COMP2611: Computer Organization

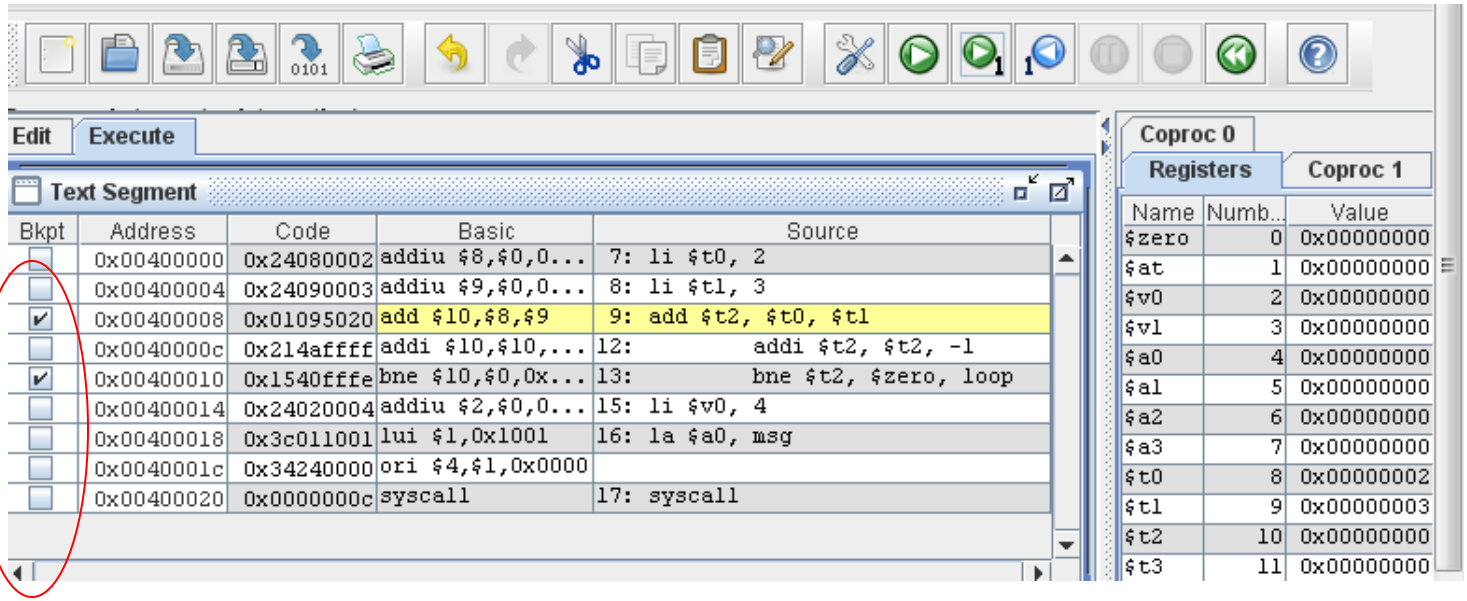
Debugging on MARS

Overview

- You will learn the following in this lab:
  - how to debug a MIPS program using the debugging features in MARS.

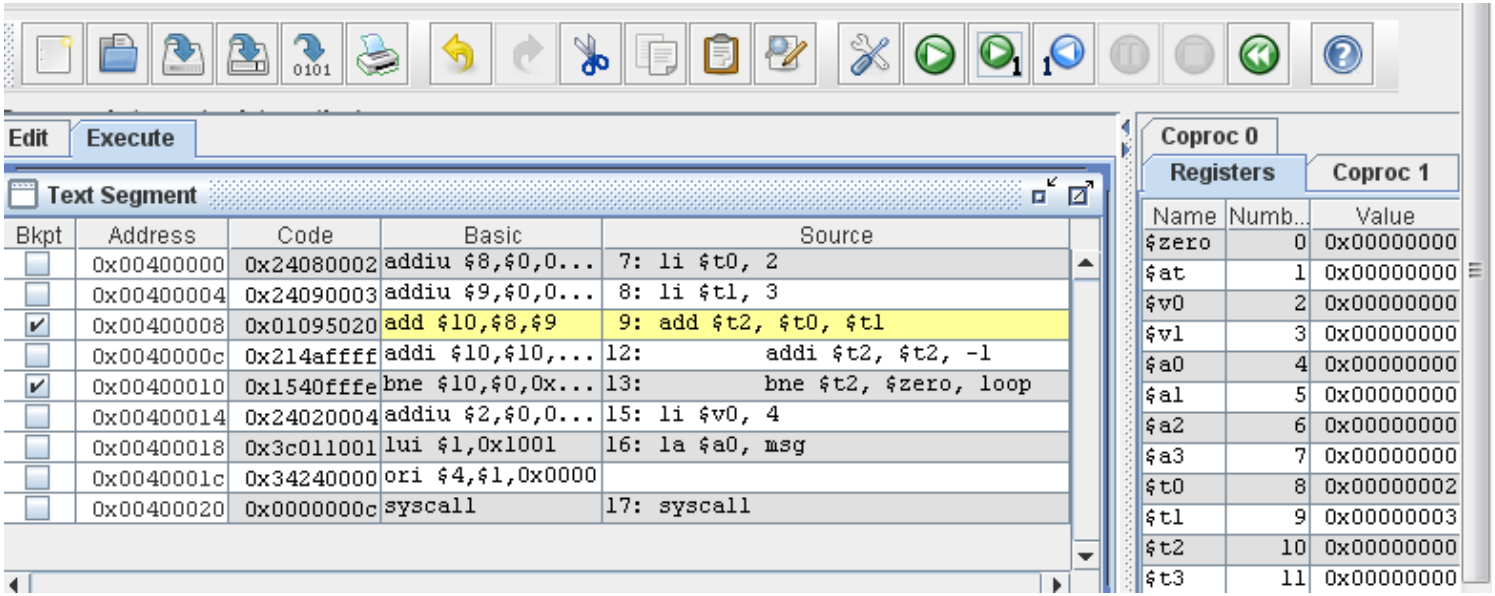
Tracing program execution

- MARS provides many debugging features:
  - Breakpoint -- pauses the execution at an instruction.
    - Click the box on the column "Bkpt" of an instruction to enable a breakpoint there.
    - All the instructions before the breakpoint were executed, and all the subsequent instructions, including the one at the breakpoint, are not executed yet.



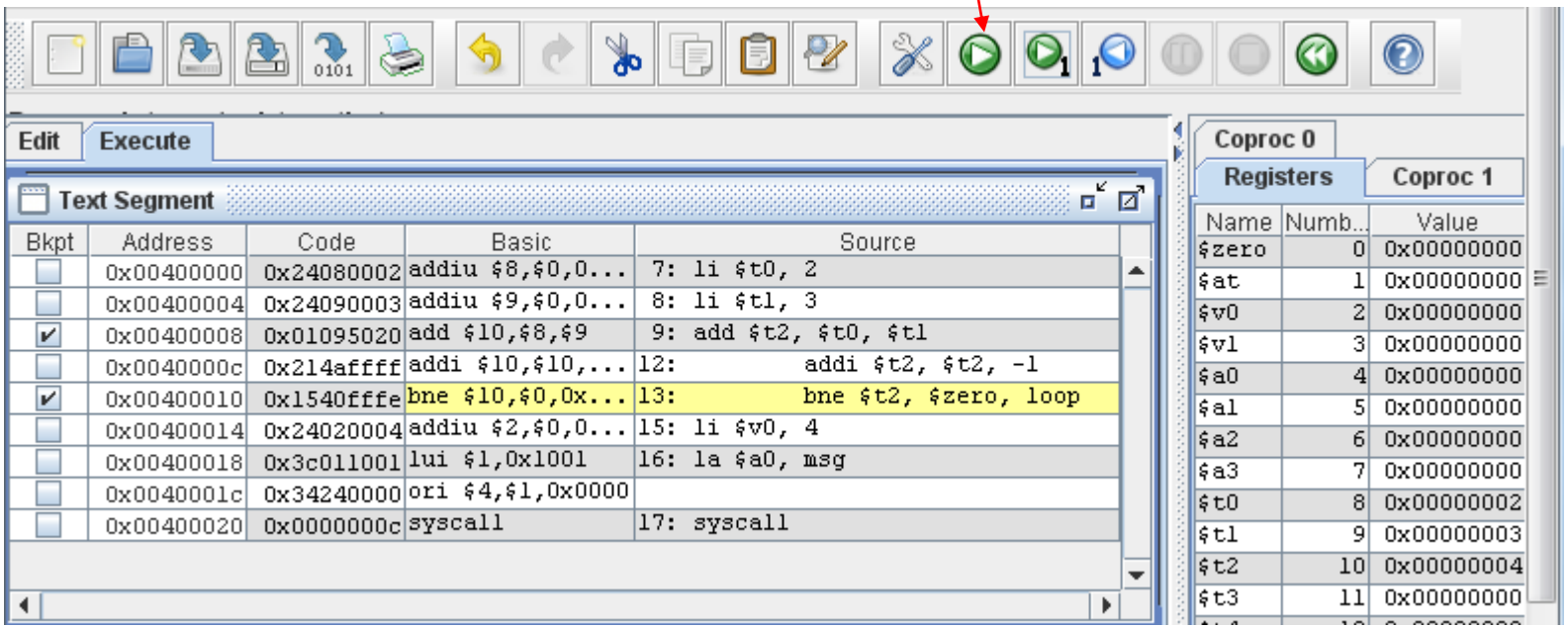
MARS Breakpoint

- Load the example program debug1.s, and try enabling the breakpoints shown below.
- Then start the execution to see how it pauses at the first breakpoint.
- The values of the registers and memory reflect the execution up to (but not including) the instruction at this breakpoint.



