CS 61 - Programming Assignment 3

Objective

The purpose of this assignment is to give you more practice with I/O, and with left-shifting, multiplying by 2, and useful 2's complement logic.

High Level Description

Store a number to the **memory address specified in your assn 3 template**. In your program, load that number in a register, and display it to the console as 16-bit two's complement binary (i.e. display the binary value stored in the register, as a sequence of 16 ascii '1' and '0' characters).
Note: Valid numbers are [#-32768, #32767] (decimal) or [x0000, xFFFF] (hex)

Your Tasks

You do not yet know how to take a multi-digit decimal number from user input and convert it to binary, so for this assignment you are going to let the assembler to do that part for you:
you will use the .FILL pseudo-op to take a literal (decimal or hex, as you wish) and translate it into 16-bit two's complement binary, which will be stored in the indicated memory location; and then you will Load that value from memory into a register.

You **MUST** use the provided assn3.asm template to set this up: it ensures that the number to be converted is always stored in the same location (the **memory address specified in your template**) so we can test your work; make sure you fully understand the code fragment we provide.

At this point, your value will be stored in, say, R1: it is now your job to identify the 1's and 0's from the number and print them out to the console one by one, from left *(the leading bit, aka the leftmost bit, aka bit 15, aka the most significant bit)* to right *(the trailing bit, aka the rightmost bit, aka bit 0, aka the least significant bit)*.

Important things to consider:

- Recall the difference between a positive number and a negative number in 2's complement binary: if the most significant bit (MSB) is 0, the number is considered positive (or perhaps zero); if it is 1, the number is negative.
- The **BR**anch instruction has parameters (n, z, p) which tell it to check whether a value is **n**egative, **z**ero, or **p**ositive (or any combination thereof). ***Hint****: what can you say about the msb of the LMR (Last Modified Register) if the n branch is taken?*
  Review the workings of the NZP condition codes and the BR instruction here .
- Once you are done inspecting the MSB and printing the corresponding ascii '0' or '1', how would you *shift* the next bit into its place so you could perform the next iteration?
  Hint*: the answer is in the objectives!*

Pseudocode:

```
for(i = 15 downto 0):
     if (msb is a 1):
          print a 1
     else:
          print a 0
     shift left
```

Note on creating LC-3 "control structures"

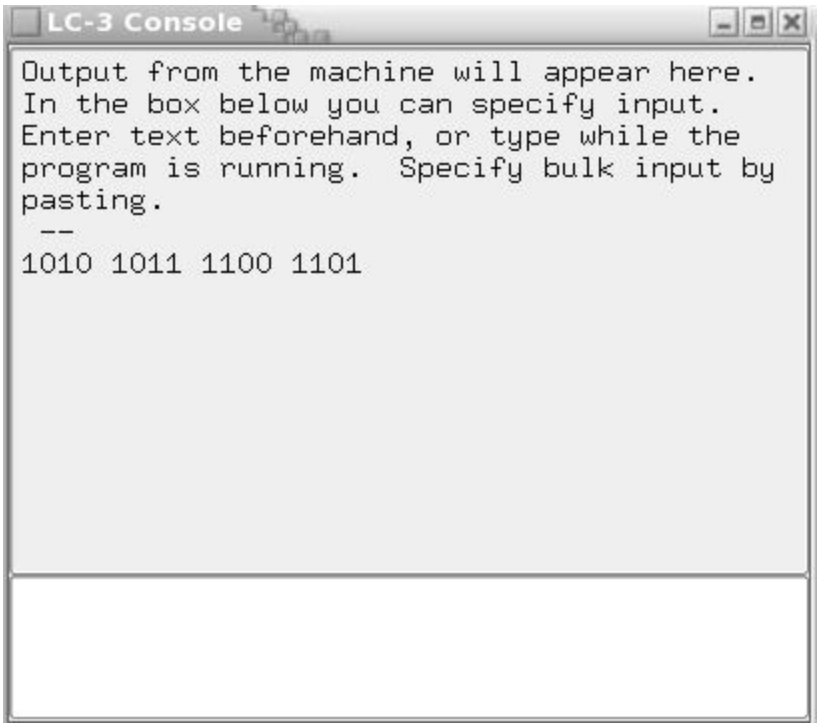
See here for tips on creating LC-3 versions of the branch and loop control structures you are familiar with from C++ *(Resources -> LC-3 Resources -> LC3 Assembly Language -> Control Stuctures in LC3)*

Expected/ Sample output

In this assignment, your output will simply be the contents of R1, printed out as 16 ascii 1's and 0's, grouped into packets of 4, separated by spaces *(as always, newline terminated, but with NO terminating space!)*

So if the hard coded value was xABCD, your output will be:

```
1010 1011 1100 1101
```



(The value stored to memory with .FILL was xABCD)

Note:

1. *There are **spaces** after the first three "packets" of 4 bits (but no space character at end!)*
2. *There is a **newline** after the output - again, there is **NO** space before the **newline***
3. You **must** use the memory address specified in your template to hold the value to be output

Your code will obviously be tested with a range of different values: Make sure you test your code likewise!

Uh...help?

