CS2110 Spring 2017
Homework 6

Created By: Shayan Pirani, Preston Olds, Roi Atalla

Make sure you read the rules and regulations at the end!

Objectives:

The goal of this assignment is to help you become comfortable coding in the LC-3 assembly language. This will involve writing small programs, reading input from keyboard, printing to the console, and converting from high-level code to assembly.

Overview:

A few requirements:

1. Your code must assemble with **NO WARNINGS OR ERRORS**. To assemble your program, open the file with Complx. It will show any errors in pop-up windows.
2. Comment your code! This is especially important in assembly because it's much harder to interpret what's happening later, and you will be glad you left notes. Comments should show what registers are being used for, and what not-so-intuitive lines of code are actually doing. To comment code in LC-3 assembly, just type a semicolon (;) and the rest of the line will be a comment. Avoid stating the obvious in your comments, it doesn't help in understanding what the code is doing.

   Good comment:
   ```
   ADD R3, R3, -1       ; counter--
   BRp LOOP             ; if counter == 0 don't loop again
   ```

   Bad comment:
   ```
   ADD R3, R3, -1       ; Decrement R3
   BRp LOOP             ; Branch to LOOP if positive
   ```

3. **DO NOT assume that anything in the LC-3 is already zero!** Treat the machine as if random values were stored in the register file and memory, and your program

was loaded on top. NOTE: To test your code with randomized memory and registers, go to "File -> Randomize and Reload", and then select your assembly file.

4. **DO NOT** use the following instructions: JMP, JSR, JSRR.
5. **DO NOT** write any TRAPs.
6. **DO NOT** execute any data as if it were a function (meaning your .fill's should go after "HALT").
7. **DO NOT** add any comments beginning with @plugin or change any pre-existing comments of this kind.
8. PLEASE test your assembly code. Don't assume it just works!
9. Automatic testers for each file have been provided with this assignment, as .xml files. Use the **lc3test** command from the terminal to run these testers on your code. Run **"lc3test"** in the terminal to see usage information. **The grade you receive from an automatic tester is NOT representative of your grade on the assignment. The TAs will check your submission with a different set of automatic tests. Provided tests are there to help you complete the assignment!**

Assembly Overview:

For this assignment, you will be writing four assembly programs. The purpose of this assignment is to get you familiar and more comfortable with writing assembly code. For each part of this homework, we will supply you with pseudo-code, and you must write an equivalent assembly program. You have been given skeleton files for this assignment. We recommend following the pseudo-code as closely as possible.

```
.orig x3000
     LEA R0, HW      ; Load the address of the string
     PUTS            ; Output the string
     HALT            ; Stop executing instructions
HW .stringz "Hello World.\n"
.end
```

Above is a simple assembly program that prints "Hello World." and a new line to the console. **Semicolons** denote comments. You don't need a semicolon after every line, only before comments. **.orig** is a pseudo-op. Pseudo-ops are "guidelines" for the assembler that are not actually assembly instructions. For example, **.orig x3000** tells the assembler to place this block of code at location x3000, where the LC-3 starts executing code. Therefore, **LEA R0, HW** is at address x3000, **PUTS** is at address x3001, and so on.

After the **.orig** line, your actual assembly code begins. **PUTS** is a pseudonym for a TRAP call that prints a string whose address is stored in R0, and **HALT** is a pseudonym for a TRAP that stops the LC-3. **.stringz** is a pseudo-op that stores a particular string of characters in memory, followed by a zero. In the above example, 'H' is stored at x3003, 'e' is stored at x3004, and so on. **.end** tells the assembler where to stop reading code for the current code block. Every **.orig** statement must have a corresponding **.end** statement. Some other pseudo-ops you should know are:

- **.fill [value]** which puts a given value into that memory location
- **.blkw [n]** which reserves the next n memory locations, filling them with 0.

Another TRAP instruction for interacting with the console is **OUT**. This instruction prints a character from R0 to the console. Below is a short example program that prints the letter 'A' to the console. The ASCII value for 'A' is 65, which is used by **OUT**.

```
.orig x3000
     LD R0, LETTER
     OUT
     HALT
LETTER .fill 65
.end
```

After writing your assembly code, you can test it using Complx. Complx is a full-featured LC-3 simulator, and we recommend running your code in the following fashion:

1. Go to the "File" menu, and select "Randomize and Reload". This randomly assigns values to every memory location and register, and loads your assembly file over the randomized memory.
2. Press the "Run" button to run your code until a HALT instruction or breakpoint is hit. You can also click "Step" to execute one instruction at a time, or "Step back" to go back one executed instruction.