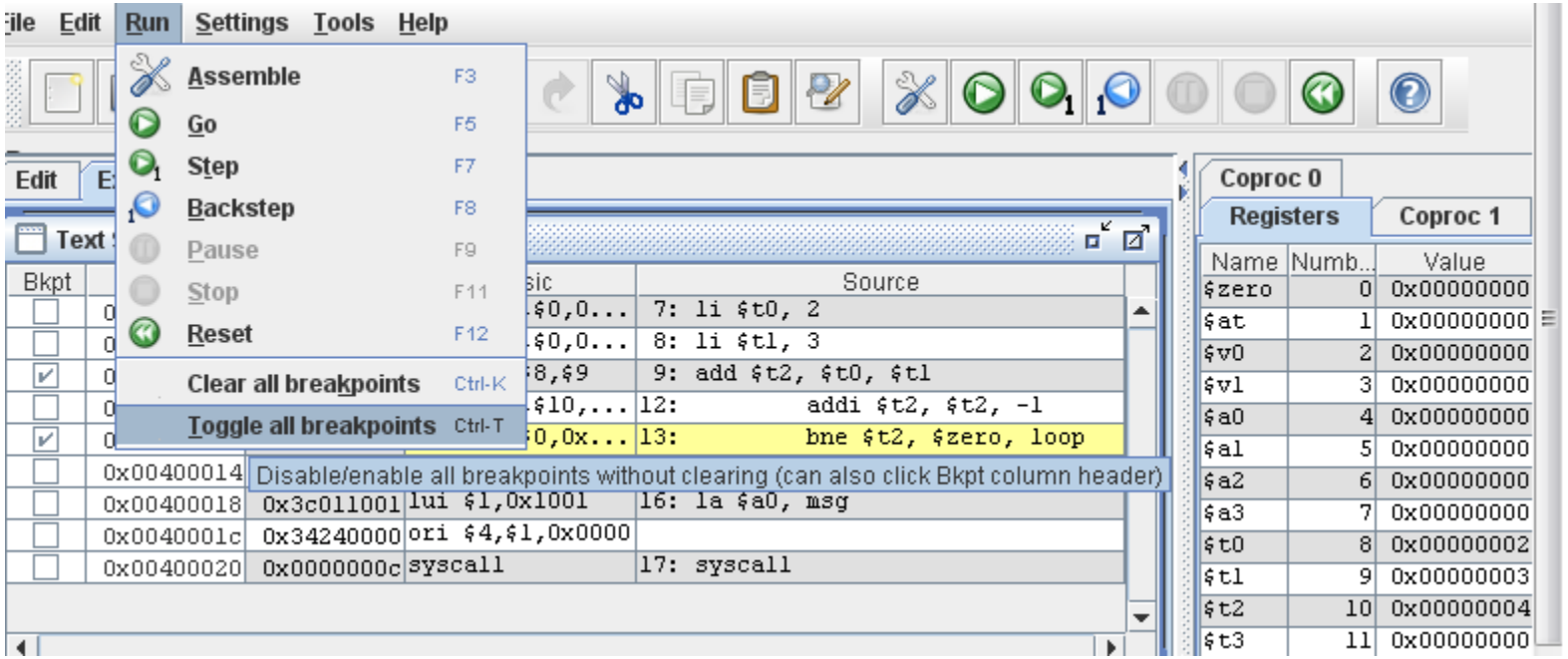
MARS Breakpoint

- Start the execution again (click the same button) to see how the execution pauses at the second breakpoint.



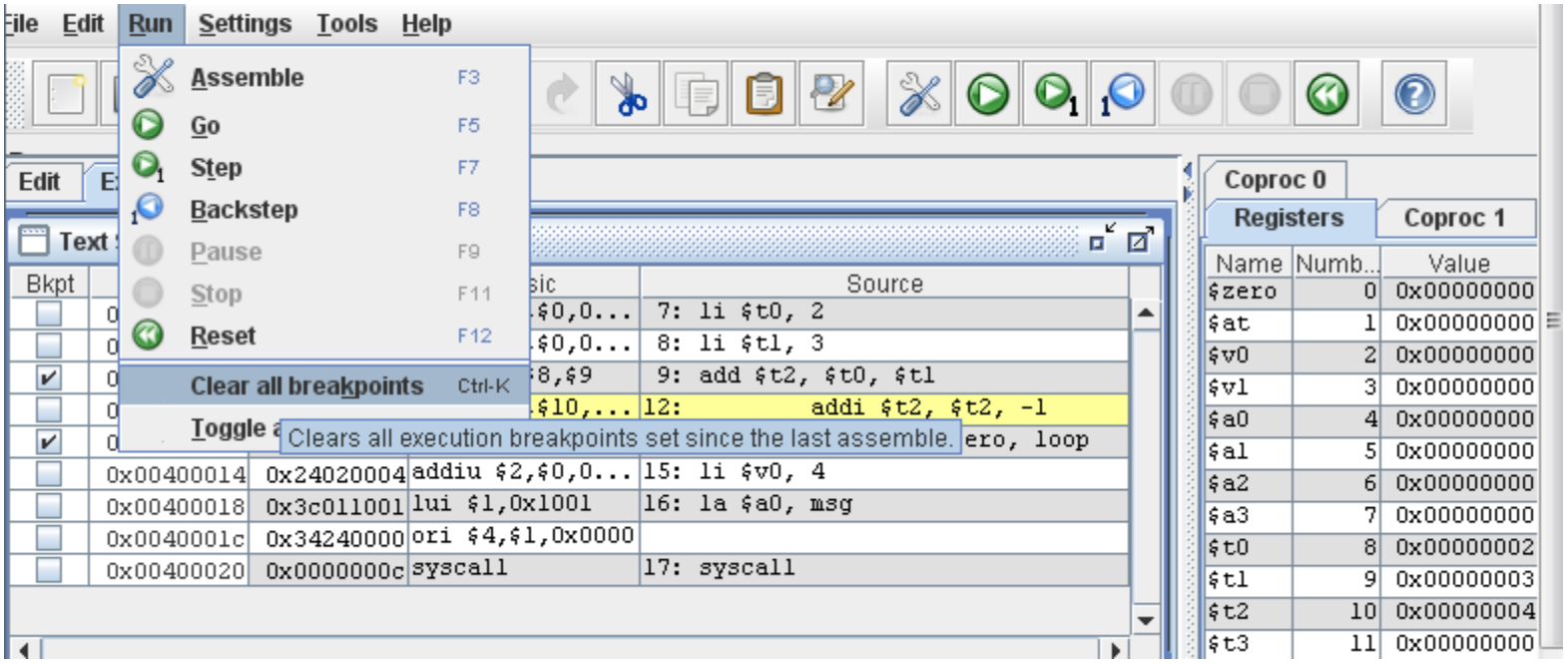
MARS Breakpoint

- All the breakpoints can be toggled between **Enabled** and **Disabled** status using the menu command *Run->Toggle all breakpoints*.



