CS061 - Programming Assignment 2

Objective

To further familiarize you with the basic LC-3 instructions;
to understand the difference between numeric characters and actual numbers;
to handle two's complement conversions;
and to perform basic input/output.

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>
```

SO if the user enters 8 and 4, these two numbers will first be echoed to the console on separate lines, then the subtraction operation will be displayed:

```
ENTER two numbers (i.e '0'....'9')
8
4
8 - 4 = 4
```

LC-3 I/O

First, read this brief intro to the LC-3 BIOS (Basic Input Output System)

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 (OUT), and store them as **character** data in separate registers.
2. Output to the console the operation being performed e.g.
   5 - 7 =
   (how will you print the operation " - "? How will you print the " = "? Note the double quotes!!)
3. Once the setup is printed, 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 *(by taking the two's complement of the second operand and adding)*, and determine the sign (+/-) of the result;
   if it is negative, determine the *magnitude* of the result (i.e. take 2's complement to turn it back into a positive number)
5. Convert resulting number back to a printable character and print it, together with minus sign if necessary.
   Remember, the number -4 when converted to text is actually two separate and distinct ascii characters, '-' and '4'.

Reminder: Make sure you always have your Text Window open when you run simpl - this is the only way to catch run-time (mostly i/o) errors!

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

- Program prompts for user input (two characters):
- user enters ‘5’, which is echoed to console and copied to a register.
- user enters ‘7’, which is echoed to console and copied to a different register.
- Program outputs

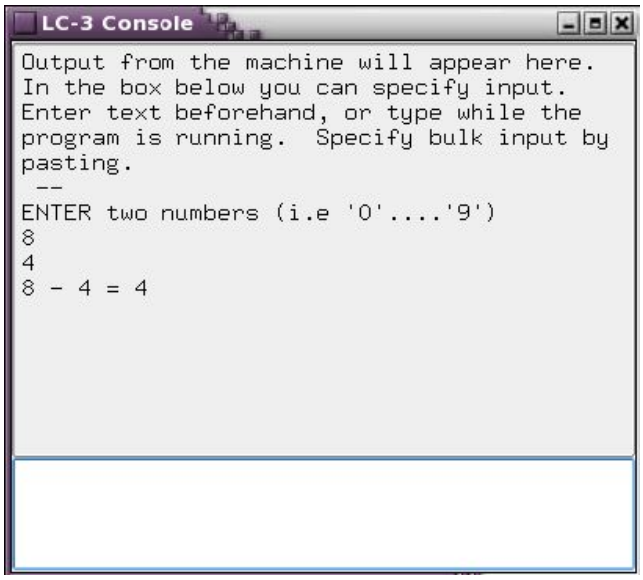
  5 - 7 =

  (this will actually require at least 4 distinct output steps using OUT and PUTS)
- Program converts ‘5’ into 5 and stores it back in the same register.
- Program converts ‘7’ into 7 and stores it back in the same register.
- Program takes 2's complement of 7, and stores the result back into the same register.
- Program adds the contents of the two registers - i.e. it performs the operation (5-7) and stores the result (-2) in a third register