One more thing: it is very important that you use Appendix A in the book to your advantage. Make sure you know what an instruction does before using it! Take a look at this instruction: **LD R2, 5**. What exactly is this instruction doing? Is it loading the number 5 into R2? Remember that the bits preceding the destination register are based on the PCOFFSET9, this is not an immediate value, you are merely loading data from an address location.

Part 1 - Integer Division (divide.asm):

Write a program that divides two non-negative numbers A and B. The program will store the quotient in QUOTIENT, and will store the remainder in REMAINDER. If B is zero, store -1 in QUOTIENT and 0 in REMAINDER. A and B are the inputs, provided as .fill'd values. QUOTIENT and REMAINDER are the outputs. Pseudo-code:

```
QUOTIENT = 0, REMAINDER = 0
if(B == 0) {
     QUOTIENT = -1;
} else {
     while (A >= B) {
        QUOTIENT = QUOTIENT + 1;
        A = A - B;
    }
    REMAINDER = A;
}
```

Part 2 - Linear Search (search.asm):

Write a program to search for a certain value in an array. The elements of an array are always contiguous in memory. The length of the array is given in LENGTH, and the starting address of the array is in ARRAY. The number you are searching for is in NUMBER. If the number exists in the array, store the number 1 in RESULT, otherwise store 0 in RESULT. **Note:** The array can have zero or more elements.

Pseudo-code:

```
var counter = 0;
RESULT = 0;
while(counter < LENGTH) {
    if(ARRAY[counter] == NUMBER) {
        RESULT = 1;
        break;
    }
    counter++;
}
```

Part 3 - Print Pyramid (pyramid.asm):

Write a program to print out a pyramid to the console. The pyramid will have a certain number of levels, stored in LEVELS. For example, if LEVELS is 5, your pyramid will look like the following. **HINT**: An ASCII table may help you in printing individual characters.

```
    *
   ***
  *****
 *******
*********
```

Pseudo-code:

```
var current = 1;
var spaces = LEVELS - current;
var stars = 1;
var counter = 0;
while(current <= LEVELS) {
    while(counter < spaces) {
```

```
                print " "
                counter = counter + 1;
            }
            counter = 0;
            spaces = spaces - 1;
            while(counter < stars) {
                print "*"
                counter = counter + 1;
            }
            print "\n"
            counter = 0;
            stars = stars + 2;
            current = current + 1;
        }
```

Part 4 - Bubble Sort (bubble.asm):

Write a program that sorts an array (whose first element is located at memory address ARRAY) of length LENGTH in ascending order. You may use whichever sorting algorithm you prefer, but you are recommended to go by the pseudo-code. ARRAY and LENGTH are provided as .fill'd values. **Note:** The actual array does NOT start at the ARRAY label. ARRAY contains the memory location at which the array actually begins. In Complx, press Ctrl + V to open a new view, and then press Ctrl + G to navigate to the location where the array begins.

Pseudo-code:

```
    for (var k = 0; k < LENGTH; k++) {
        var isSorted = 1;
        for (var i = 1; i < LENGTH - k; i++) {
            if (ARRAY[i] < ARRAY[i - 1]) {
                var temp = ARRAY[i];
                ARRAY[i] = ARRAY[i - 1];
                ARRAY[i - 1] = temp;
                isSorted = 0;
            }
        }
        if (isSorted) {
            break;
        }
    }
```

Deliverables:

Remember to put your name at the top of EACH file you submit. The files should be named exactly as given:

- divide.asm
- search.asm
- pyramid.asm
- bubble.asm

Rules and Regulations:

General Rules

- Starting with the assembly homework assignments, Any code you write (if any) must be clearly commented and the comments must be meaningful. You should comment your code in terms of the algorithm you are implementing we all know what the line of code does.

- Although you may ask TAs for clarification, you are ultimately responsible for what you submit. This means that (in the case of demos) you should come prepared to explain to the TA how any piece of code you submitted works, even if you copied it from the book or read about it on the Internet.

- Please read the assignment in its entirety before asking questions.

- Please start assignments early, and ask for help early. Do not email us the night the assignment is due with questions.

- If you find any problems with the assignment, it would be greatly appreciated if you reported them to the author (whose name can be found at the top of the assignment). Announcements will be posted if the assignment changes.

Submission Conventions

- All files you submit for assignments in this course should have your name at the top of the file as a comment for any source code file, and somewhere in the file, near the top, for other files unless otherwise noted.

- When preparing your submission you may either submit the files individually to T-Square or you may submit an archive (zip or tar.gz only please) of the files (preferred). You can create an archive by right clicking on files and selecting the appropriate compress option on your system.

- If you choose to submit an archive, please don't zip up a folder with the files, only submit an archive of the files we want (see **Deliverables**).

- Do not submit compiled files, that is, .class files for Java code and .o files for C code. Only submit the files we ask for in the assignment.