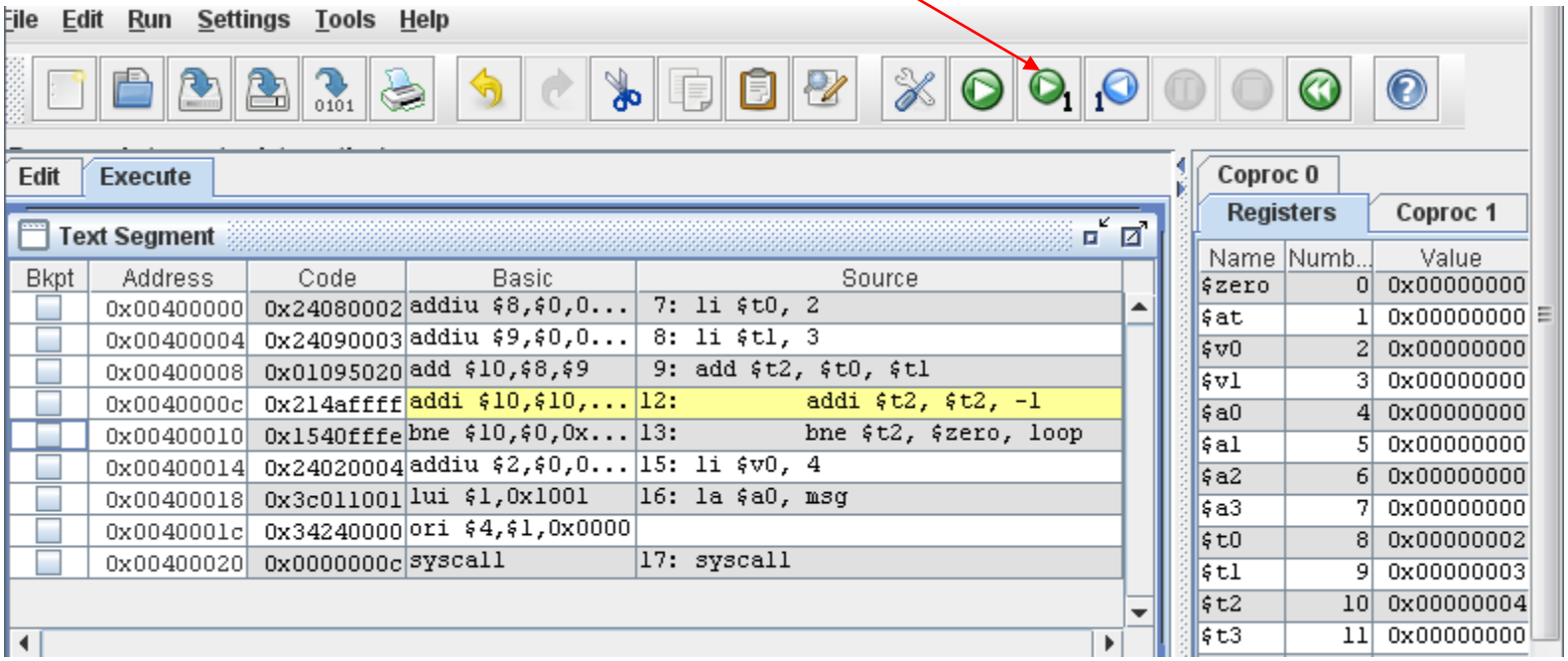
MARS Breakpoint

- All the breakpoints can be cleared out using the menu command *Run->Clear all breakpoints*.
- An individual breakpoint can also be cleared out by clicking on it to remove the tick on its box.



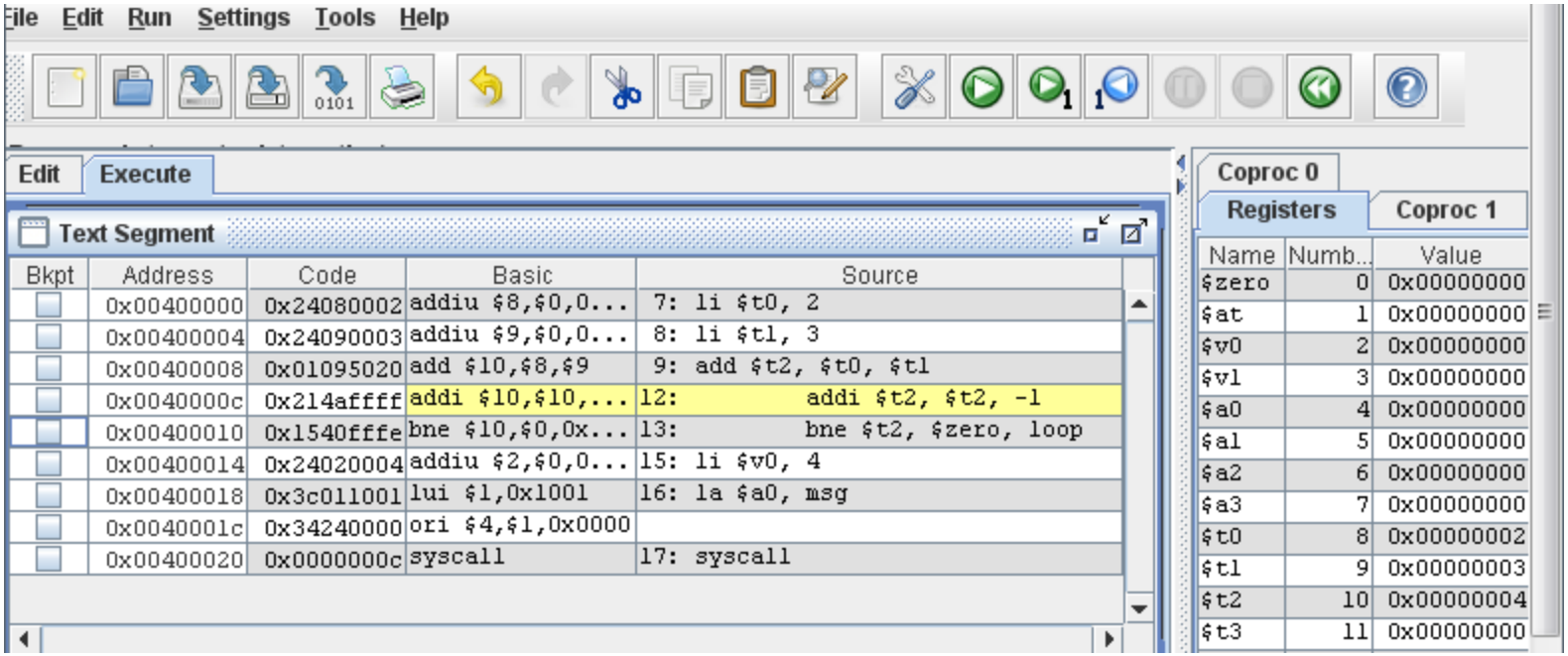
MARS Single Step

- Single Step – executes one instruction and then pauses the execution.
  - Click this **Single Step** button to do a Single Step.
  - It can be used at the very beginning to start executing the program (executing its first instruction) or at any time when the program execution is paused (e.g., by a breakpoint).



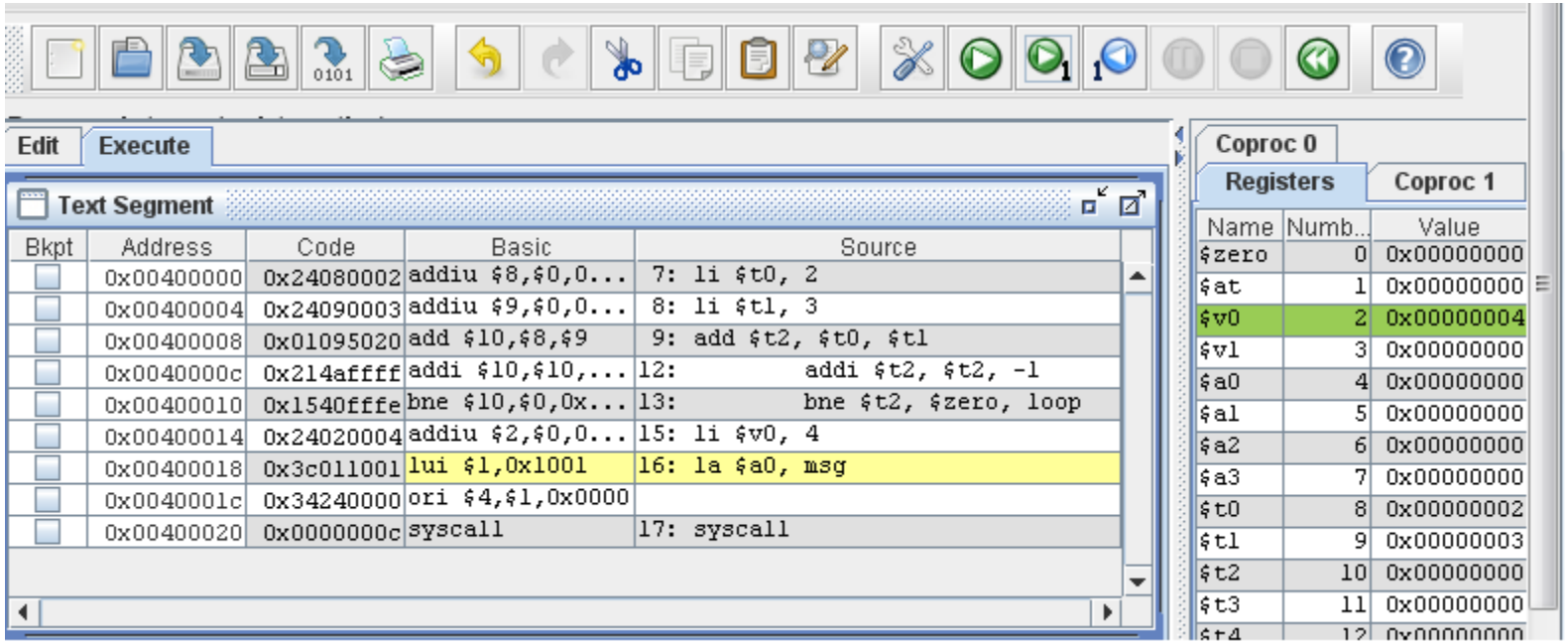
MARS Single Step

- Try executing each instruction in debug1.s using Single Step.
- See how the execution of the loop in debug1.s is traced in this way.
- See how the values of the registers and/or memory are changed to reflect the latest execution.



