
102             slli t6, t0, 2 # min_idx * 4
103             add t6, a0, t6
104             lw t1, 0(t6) # t1 == array[i]
105
106         continue_2:
107
108         # Increment i:
109         addi t3, t3, 1
110
111         # Jump to Loop:
112         jal zero, for_loop_2
113
114     end_loop_2:
115     # Return min_idx:
116     add a0, t0, zero
117     # Return:
118     jalr zero, ra, 0

```

```

118      # swap takes a0 (address of first element) and a1
      (address of second element).
119      swap:
120          # t0 is temp
121          # t1 is temp_2
122
123          # Interchange the values:
124          lw t0, 0(a0) # temp = *a0
125          lw t1, 0(a1) # temp_2 = *a1
126          sw t1, 0(a0) # *a0 = temp_2
127          sw t0, 0(a1) # *a1 = temp
128
129          # Return:
130          jalr zero, ra, 0

```

b)

Assume that the selectionSort is the function called. Draw the status of the stack before calling selectionSort and during each function call. Indicate stack addresses and names of registers and variables stored on the stack; mark the location of sp; and clearly mark each stack frame. Assume the sp starts at 0x8000.

Before calling selectionSort:

<i>Addresses</i>	<i>Registers</i>	<i>Stack_Pointer</i>	<i>Variables</i>	<i>Stack_Frame</i>
0x8000	???	<i>SP</i>	???	*

During the first call to selectionSort. The stack remains the same for each iteration in the loop. Hence, for findMinimum and swap, the stack remains the same.

<i>Addresses</i>	<i>Registers</i>	<i>Stack_Pointer</i>	<i>Variables</i>	<i>Stack_Frame</i>
0x8000	???		???	
0x7FFC	<i>ra</i>		???	<i>selectionSort</i>
0x7FF8	<i>s4</i>		???	<i>selectionSort</i>
0x7FF4	<i>s3</i>		???	<i>selectionSort</i>
0x7FF0	<i>s2</i>		???	<i>selectionSort</i>
0x7FEC	<i>s1</i>		???	<i>selectionSort</i>
0x7FE8	<i>s0</i>	<i>SP</i>	???	<i>selectionSort</i>

After calling selectionSort:

<i>Addresses</i>	<i>Registers</i>	<i>Stack_Pointer</i>	<i>Variables</i>	<i>Stack_Frame</i>
0x8000	???	<i>SP</i>	???	*