- Do not submit links to files. We will not grade assignments submitted this way, as it is easy to change the files after the submission period ends.

Submission Guidelines

- You are responsible for turning in assignments on time. This includes allowing for unforeseen circumstances. If you have an emergency let us know ***IN ADVANCE*** of the due time supplying documentation (i.e. note from the dean, doctor's note, etc). Extensions will only be granted to those who contact us in advance of the deadline and no extensions will be made after the due date.

- You are also responsible for ensuring that what you turned in is what you meant to turn in. After submitting you should be sure to download your submission into a brand new folder and test if it works. No excuses if you submit the wrong files, what you turn in is what we grade. In addition, your assignment must be turned in via T-Square. Under no circumstances whatsoever we will accept any email submission of an assignment. **Note:** if you were granted an extension you will still turn in the assignment over T-Square.

- There is a 6-hour grace period added to all assignments. You may submit your assignment without penalty up until 11:55PM, or with 25% penalty up until 5:55AM. *So what you should take from this is not to start assignments on the last day and plan to submit right at 11:54AM.* You alone are responsible for submitting your homework before the grace period begins or ends; neither T-Square, nor your flaky internet are to blame if you are unable to submit because you banked on your computer working up until 11:54PM. The penalty for submitting during the grace period (25%) or after (no credit) is non-negotiable.

Syllabus Excerpt on Academic Misconduct

Academic misconduct is taken very seriously in this class.
Quizzes, timed labs and the final examination are individual work.

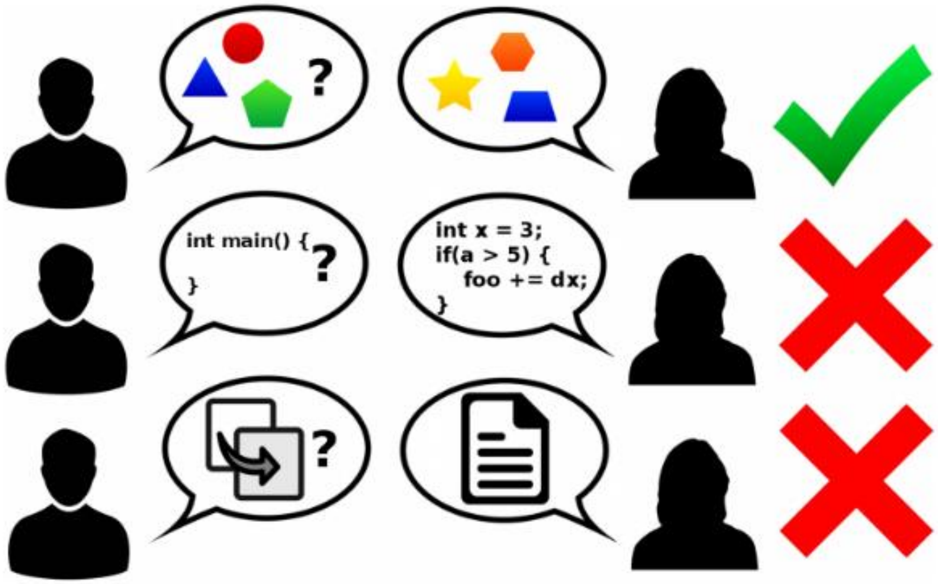
Homework assignments are collaborative. In addition, many homework assignments will be evaluated via demo or code review. During this evaluation, you will be expected to be able to explain every aspect of your submission. Homework assignments will also be examined using electronic computer programs to find evidence of unauthorized collaboration.

What is unauthorized collaboration? Each individual programming assignment should be coded by you. You may work with others, but each student should be turning in their own version of the assignment. Submissions that are essentially identical will receive a zero and will be sent to the Dean of Students' Office of Academic Integrity. Submissions that are copies that have been superficially modified to conceal that they are copies are also considered unauthorized collaboration.

You are expressly forbidden to supply a copy of your homework to another student via electronic means. This includes simply e-mailing it to them so they can look at it. If you supply an electronic copy of your homework to another student and they are charged with copying, you will also be charged. This includes storing your code on any site which would allow other parties to obtain your code such as but not limited to public repositories (Github), pastebin, etc. If you would like to use version control, use github.gatech.edu

Is collaboration allowed?

Collaboration is allowed on a high level, meaning that you may discuss design points and concepts relevant to the homework with your peers, as well as help each other debug code. What you shouldn't be doing, however, is paired programming where you collaborate with each other on a low level. Furthermore, sending an electronic copy of your homework to another student for them to look at and figure out what is wrong with their code is not an acceptable way to help them, and it is often the case that the recipient will simply modify the code and submit it as their own.


?
int main() {
}
?
int x = 3;
if(a > 5) {
foo += dx;
}
?