

### Objective

The purpose of this assignment is to familiarize students with the basics of LC3 assembly language programming, the SIMPL simulator, and rudimentary debugging.

### High Level Description

Prompt the user to input two single digit numbers; the second will then be subtracted from the first, and the operation reported in the console:

<first number> - <second number> = <difference>

### Low Level Breakdown

This assignment comprises five tasks:

1. Prompt the user, and read two numeric characters ('0' ... '9') from the user using Trap x20 (GETC). Echo the characters to the console as they are input, and store them as **character** data in separate registers.
2. Output to the console the operation being performed e.g.  
5 - 7 =
3. Using the same registers, convert the numeric characters into the actual numbers they represent (e.g. convert the ASCII code for '7' into the binary representation of the number 7).
4. Perform the subtraction operation, and determine the sign (+/-) of the result; if negative, determine the magnitude of the result (i.e. take 2's complement)
5. Convert resulting number back to a printable character and print it, together with minus sign if necessary.

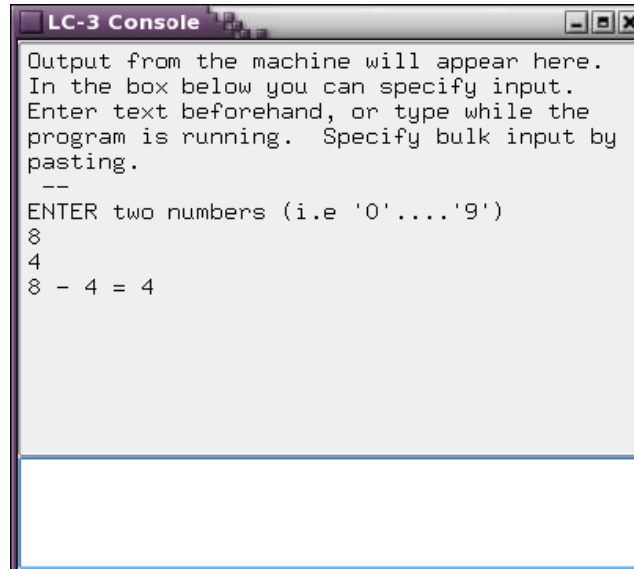
### Example with algorithm (*we won't always give you this!*)

1. Program prompts for user input, user enters '5', which is echoed to console and stored in a register.
2. Program prompts for user input, user enters '7', which is echoed to console and stored in a register.
3. Program outputs  
5 - 7 =
4. Program converts '5' into 5 and stores it back in the same register.
5. Program converts '7' into 7 and stores it back in the same register.
6. Program performs (5-7) and stores the result, -2, in a register (obviously as a 2's complement number)
7. Program recognizes that result is negative, converts -2 to 2, and sets flag for minus sign
8. Program converts 2 into '2', and stores it back in same register
9. Program outputs the **two** characters  
-2  
followed by a newline, thus completing the subtraction operation output

### Expected/ Sample output

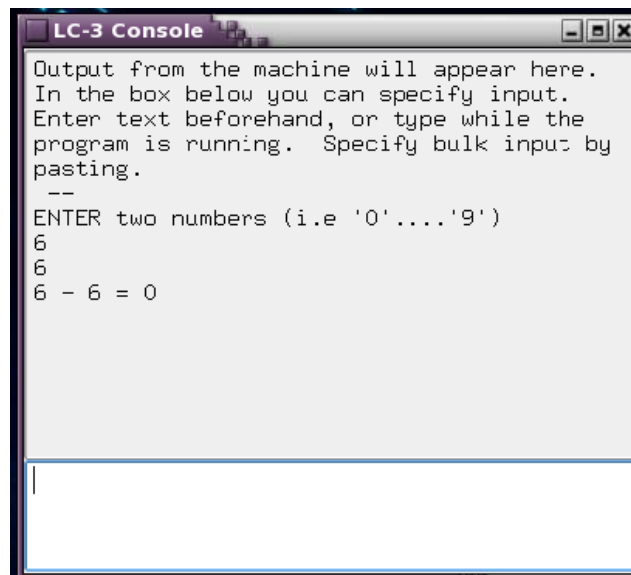
In this assignment, your output must **exactly** match the following, including:

