COMP15111 Lab 2 – Control Structures

1.1 Aims

To practice converting simple Python statements into RISC-V assembly code.

1.2 Learning Outcomes

On successful completion of this exercise, you will:

- have used various techniques to program control flow with RISC-V assembly.
- translate Python code to RISC-V assembly.

1.3 Summary

Create a small arithmetic calculator that performs a number of basic operations.

1.4 Deadline

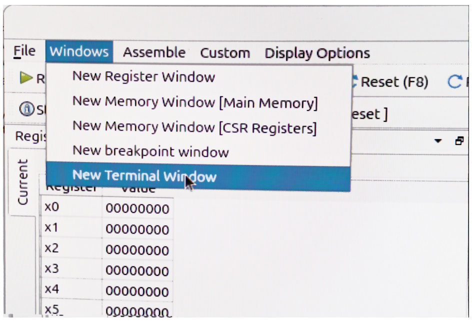
Each lab exercise has the usual deadline which is the Friday of the week after the current one. All of our deadlines are listed on the unit's landing page on Blackboard. *We encourage you to engage with this assignment long before the deadline*: a) this will allow you to use the lab sessions productively, b) you will be able to manage your time better (e.g. not having 2-3 deadlines at the same time), and c) you will be able to accommodate unexpected delays. You can submit earlier if you are ready.

Remember that you must tag your commits in the usual way to show that you completed your work by the deadline. The tag for this assignment is **Lab-2-Marking**

On Blackboard, there are specific instructions on how to use git and Bennett.

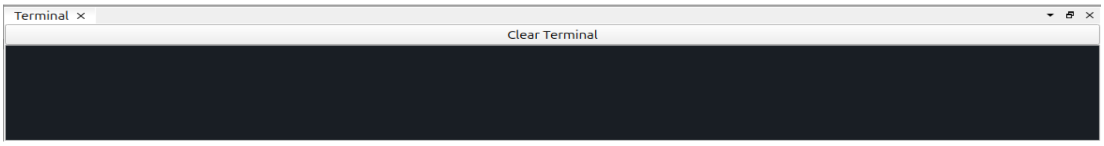
1.5 Description

As usual, we will use Bennett to run our programs. In case you are not familiar with Bennett, please revisit Lab 1.



Lab 2 consists of four parts, which require us to interact with Bennett by providing input and receiving output. In order to enable Input/Output functionality to Bennett, we need to enable its terminal by navigating the top menu bar by clicking Windows → New Terminal Window.

After you do that, you should see the terminal of Bennett at the bottom:



You can use the terminal, to provide input to Bennett as well as receive output from your running programs (via the **ecall** operations). It might be the case that the background colour is white or black; it does not make any difference. <u>You can reset the terminal by pressing "Clear Terminal" towards its top</u>.

Part 1 – Simple Addition Program

Your copy of the file "part1.s" contains the skeleton of a RISC-V program, with some pseudo-Python code in comments. The program outputs "Operand 1: " in the Terminal window, waits for you to type any decimal digit into the Terminal window, stores the number **corresponding** to that digit and prints it. Subsequently, it does the same for Operand 2. Finally, it prints "Result of Addition: " followed by the sum of the two operands.

Task (3 point): Edit the program (your .s file) to insert RISC-V instructions that are a translation of the pseudo-code in the comments.

The operands and the result must be stored in memory, in variables `op1`, `op2`, and `res`.

Note: You can find a list of all ecall operations in the handout of Video 11 ("RISC-V Leftovers").

If you open the .s file you will see some pseudo-Python code inside the file as a comment. You will need to provide the corresponding RISC-V instructions. When a comment refers explicitly to a register, e.g. x10, you should just use that register rather than a variable. Do not change any of the RISC-V instructions already in the program.

Hint 1: The assembler automatically translates character literals (e.g. 'c') into their ASCII code. Similarly, it converts strings (e.g. "Hello") into a sequence of bytes in memory where each byte is the ASCII code of the corresponding character.

Hint 2: The "return" (enter) character, that you use to change lines is the character '\n'.