- **MSB**
  - Stands for Most Significant Bit
    - aka “left most bit” or “leading bit” or bit 15
  - When MSB is 0:
    - Means that the number is **Not Negative** (Positive or Zero)
  - When MSB is 1:
    - Means that the number is **Negative**
  - **Further Reading**
    - https://en.wikipedia.org/wiki/Most_significant_bit

- **Left Shifting**
  Left shifting means that you shift all the bits to the left by 1: so the MSB is lost, and is replaced by the bit on its right. A 0 is "shifted in" on the right to replace the previous LSB.

  4-bit Example:

```
0101 ; #5
When Left Shifted, with 0 shifted in to LSB:
1010 <---- 0101
1010 ; #10
```

  What happened when we left shifted? How did the number change?
  When left shifting, the number gets multiplied by 2? Why 2?
  Well, what happens when you shift a *decimal* number one place to the left? Why?
  (Practical differences between decimal and binary numbers are that we don't usually limit decimal numbers to a specific number of places, nor do we usually pad them with leading zeros).

  Further Reading
  - https://en.wikipedia.org/wiki/Logical_shift

Submission Instructions

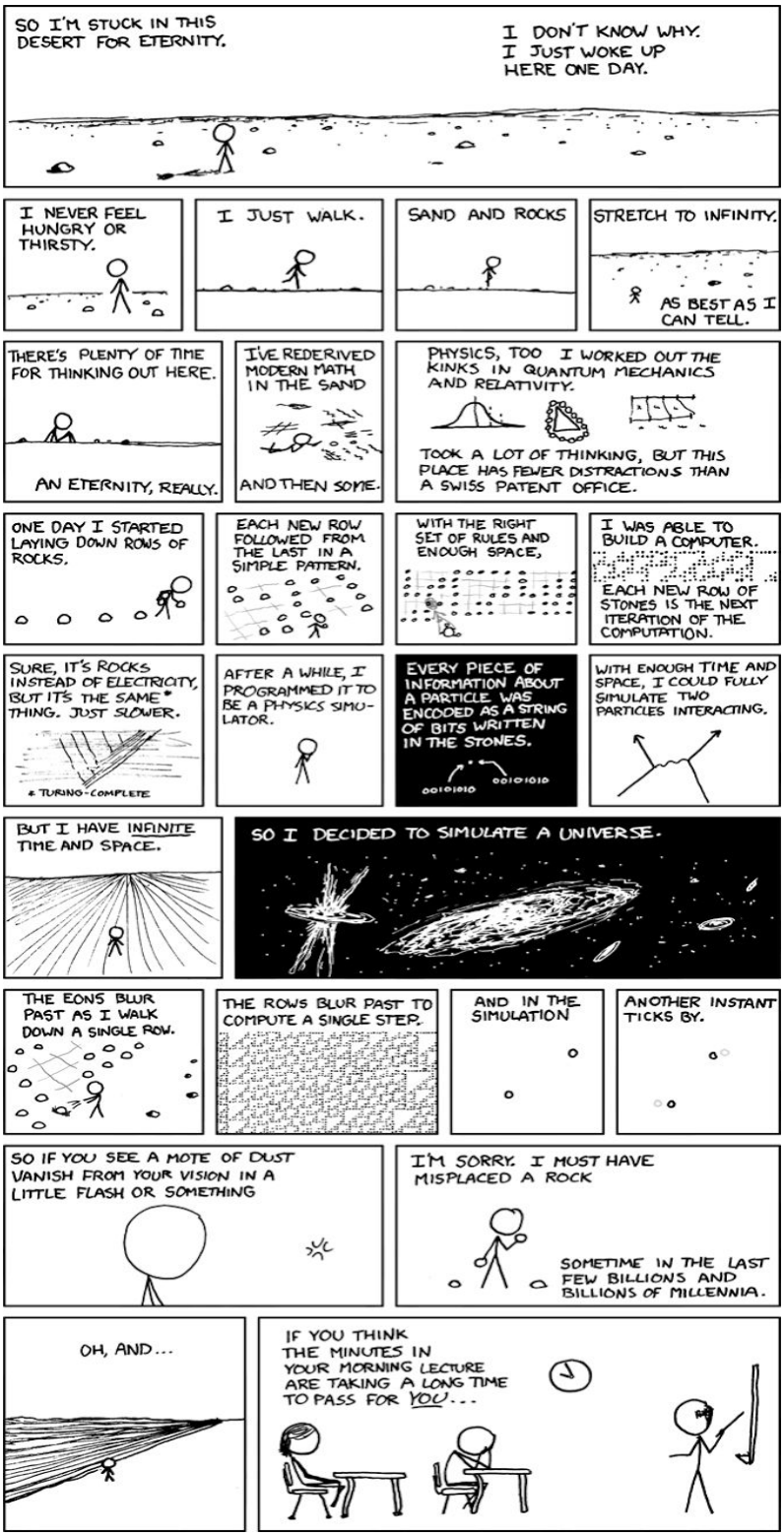
Submit ("Upload") your **assignment2.asm** file *(and ONLY that file!)* to the Programming Assignment 2 folder in Gradescope: the Autograder will run & report your grade within a minute or so.
You may submit as many times as you like - your grade will be that of your last submission.
If you wish to set your grade to a previous submission with a higher score, you may open your "Submission history" and "Activate" any other submission - that's the one we will see.

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 output, resulting in a grade of 0.

Comics??! Sweet!!



Source: http://xkcd.com/505/