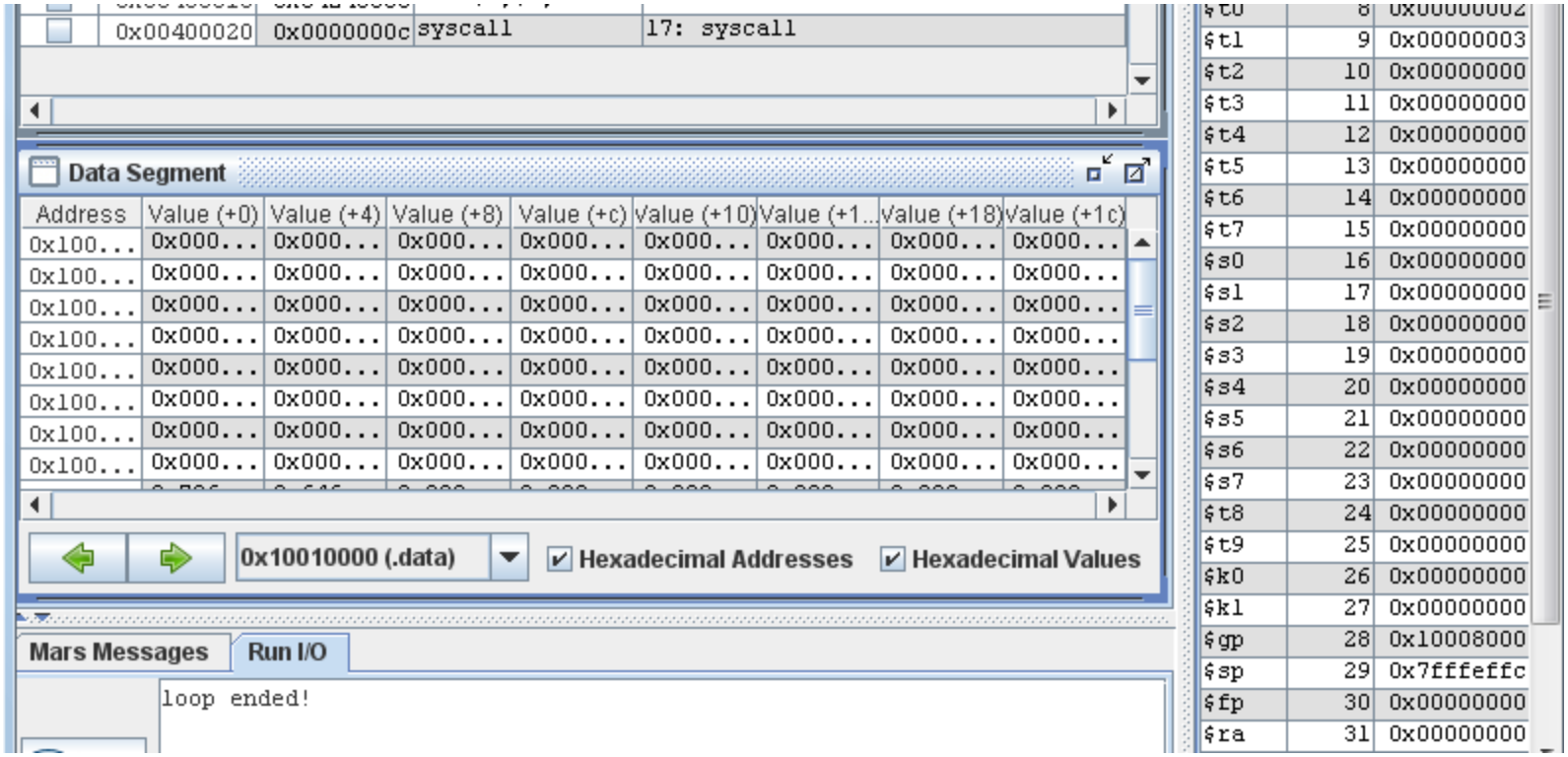
MARS Single Step

- The register whose value has just been changed by an instruction execution is highlighted in green at that moment.



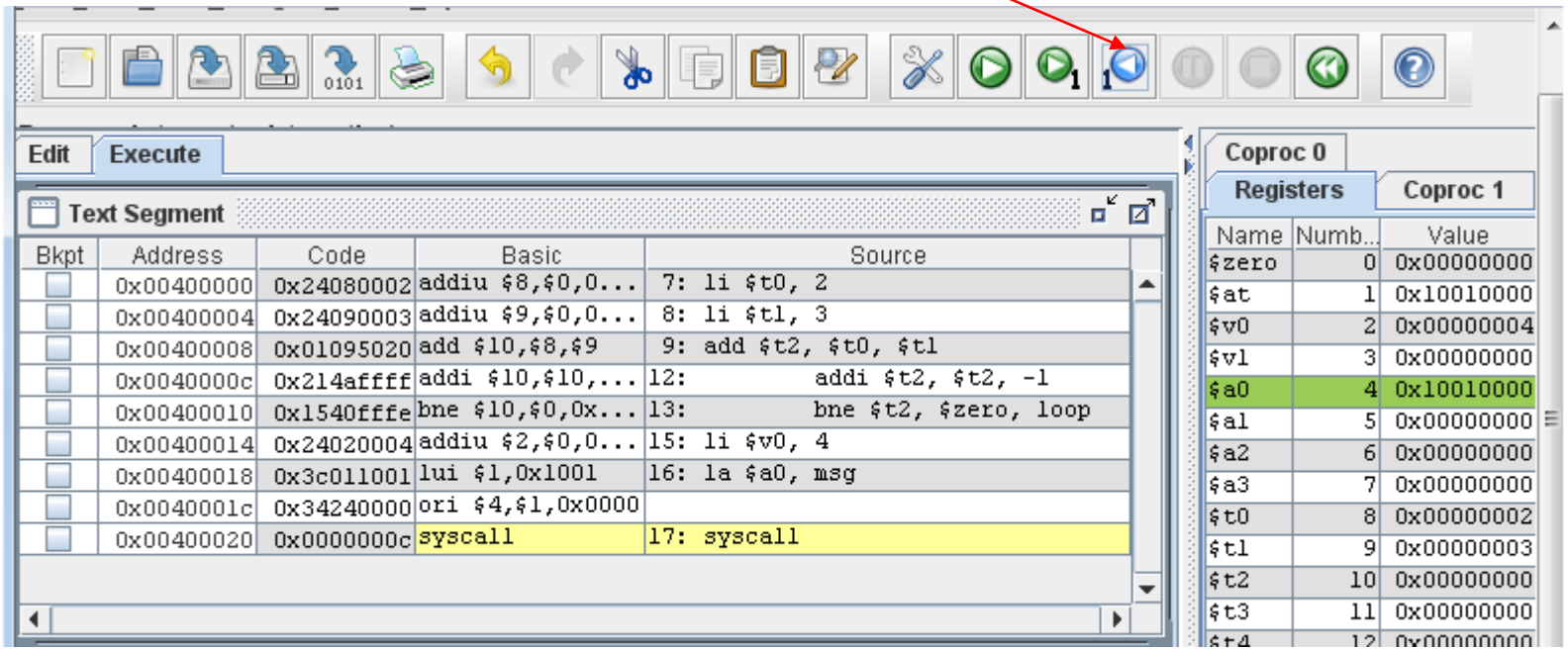
MARS Single Step

- See how the console window reflects the Input/Output in the latest execution of an I/O syscall.



