Homework 5 [Due at lecture on Wed, Mar 18]

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Problem 1 (3 points)

Consider a 16 bit processor (each instruction is 16 bits wide). All the instructions have the following format:

<table>
<thead>
<tr>
<th>Opcode</th>
<th>Destination</th>
<th>Source 1</th>
<th>Source 2</th>
<th>Immval</th>
</tr>
</thead>
</table>

where destination, Source 1 and Source 2 are registers, and immval is the PC relative value of the offset in 2's complement form.

If there are 8 different instructions supported and there are 4 registers, specify:

a. The number of bits required for the opcode field
b. Number of bits required for destination, Source1, Source2 fields
c. The maximum and minimum values of the immval field.

Problem 2 (2 points)

Assume there exists another computer which can address $2^{32}$ memory locations, and assume that each of the memory locations contain 16 bits of data.

a. What is the size of MAR?
b. What is the size of MDR?
Problem 3 (10 points)

Write LC-3 instructions (in binary) to do the following:

a. Place a value 0x0005 into R1
b. Place the value at memory location 0x3005 into R2.
c. Store 2's complement of R3 into R4
d. Move the value of R5 into R6
e. Logically OR the contents of R5 and R6 and store the result into R0, i.e., R0 = R5 OR R6

Note: You can assume that each of these instructions start at memory location x3000

Problem 4 (9 points)

0010 000 011111111
0001 000 000 1 00001
1001 001 000 1 11111
0101 010 001 1 11000
0011 000 011111011
0011 001 011111011
0011 010 011111011

a. (4 points) Fill in the comments for the above program describing what each instruction does. For example, if one of the instructions was 1001 0100 1111 1111, then the comment for this instruction can be either "This instruction stores the complement of value at R3 into R2" or "R2 <-- NOT(R3)".

b. (3 points) If the initial condition of the memory locations 0x3100 to 0x3103 before executing the code are as shown below (ie, all are 0), what are the final values at these memory locations after executing the code?

<table>
<thead>
<tr>
<th>Address</th>
<th>Initial Value</th>
<th>Final Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x3100</td>
<td>0x0000</td>
<td></td>
</tr>
<tr>
<td>0x3101</td>
<td>0x0000</td>
<td></td>
</tr>
<tr>
<td>0x3102</td>
<td>0x0000</td>
<td></td>
</tr>
<tr>
<td>0x3103</td>
<td>0x0000</td>
<td></td>
</tr>
</tbody>
</table>
c. (2 points) If these instructions start at 0x2000 (instead of 0x3000) and the data values start at 0x2100 (instead of 0x3100), will these instructions still work? Specify why or why not.

**Problem 5 (4 points)**

A LD instruction in LC3 is located at 0x4200.

a. What are the largest and smallest addresses from where the data can be loaded using this instruction?

b. If LC3 used unsigned number for offset instead of two’s complement number, what would be the largest and smallest address from where the data can be loaded using this instruction?

**Problem 6 (2 points)**

The purpose of this problem is to get you setup with the PennSim LC-3 simulator, which will be important for subsequent homeworks. To get started with PennSim, look at the information on the Computing page. Specifically, go through the PennSim Guide.

Download the PennSim simulator from the Computing page and run it. You should be able to run PennSim on any computer (with Java 1.6 or higher installed). They do not require any installation; they are self-contained executable files.

- To run on a Windows/Mac computer: double click the PennSim.jar file.
- To run on a linux machine: open Terminal and navigate to the folder containing PennSim.jar. Execute the following command "java -jar PennSim.jar"

a. (2 points) Once you have opened the simulator, list the register names used by the simulator (visible on the upper left corner). Hint: The names begin with R0 and end with CC.