Hint 3: The ASCII characters for decimal numbers ('0'-'9') are in a single ASCII block that starts with '0' and ends with '9'. A character is then a decimal digit if its code is in the range ['0', '9']. For the same reason, translating ASCII codes for decimal digits into numbers is straightforward. Ask us in the lab if you cannot figure it out.

Compile, load, reset and run your edited code; remember to check that there are no syntax errors. Test for these corner cases explicitly:

- What happens if the user tries to input non-digit characters, e.g. 'a'?
- What happens if the user gives '0' or '9'?
- What happens if the user sets both operands to 9?

If you get it right, the output should look like the one from the image below:

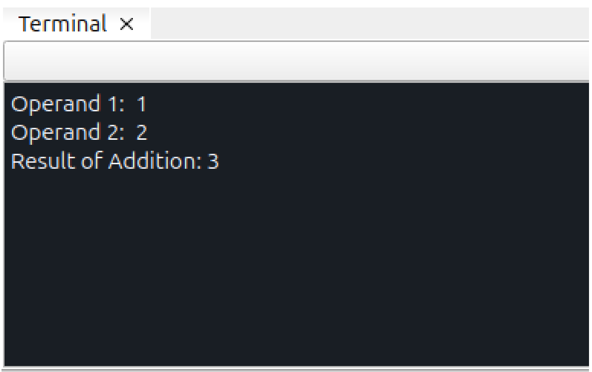


Figure 1: Simple Calculator doing only addition

Part 2 – Enhancing the calculator

First, copy your solution in **part1.s** into a new file called **part2.s**. This will be the starting point for your work in Part 2.

Task (2 points): Edit the program to: a) allow the user to select an operator (plus or minus) to apply on the operands, and b) apply the selected operator. If the user selects an operator that does not exist, the program should exit. The output should look like the ones below:

```
Terminal ×

Operand 1:  5
Operand 2:  3
Please Select Your Operation (+, -): -
Result of Operation: 2
```

Figure 2: Subtraction Example

```
Terminal ×

Operand 1:  2
Operand 2:  3
Please Select Your Operation (+, -): b
```

Figure 3: Invalid Operation Example

Part 3 – Continuous Operation

First, copy your solution in **part2.s** into a new file called **part3.s**. This will be the starting point for your work in Part 3.

Task (2 points): Edit the program to make it operate continuously until an exit character is entered. Turn the main body of the previous program into a loop and execute the STOP ecall <u>only when the user asks for the specific operation "e"</u>. If a non-existing operation is requested, the program ignores the operands and returns to the start of the loop. The output of the program should look like this:

```
Terminal ×

Operand 1:  2
Operand 2:  1
Please Select Your Operation (+, -, e): -
Result of Operation: 1
Operand 1:  6
Operand 2:  7
Please Select Your Operation (+, -, e): -
Result of Operation: -1
Operand 1:  0
Operand 2:  0
Please Select Your Operation (+, -, e): c
Operand 1:  1
Operand 2:  1
Please Select Your Operation (+, -, e): d
Operand 1:  1
Operand 2:  2
Please Select Your Operation (+, -, e): e
```

Figure 4: Executing in a loop, including a) producing negative results, b) inputing an invalid operation, c) ending the program

Part 4 – Optimise

Make your changes directly in **part3.s**. Your changes should not change the console output!

Task A (1 point): Edit the program to eliminate the use of temporary variables, including the ones used to store the operands and the result. Ideally, your only memory data after this should your strings.

Task B (1 point): Edit the program to minimise the number of control flow instructions (jumps and branches) inside the loop. The lowest number we have achieved is seven, including any instructions that return control to the start of the loop at the end of each iteration. You don't need to produce a perfect solution: eight instructions will get the full point, nine will get most of the point, ten will get something.

Task C (1 point): Edit the program to minimise the number of instructions executed inside the loop. Consider for example whether you actually need to reload some immediate values in every iteration. Each iteration applying an addition or a subtraction should take fewer than 55 steps to execute, to get the full mark. Our lowest count is currently 49, but it's probably possible to go lower.