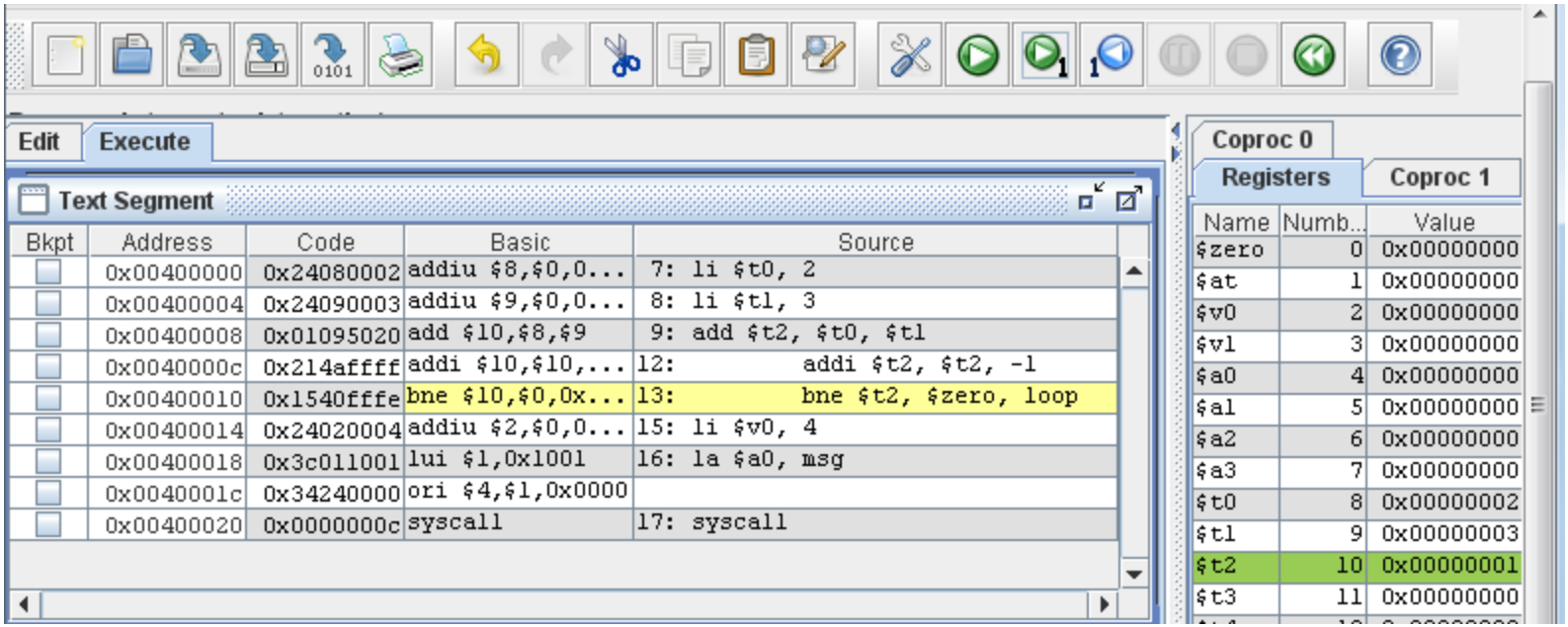
MARS Undo Step

- Undo Step – undo the last instruction (up to a maximum of 2000 instructions by default) and then pauses the execution.
  - Click this **Undo Step** button to do an Undo Step.
  - It can only used when the program execution is paused.
  - It can still be used after the program execution terminated (but before it is reset). Try this after executing debug1.s.



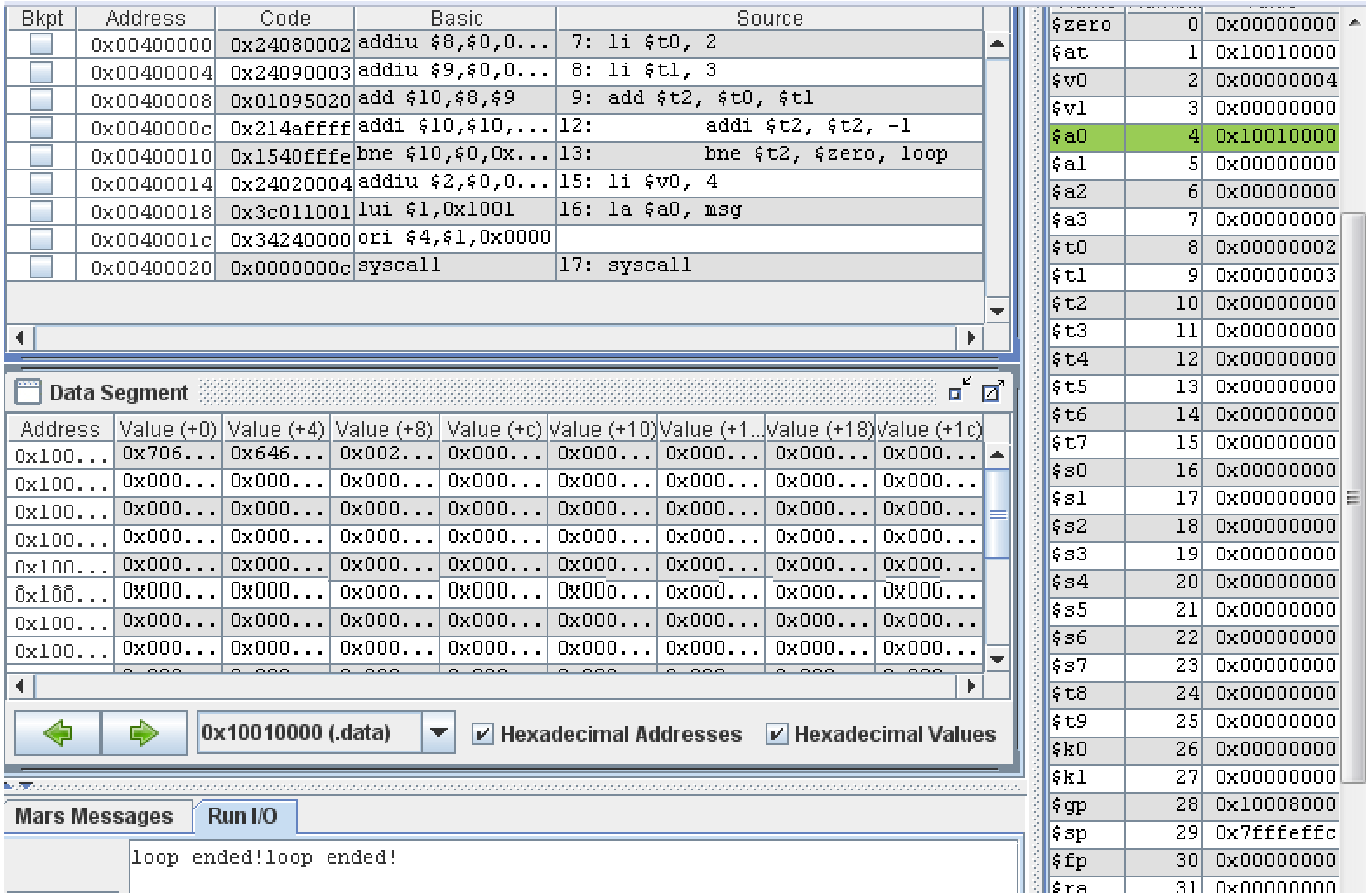
MARS Undo Step

- Try reversing the execution of the loop in `debug1.s`, too.
- See how the values of the registers and memory are changed back as the execution reverses.



MARS Undo Step

- Now execute the program forward again. You will get another output of "loop ended!" on the I/O console.



MARS Undo Step

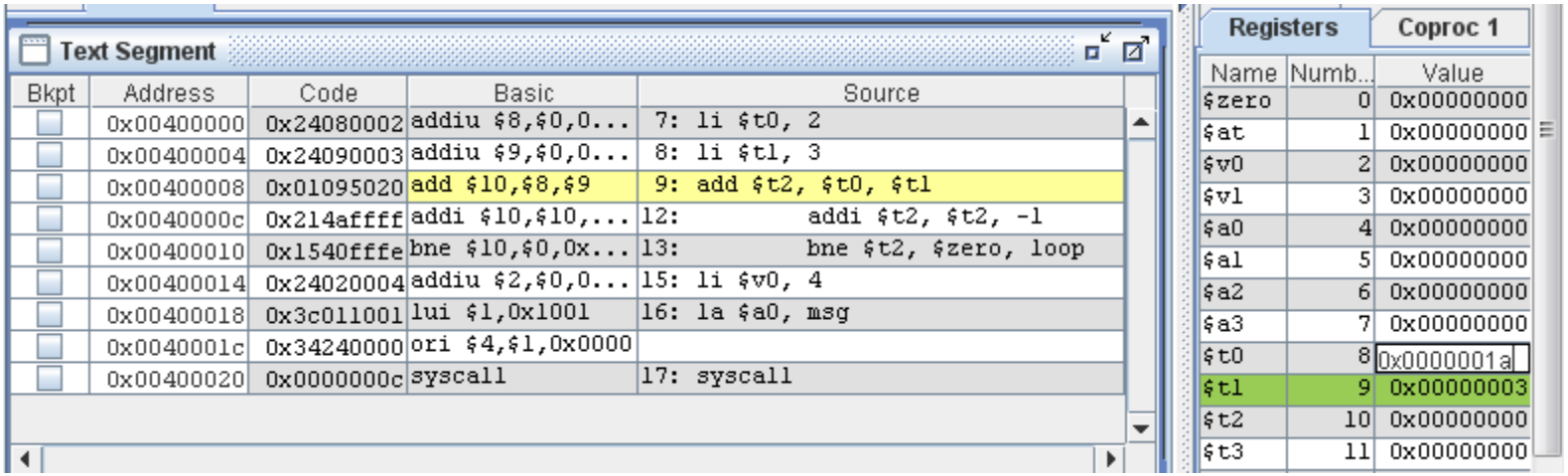
- Undo Step can only undo the change in a register or memory but not in the syscall service such as Console I/O that has already been performed.