- A. the prompt, followed by newline
- B. each input "echoed" and followed by a newline
- C. the subtraction operation, including spaces as shown, also followed by a newline:



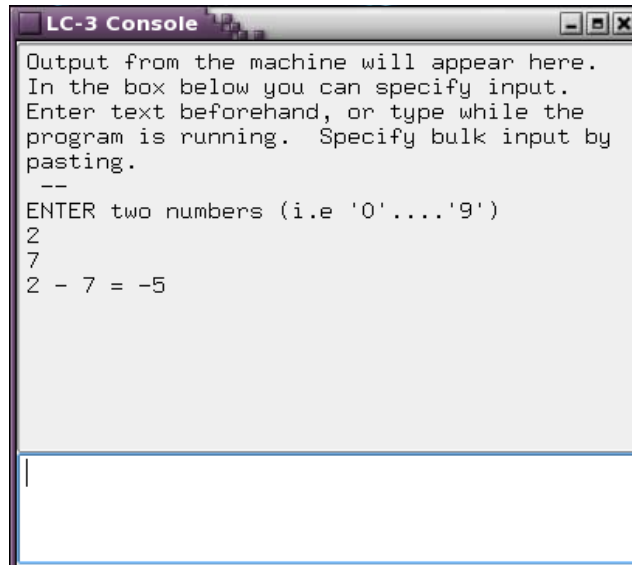
```
LC-3 Console
Output from the machine will appear here.
In the box below you can specify input.
Enter text beforehand, or type while the
program is running. Specify bulk input by
pasting.
--
ENTER two numbers (i.e '0'....'9')
8
4
8 - 4 = 4
```

(Difference if Positive)



```
LC-3 Console
Output from the machine will appear here.
In the box below you can specify input.
Enter text beforehand, or type while the
program is running. Specify bulk input by
pasting.
--
ENTER two numbers (i.e '0'....'9')
6
6
6 - 6 = 0
```

(Difference is Zero)

A screenshot of a window titled "LC-3 Console". The window contains the following text: "Output from the machine will appear here. In the box below you can specify input. Enter text beforehand, or type while the program is running. Specify bulk input by pasting." followed by two dashes "--". Then it says "ENTER two numbers (i.e '0'....'9')". Below this, the numbers "2" and "7" are entered on separate lines. The result "2 - 7 = -5" is displayed. At the bottom of the window is a text input field with a cursor.

(Difference is Negative)

Your code will obviously be tested with a range of different operands giving all possible results. Make sure you test your code likewise!

**NOTE:**

- All console output must be **NEWLINE terminated**.
- We will test only with **positive single digit numeric input**
- **NO** error message is needed for invalid input

**Uh...help?**

- The instruction "Trap x20" (aka GETC) will *always* store the input character into R0. You cannot specify any other register.
- The instruction "Trap x21" (aka OUT) will *always* print whatever ASCII code is stored in R0. You cannot specify any other register.
- If the user enters '7', the value stored into R0 is the ASCII code b0000 0000 0011 0111 (= x0037 = '7'), **not** the number 7 = b0000 0000 0000 0111 (= #7).  
Go to [www.asciitable.com](http://www.asciitable.com) and see why.  
(conversion between a character and the number it represents will be used repeatedly in this course, so make sure you understand how to do it now!!)
- To take the Two's Complement of a number (i.e. to make a positive number negative or vice versa):
  - Invert the bits (*what assembly instruction does this?*)
  - Add one
- A neat trick in LC3 to copy the value of one register directly to another:  
ADD R5, R6, #0 ;  $R5 \leftarrow (R6) + 0$ , i.e.  $R5 \leftarrow (R6)$
- If the result is negative, remember that you will have to print two characters, not one (there is no ASCII code for '-1', right?)
- If you are struggling with writing LC3 code from scratch, try writing the program out in pseudo-code or even C++ first. Then, your only task is to convert the logic/code into LC3.

### Submission Instructions

Submit to iLearn for testing, feedback and grading. Some feedback will be sent via E-mail.

### Comments/Feedback

In the diff files sent to you in the feedback email, there will be two columns: the left column is the output from your program, and the right is the expected output. Any line that has a | on it means your output did not match the solution.

