CS/ECE 252: INTRODUCTION TO COMPUTER ENGINEERING

UNIVERSITY OF WISCONSIN—MADISON

Prof. Mark D. Hill

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Midterm Examination 3
In Class (50 minutes)
Wednesday, April 15, 2015
Weight: 17.5%

NO: BOOK(S), NOTE(S), OR CALCULATORS OF ANY SORT.

The exam has ten pages. Circle your final answers. Plan your time carefully since some problems are longer than others. You must turn in the pages 1-8. Use the blank sides of the exam for scratch work.

Note: LC-3 instruction set is provided on Page 9

LAST NAME: _____________________________________________________________

FIRST NAME: ____________________________________________________________

ID#: ____________________________________________________________________

1
<table>
<thead>
<tr>
<th>Problem</th>
<th>Maximum Points</th>
<th>Points Earned</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
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<td>7</td>
<td>6</td>
<td></td>
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<tr>
<td>Total</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>
Problem 1 (3 points)

a. (1 point) Which of the following LC-3 instructions performs R3 = R3 + R2?

   i. 0001 010 011 0 00 011
   ii. 0001 011 010 0 00 010
   iii. 0001 011 010 0 00 011
   iv. 0001 010 010 0 00 011

b. (1 point) The LC-3 branch instruction 0000 101 000011110 is located at memory address 0x4000. If the branch is taken, what does that imply about the values of the condition codes before the instruction is executed?

   i. Both N = 1 and P = 1, and Z = 0.
   ii. Either N = 1 or P = 1, and Z = 0.
   iii. Both N = 1 and Z = 1, and P = 0.
   iv. Either N = 1 or Z = 1, and P = 0.

c. (1 point) Which of the following instructions loads the data at address 0x300A into R2? Assume that R1 contains 0x3005. Also, assume that each instruction below is located at address 0x3000.

   i. 0010 010 000001001
   ii. 0110 010 001 000101
   iii. 1110 010 000001001
   iv. Both ii and iii, and not i
   v. Both i and ii, and not iii
   vi. All three of them, ie, i, ii and iii.
Problem 2  

(2 points)

Assume that the following instructions are a part of a program and that the second instruction (which is a branch) is taken:

0001 000 000 1 11001
0000 010 000000111

What was the value of R0 just before executing these two instructions?

\[ R0 = 7 \]

Problem 3  

(2 points)

An LDR instruction, located at 0x3000, uses R1 as its base register. The value currently in R1 is 0x2000.

a. (1 point) What is the largest address this instruction can load from?

Largest address = 0x2000 + 0x1F

b. (1 point) What is the smallest address this instruction can load from?

Smallest address = 0x2000 - 0x20

Problem 4  

(6 points)
Given below are six instructions that writes some value into register R2. Assuming that initial values of \( R0 = 0x101 \) and \( R1 = 3 \) before executing each of these instructions, specify which value is getting stored in R2 after executing each instruction. You can assume that each of these instructions is located at \( 0x3000 \).

a. **(1 point)** 0001 010 001 0 00 000
   
   \[ R2 = 0x0104 \]

b. **(1 point)** 0001 010 001 1 00000
   
   \[ R2 = R1 + 0 = 0x3 \]

c. **(1 point)** 0101 010 001 0 00 000
   
   \[ R2 = R1 \text{ AND } 0x3 = 0x1 \]

d. **(1 point)** 0101 010 000 1 00000
   
   \[ R2 = 0x0100 \]

e. **(1 point)** 1001 010 001 11111
   
   \[ R2 = 1111 \text{ 1111 \text{ 1110} = 0xFFF} \]

f. **(1 point)** 1110 010 00000001
   
   \[ R2 = 0x3002 \]
Assume that the initial value of R0 = 6 and that the initial value of R2 = 0.

a. **(3 points)** Fill in the three missing comments for the program below.