Modifying registers or memory

- When you figure out a possible solution to fix a buggy program, you can modify the program code to try it out.
- You can also just modify the values of the registers or memory (according to the solution) during the (buggy) program execution.
- This lets you get a sense of whether the solution should work before you modify any codes.
- To modify a register or memory,
  - double-click on it on the Registers or Data Segment window.
  - Type the new value in hexadecimal or decimal format.
  - Finally, press the enter key to apply the new value.
- The modification can only be done before the program execution starts or when it is paused.
- The new value will be applied to all the subsequent executions.

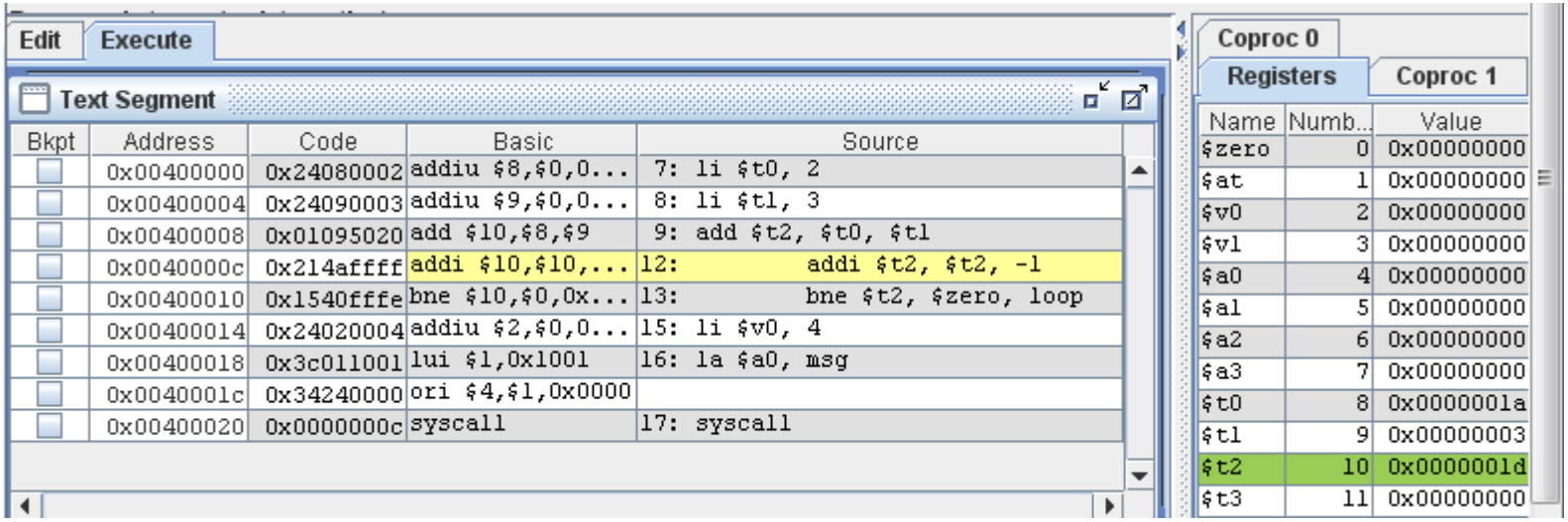
Modifying registers

- Try executing the program debug1.s.
- Then pause it at the instruction in Line 9 and modify the value of the register t0 to 0x0000001a (as shown by the image below).



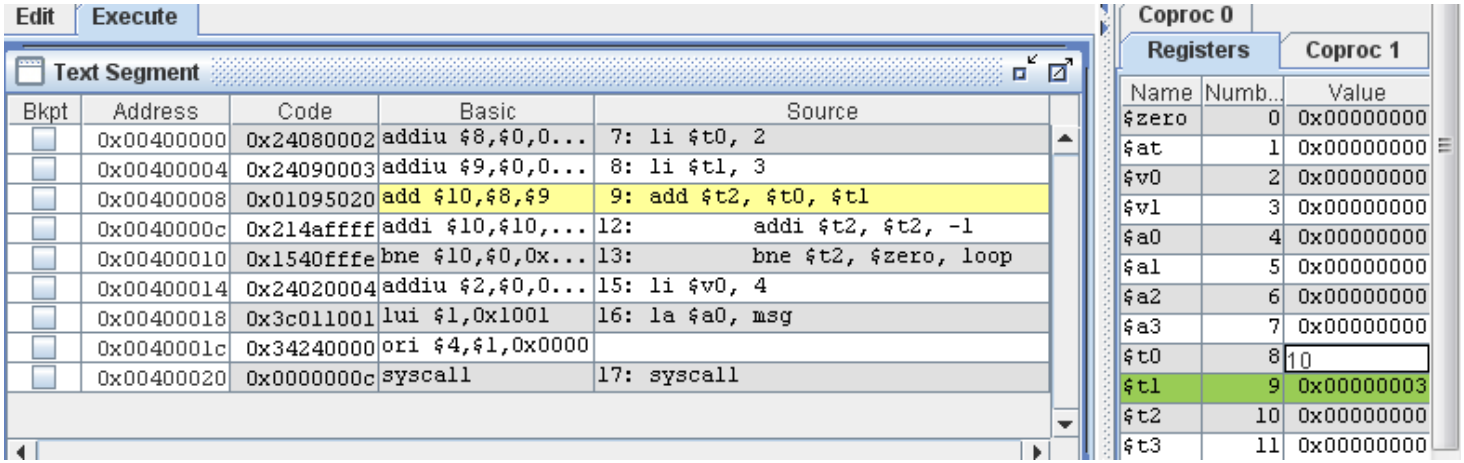
Modifying registers

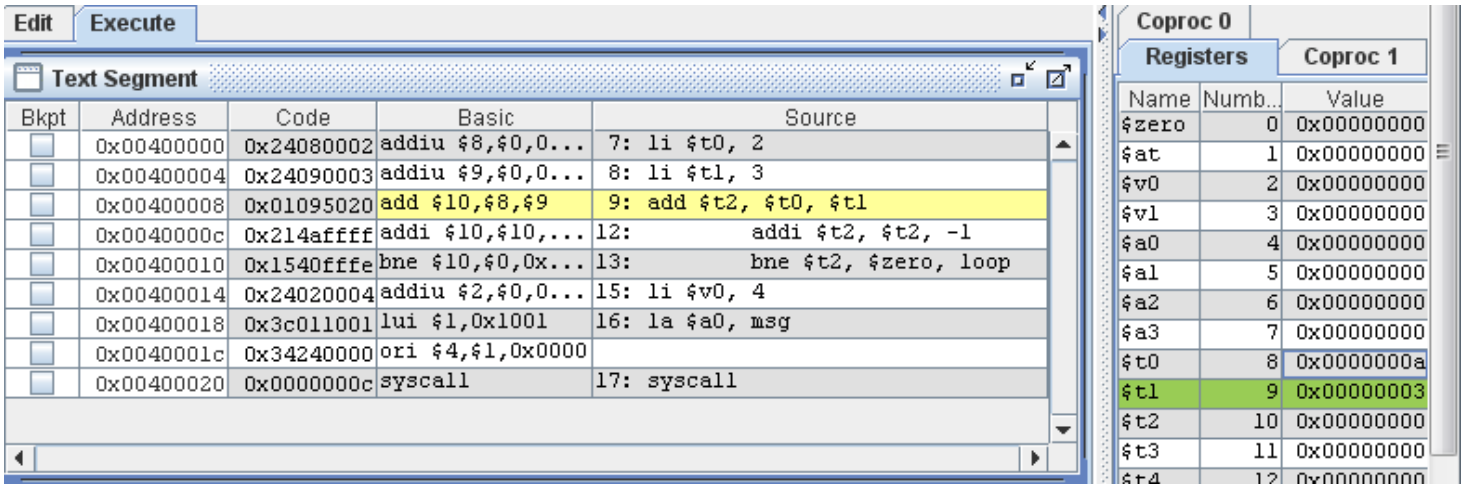
- Single Step the add instruction in Line 9.
- See how the addition used the new value of the register t0 (look at the sum in the register t2).