- Program recognizes that result is negative, obtains the magnitude of -2 (= 2), and outputs **'-'** (minus sign)
- Program converts 2 into '2', and stores it back in same register
- Program outputs ***'2'*** <u>followed by a newline</u>.

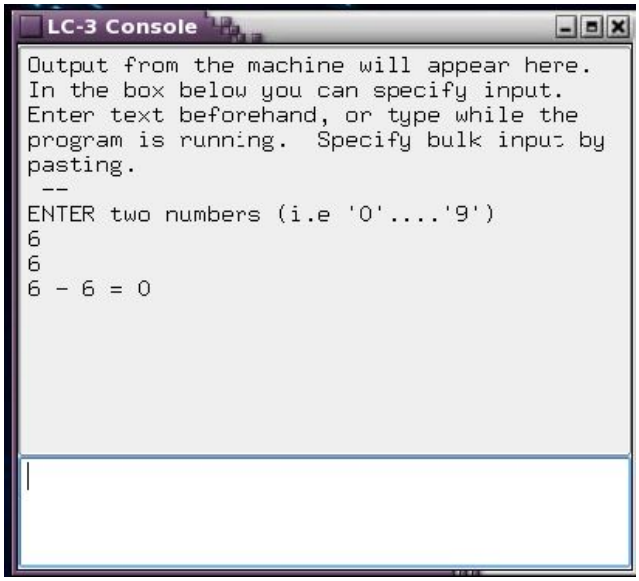
Expected/ Sample output

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

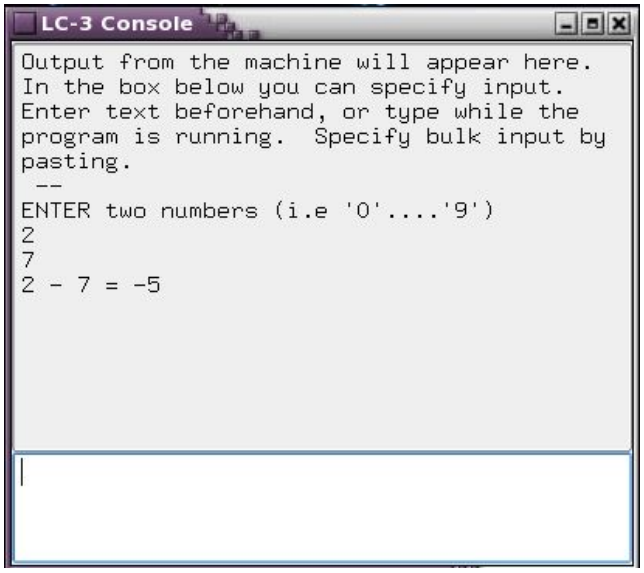
- the prompt, <u>*followed by newline*</u>
- Each digit input "echoed" and <u>*followed by a newline*</u>
- the subtraction operation, including spaces as shown, also <u>*followed by a newline*</u>:



(Difference is Positive)



(Difference is Zero)



(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!

NOTES:

- All console output must be **NEWLINE terminated.**
- We will test only with **positive single digit numeric inputs**
- **NO** error message is needed for invalid input (i.e. we will not test with non-numeric inputs)

Uh...help?

- Trap x20 (GETC) will *always* store the input character into R0.
  You cannot specify any other register to receive the keyboard input.
- Trap x21 (OUT) will *always* print whatever ASCII code is stored in R0. You cannot specify any other register to output to screen.
- 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 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 ← (R6) + 0,  i.e.  R5 ← (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 LC-3 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 LC-3.

Submission Instructions

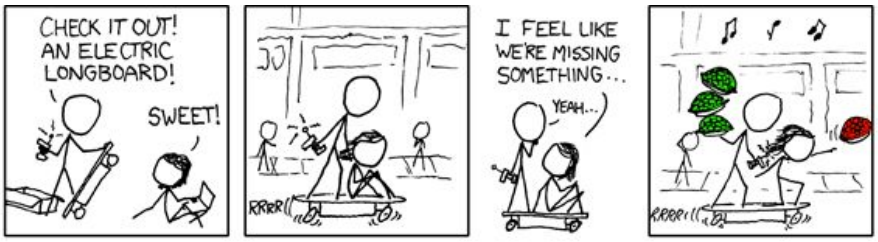
Submit ("Upload") to the Programming Assignment 2 folder in Gradescope: the Autograder will run & report your grade.
You may submit as many times as needed - your grade will be that of your last submission.

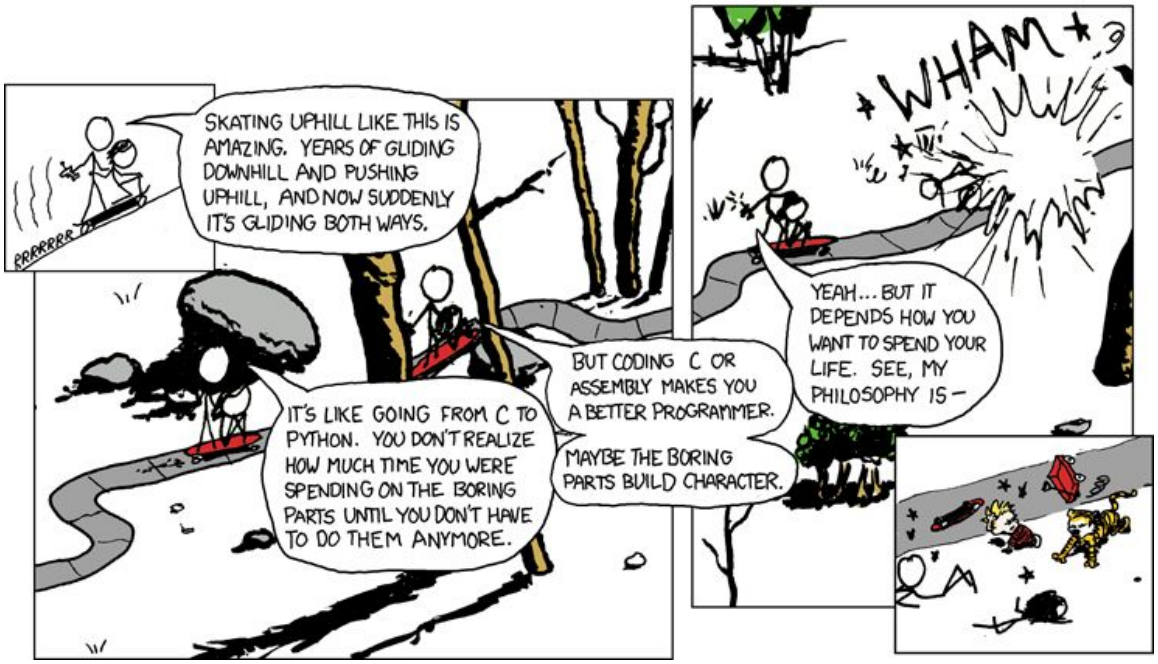
Rubric

- To pass the assignment, you need a score of >= 80%.
  The autograder will run several tests on your code, and assign a grade for each.
  But certain errors *(run-time errors, incorrect usage of I/O routines, missing newlines, etc.)* may cause ALL tests to fail => 0/100! So submit early and study the autograder report carefully!!

- **You must use the template we provide** - if you make *any* changes to the provided starter code, the autograder may not be able to interpret the ouput, resulting in a grade of 0.

Comics??! Sweet!!!





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