<table>
<thead>
<tr>
<th>Instruction address</th>
<th>Instruction</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x3000</td>
<td>0001 010 010 1 00010</td>
<td>ADD R2, R2, #2</td>
</tr>
<tr>
<td>0x3001</td>
<td>0001 000 000 1 11111</td>
<td>ADD R0, R0, #-1</td>
</tr>
<tr>
<td>0x3002</td>
<td>0000 101 111111101</td>
<td>BRnp 0x3000</td>
</tr>
<tr>
<td>0x3003</td>
<td>1111 0000 0010 0101</td>
<td>HALT</td>
</tr>
</tbody>
</table>

b. **(2 points)** What is the value of R2 upon reaching the HALT instruction?

Loop repeats 5 times since R0 = 5

=> R2 = 2*6 = 12 = 0xC
Assume that the initial contents of R0 = 0x3010 and R1 = 0x3011. Also, assume that the initial values of memory locations from 0x300F to 0x3012 are all zeros.

For each of the instructions below, starting at 0x3000, specify what the values of memory locations 0x300F to 0x3012 are after executing each instruction.

<table>
<thead>
<tr>
<th>Instruction address</th>
<th>Instruction</th>
<th>Values at memory locations after executing the instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x3000</td>
<td>0011 000 000000111</td>
<td>Value at 0x300F:0x0 Value at 0x3010:0x3010 Value at 0x3011:0x0 Value at 0x3012:0x0</td>
</tr>
<tr>
<td>0x3001</td>
<td>0111 001 000 000010</td>
<td>Value at 0x300F:0x0 Value at 0x3010:0x3010 Value at 0x3011:0x0 Value at 0x3012:0x3011</td>
</tr>
<tr>
<td>0x3002</td>
<td>1011 001 00001111</td>
<td>Value at 0x300F:0x0 Value at 0x3010:0x3010 Value at 0x3011:0x3011 Value at 0x3012:0x3011</td>
</tr>
</tbody>
</table>

Problem 7 (6 points)
We are about to execute the program below. Assume that the condition codes before execution are N = 1, Z = 0, P = 0.

<table>
<thead>
<tr>
<th>Address</th>
<th>Instruction</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x3000</td>
<td>0011 001 000001011</td>
<td>Store R1 into location 0x300C</td>
</tr>
<tr>
<td>0x3001</td>
<td>0000 100 000000011</td>
<td>If N flag is set, branch to 0x3005</td>
</tr>
<tr>
<td>0x3002</td>
<td>0001 000 000 1 11011</td>
<td>R0 &lt;- R0 - 5</td>
</tr>
<tr>
<td>0x3003</td>
<td>0101 010 010 00 000</td>
<td>R2 &lt;- R2 AND R0</td>
</tr>
<tr>
<td>0x3004</td>
<td>1111 0000 010 0101</td>
<td>HALT</td>
</tr>
<tr>
<td>0x3005</td>
<td>1010 010 000000100</td>
<td>LDI R2, 0x300A</td>
</tr>
<tr>
<td>0x3006</td>
<td>1111 0000 0010 0101</td>
<td>HALT</td>
</tr>
</tbody>
</table>

a. **(3 points)** Fill in the four missing instructions in the program above.

b. **(3 points)** Suppose a section in memory before execution of the program is as follows:

<table>
<thead>
<tr>
<th>Address</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x300A</td>
<td>0x300C</td>
</tr>
<tr>
<td>0x300B</td>
<td>0x30FF</td>
</tr>
<tr>
<td>0x300C</td>
<td>0xACED</td>
</tr>
<tr>
<td>0x300D</td>
<td>0x300B</td>
</tr>
</tbody>
</table>

Given the initial values of the below registers, fill in the values after the program has completed execution (reached a HALT). Give your answers in *hex*.

<table>
<thead>
<tr>
<th>Register</th>
<th>Initial Value</th>
<th>Final Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>R0</td>
<td>0xFACE</td>
<td>0xFACE</td>
</tr>
<tr>
<td>R1</td>
<td>0x1234</td>
<td>0x1234</td>
</tr>
<tr>
<td>R2</td>
<td>0x300A</td>
<td>0x1234</td>
</tr>
</tbody>
</table>