Modifying registers

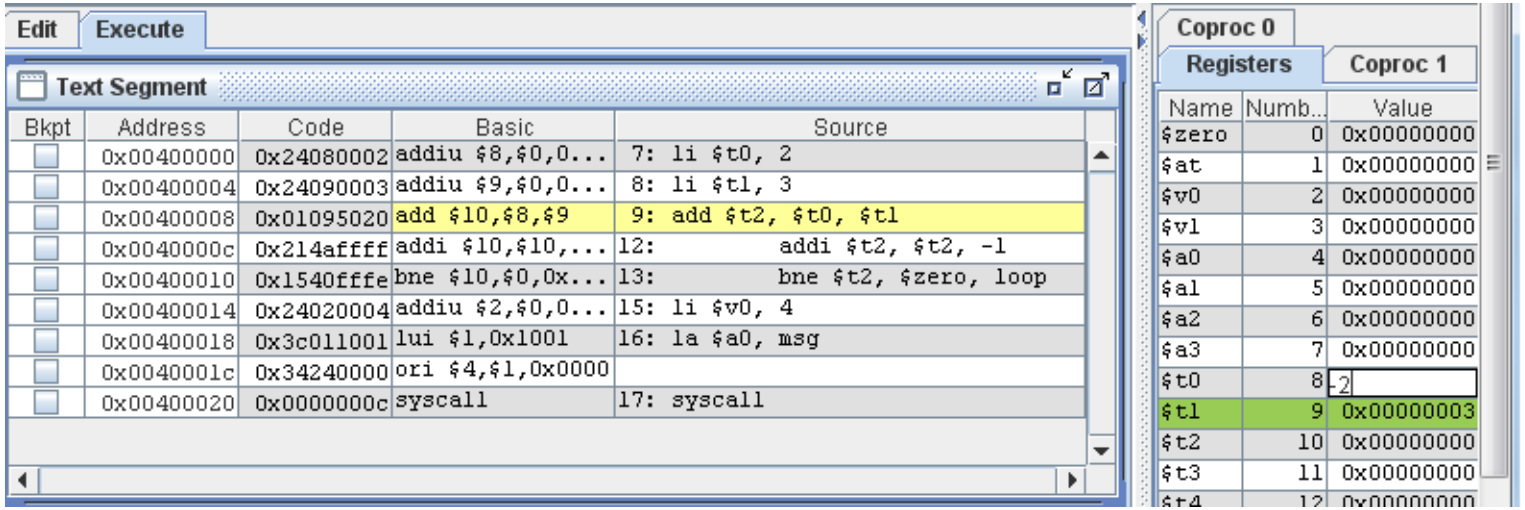
- New decimal values entered will be converted to the display format of the Registers window (hexadecimal by default).

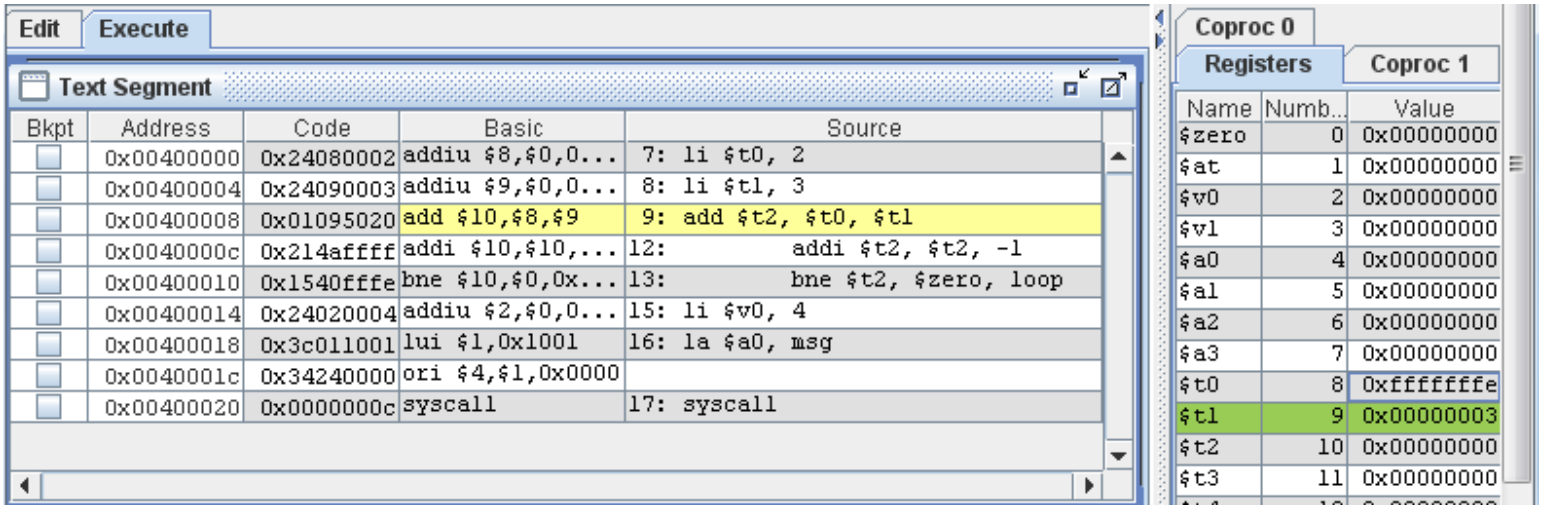




Modifying registers

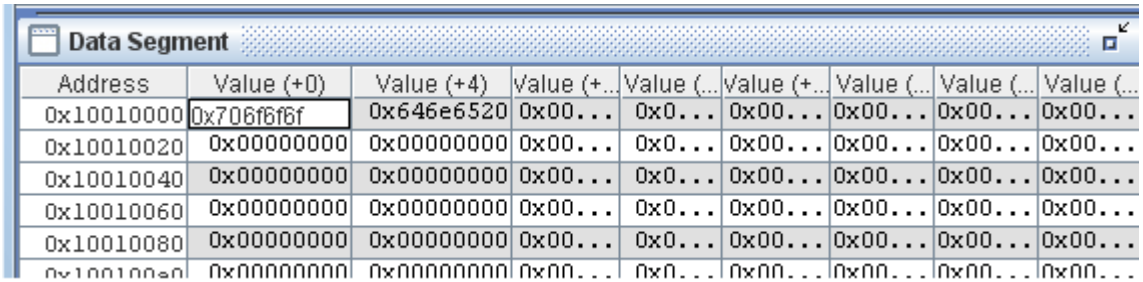
- **The hexadecimal format on MARS uses 2's complement.**