You can calculate the number of steps it takes by comparing the steps counter (under the single step button) between two consecutive iterations of the program's main loop. For example, on the left below is a screenshot of Bennett when it stopped to wait for the first operand before the addition, while on the right is a screenshot when it stopped for the first operand after the addition (before the next operation). The steps counter changed from 18 to 67, so we executed 49 steps.

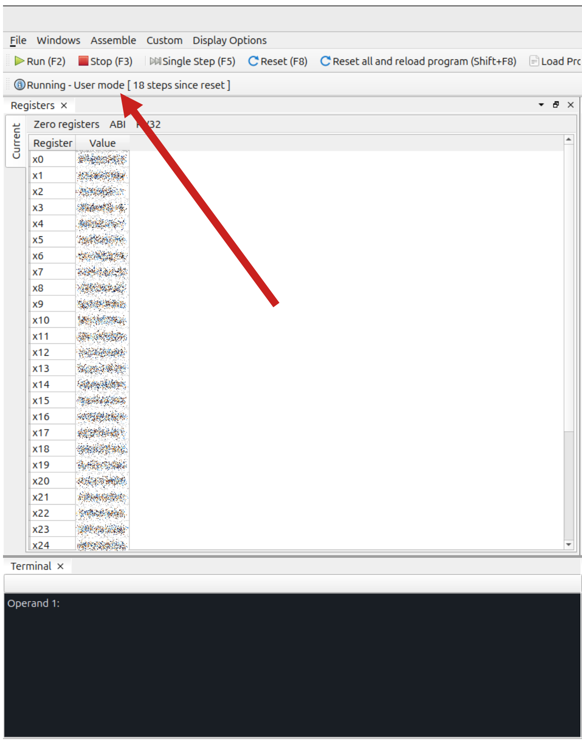


Figure 5: State of Bennett when the program stops to read the first input in the first iteration. Steps count is 18.

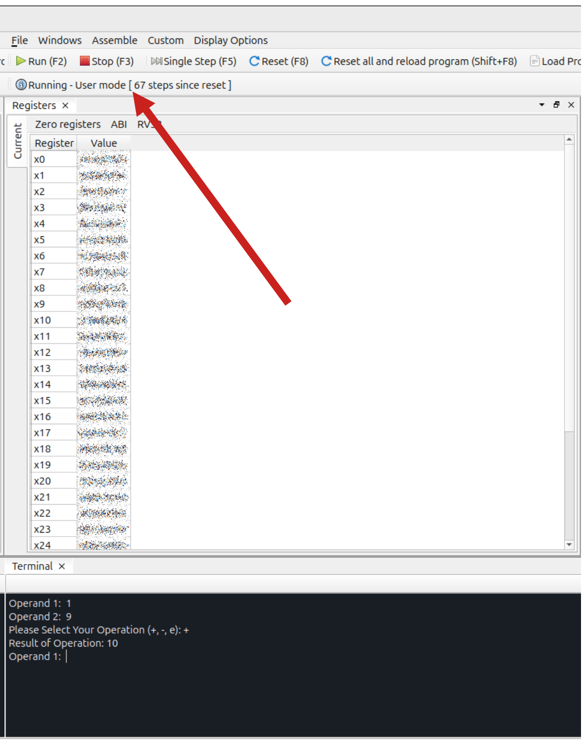


Figure 6: State of Bennett when the program stops to read the first input in the second iteration. Steps count is 67.

The output of the program should remain the same.

1.6 Completion, Feedback and Marking Process

The total mark for Lab 2 is 10 points. As soon as you have completed the exercise, you need to git commit and push to your repository your three files. Make sure that any new files you might create are added to the repository (git add).

We will mark all submissions within 2 weeks of the deadline. We will provide detailed feedback, which you will receive by email when we mark your submission. We will also discuss this assignment in a live session after the extended submission deadline.

File(s) to be committed to Gitlab

1. part1.s,
2. part2.s and
3. part3.s.