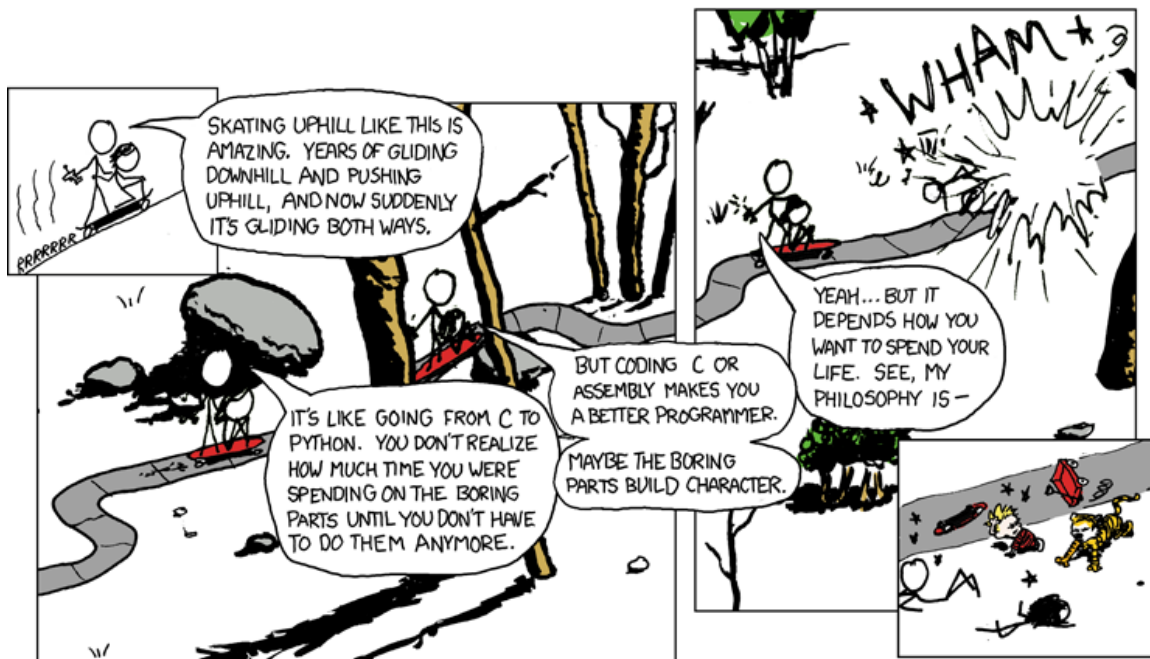
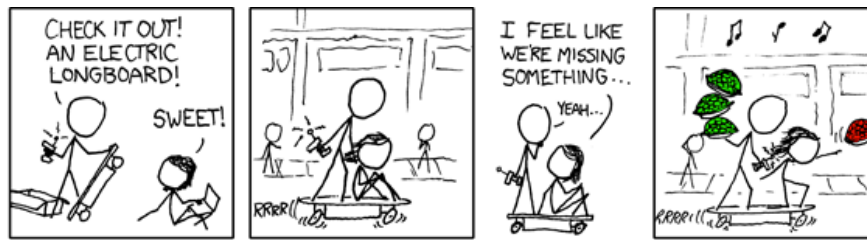
The only line numbers of interest are 13 - 16. You can ignore the rest, even if they have a '|'.

Comment	Meaning
Invalid Prompt	Prompt did not match that of the specs
Did not echo [1]	Did not echo to console first input received
Did not echo [2]	Did not echo to console second input received
Wrong Output	Your output did not match that of the specs above. <b>Common mistakes:</b> <ul style="list-style-type: none"><li>• Did not add spaces correctly between bits</li><li>• Extra space at the end</li></ul>
Did not have ending NEWLINE	Program did not end with a NEWLINE

### Rubric

- Grades fall into the following four ranges:
  - (i) 8 - 10: pass (perhaps with minor errors - missing spaces, mis-spellings, etc.)
  - (ii) 5 - 7: failed, but easily fixable (e.g. missing newlines)
  - (iii) 1 - 4: failed - wrong output, you should probably throw it away and start over!
  - (iv) 0: abject fail - no submission, or did not assemble (*same as fail, but even more embarrassing!*)
- Using the provided template is **required**.

Comics??! Sweet!!!



Source: <http://xkcd.com/409/>