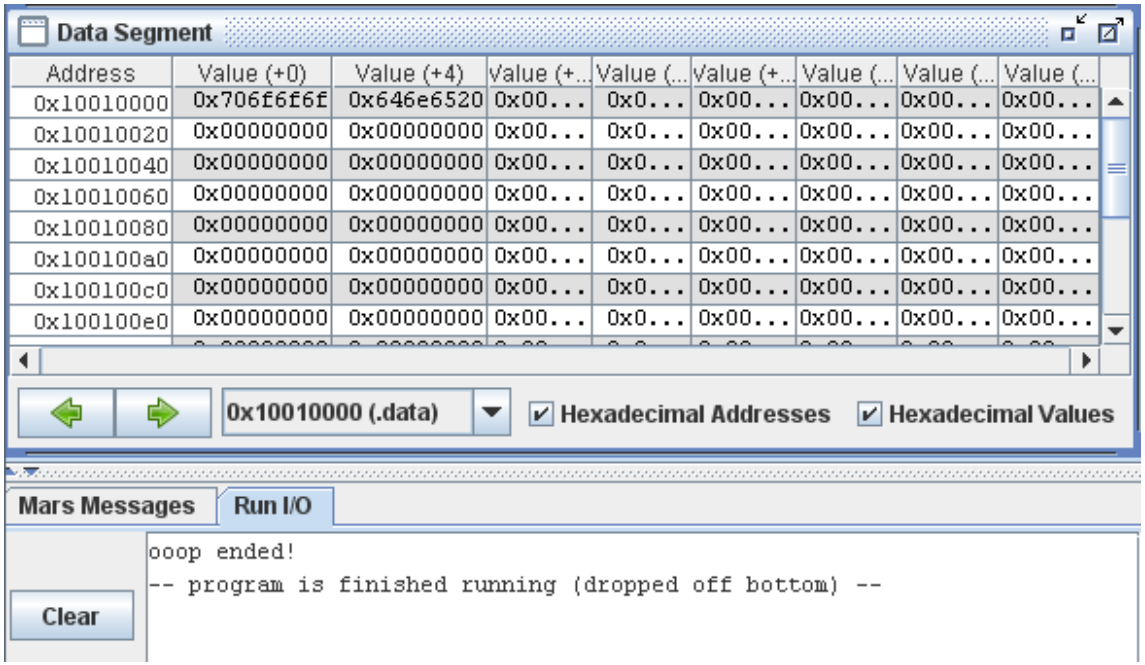




Modifying memory

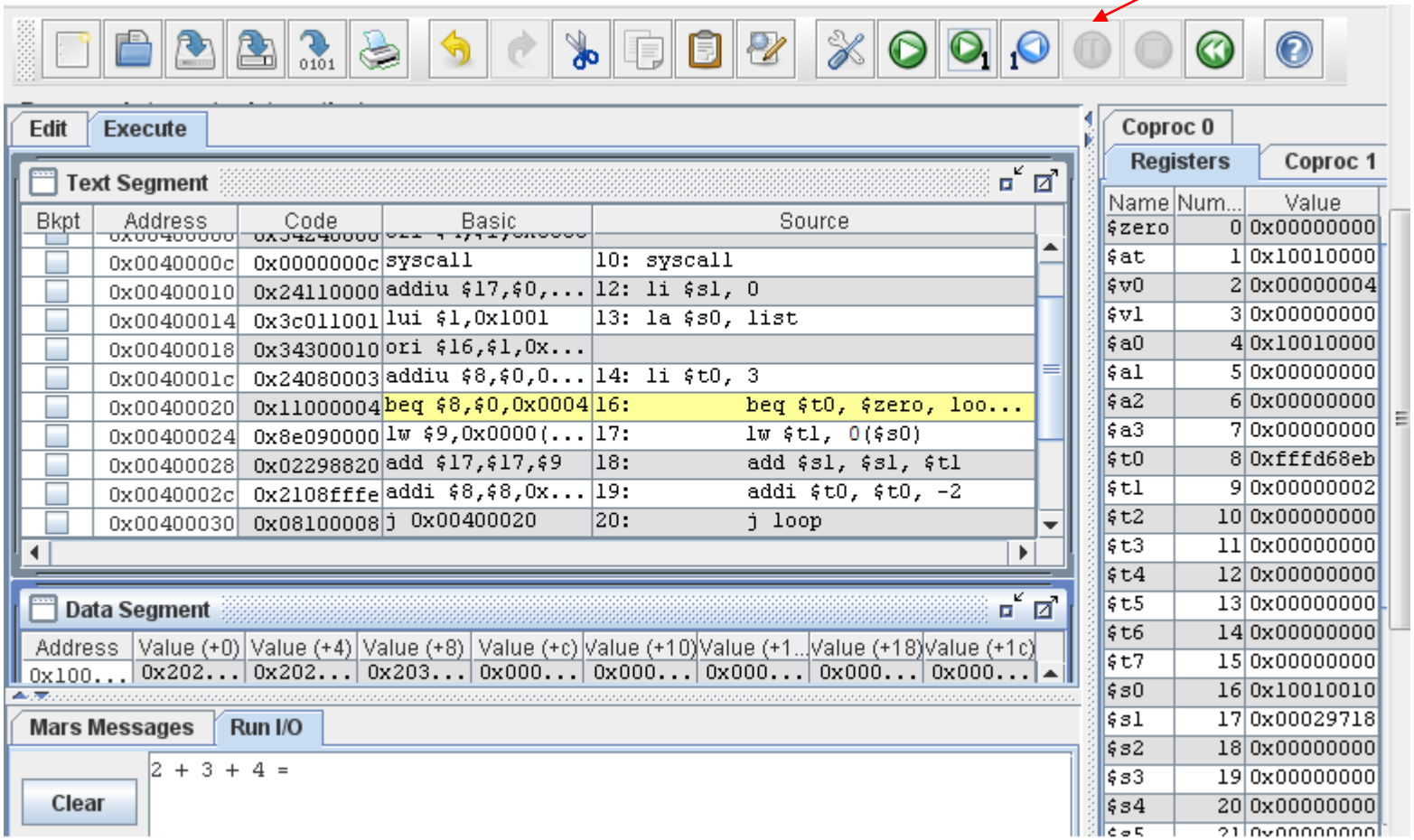
- For example, modify the string msg in `debug1.s`.





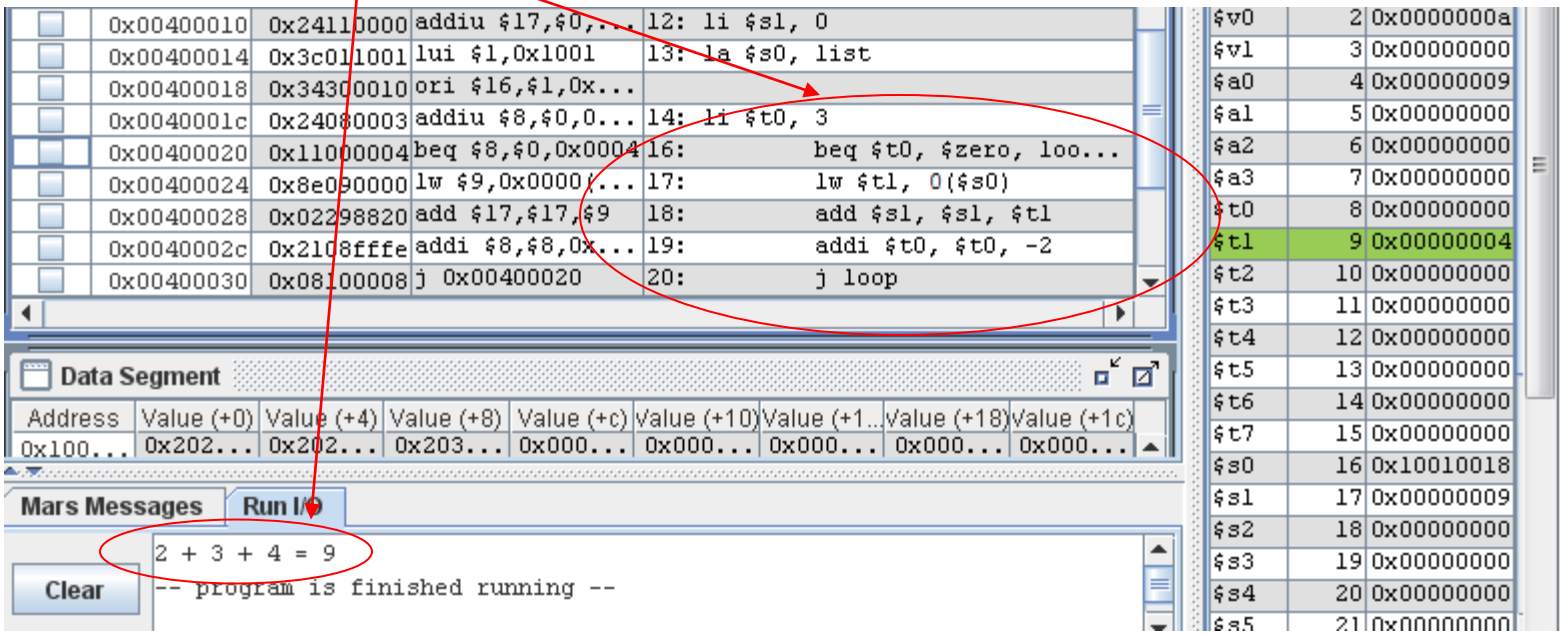
Example program

- Try to debug the example program debug2.s.
  - To pause the program execution (e.g., during its infinite loop), click this **Pause** button.



Example program

- After figuring out a possible solution to the bug, try it by modifying only the registers (not the program code) to get a sense of whether it should work (computing the correct sum).
- For example, see how the register modifications yield the correct result (in the register s1) of the addition done in each of the first three iterations of the loop in debug2.s.
- After a correct solution is found, fix the program code then.



Another example program

- Try to debug the program debug3.s.
  - You may debug it by modifying the registers or program code first (whichever way you feel efficient with).
  - The program execution may run for a while, looking like in an infinite loop initially, but will eventually terminates with an Exception error at a particular instruction code.
  - See the message about the Exception on MARS' Messages Window.
  - The Exception is about an invalid memory access by the instruction. What is the cause?

Exercise

- Try to debug the program debug4.s.
  - The program prompts the user to input a number to search in a list of pre-specified numbers and outputs whether it is found in the list.
  - However, if the input number is found in the list, the program execution terminates with an Exception error about an invalid Program Counter value.
  - See the message about the Exception on MARS' Messages Window.
  - Figure out the cause of the Exception and debug the program.

Exercise (optional)

- Try to debug the program debug5.s at your own time.
  - The program prompts the user to input a number and calculate the factorial of that number. However, the output is not correct.
  - Figure out the cause of the problem and debug the program.

Conclusion

- You have learnt:
  - how to debug a MIPS program using the debugging features in MARS.