CS/ECE 252: INTRODUCTION TO COMPUTER ENGINEERING

UNIVERSITY OF WISCONSIN—MADISON

Professor Guri Sohi
TAs: Newsha Ardalani and Rebecca Lam

Examination 4
In Class (50 minutes)
Wednesday, Dec 14, 2011
Weight: 17.5%

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

This exam has 12 pages, including a blank page at the end. Plan your time carefully, since some problems are longer than others. You must turn in pages 1 to 9.

LAST NAME: ________________________________________________

FIRST NAME: ______________________________________________

SECTION: __________________________________________________

ID# _________________________________________________________
<table>
<thead>
<tr>
<th>Question</th>
<th>Maximum Point</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>
Q1. Syntax Errors in LC-3 Assembly Codes (3 points)

a. (1 pt) Circle any illegal labels in an assembly language program:
   
   - ADD
   - END
   - .FILL
   - BLKW
   - OR
   - NAND

b. (2 pt) The following program has multiple syntax errors. One of them, along with an explanation of the error, is indicated in the table below. In the two blank rows of the table, identify and explain two more syntax errors:

```
.ORIG x3000
LDI   R1, COUNT
AND   R1, R1, M1
LOOP  LEA   R0, x2FF
       ADD   R0, R1, R2
       BRz   LOOP
NOT   R1, R1, R1
HALT
M1    .FILL x4000
COUNT .FILL #100
.END
```

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>AND R1, R1, M1</td>
<td>AND reg, reg, label is illegal</td>
</tr>
<tr>
<td>LOOP LEA R0, x2FF</td>
<td>x2FF is &gt; PCoffset9 field for LEA</td>
</tr>
<tr>
<td>NOT R1, R1, R1</td>
<td>NOT reg, reg, reg is illegal</td>
</tr>
</tbody>
</table>


Q2. (5 points)

An assembly language LC-3 program is given below:

```
.ORIG x3000
L1
 LEA R1, L1
 AND R2, R2, x0
 ADD R2, R2, x3
 LD R3, P1
L2
 LDR R0, R1, xC
 TRAP x21 ; OUT (Write char)
 ADD R3, R3, #-1
 BRz GLUE
 ADD R1, R1, R2
 BRnzp L2
GLUE
 HALT
P1
 .FILL x7
 .STRINGZ “GWHoeiolTdchboymreee”
.END
```

a. Fill in the symbol table created by the first pass of the assembler on the above program. (2 points)

<table>
<thead>
<tr>
<th>Symbol Name</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>x3000</td>
</tr>
<tr>
<td>L2</td>
<td>x3004</td>
</tr>
<tr>
<td>GLUE</td>
<td>x300A</td>
</tr>
<tr>
<td>P1</td>
<td>x300B</td>
</tr>
</tbody>
</table>

b. After the program is assembled and loaded, what binary pattern is stored in memory location x3005? (1 point)
   TRAP x21 -> 0xF021 -> 1111 0000 0010 0001

c. What is the output of this program? (2 points)
   Goodbye
Q3. (4 points)

We want the following code to shift the value at memory location M1 to the left by the number of bits stored at memory location M2, but there is one error in this code.

```
.ORIG   x3000
LD      R1, M1
LD      R2, M2
LOOP    BRz    DONE
       ADD     R2, R2, #-1
       ADD     R1, R1, R1
       BR      LOOP
DONE    HALT
```

M1 .FILL x000C
M2 .FILL x0008
.END

1. How many times does the instruction labeled LOOP get executed? Explain. (2 points)
   \[ 16 - 2 + 1 = 15 \text{ times} \]

2. What is wrong with this program? Explain. (2 point)
   ADD R2, R2, #-1 and ADD R1, R1, R1 are misplaced, they should exchange their location.
Q4. Trap Handling (3 points)

The figure shown below represents the flow control from a user program to an OS service routine and back when a trap instruction is called. The flow control goes from A within a user program, to B, the operating system service routine, and back to the user program C. Fill out the three empty boxes below corresponding with question marks. Boxes 1 and 2 should be filled with addresses and box 3 should be filled with an instruction. Write your answers in hexadecimal.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>x0023</td>
<td>x05E0</td>
<td>xC1C0</td>
</tr>
</tbody>
</table>
Q5. Traps and subroutines (5 points)

An LC-3 programmer wrote the code below to read 10 single-digit decimal numbers from the keyboard, compute their average, and display the ceiling of the resultant average on the monitor.

Fill in the blanks below with assembly code to complete the program.

```
.ORIG x3000

AND R2, R2, #0 ; R2 keeps track of the sum
LD R6, CHtoD ; Char->Digit template
LD R5,DtoCH ; Digit->Char template
LD R7, COUNT ; Initialize to 10
AGAIN TRAP x23 ; Get char
LD R7, SAVEDREG ; Restore ? before continuing
ADD R0, R0, R6 ; Convert to number
ADD R2, R2, R0 ; Add the new number to the sum
ADD R7, R7, -1 ; Decr counter
ST R7, SAVEDREG ;
BRp AGAIN ; More digit?
LD R1, COUNT ;
JSR DIV
ADD R0, R0,R5 ; Convert to char
TRAP x21 ; Output char
HALT

; DIV subroutine
; Args: R2,R1 RET: R0=R2/R1
DIV AND R0, R0, #0 ; Initialize to 0
NOT R1, R1 ;
ADD R1, R1, #1 ; Negate R1
LOOPDIV ADD R0, R0, #1
ADD R2, R2, R1
BRP LOOPDIV
RET

DtoCH .FILL x0030
CHtoD .FILL xFFD0
COUNT .FILL #10
SAVEDREG .BLKW 1
.END
```
Q6. Short Answer Questions (5 points)

Answer the following short answer questions in one or two sentences.

1. What problem could occur if the keyboard hardware does not check the DSR before writing to the DDR? (1 point)

   The DSR bit 15 indicates when the last character written in the DDR has been read by the display, so if we don’t check we could overwrite the previous value before it has been displayed by the monitor.

2. What is the difference between asynchronous and synchronous I/O? (1 point)

   Asynchronous I/O:
   Data is not sent at a fixed rate
   Needs some method of synchronization (e.g. handshaking) with the processor

   Synchronous I/O
   Data is sent at a fixed rate
   Doesn’t need additional synchronization

3. What is the difference between memory mapped I/O and special I/O instructions? (1 point)

   Memory mapped I/O has reserved locations in memory that store the addresses of the I/O devices and corresponding registers whereas special I/O instructions use special opcodes for I/O.

4. Give one potential benefit and one potential drawback of RFID implants (2 points).

   Benefits: storage of personal health information, usage as personal ID
   Drawbacks: privacy concerns, concerns about body integrity
Q7. General Questions (5 points, 1 point each)

Circle the best answer for the following questions about LC-3:

1. Which of the following can be used only once per file?
   a. .STRINGZ
   b. .BLKW
   c. .ORIG
   d. .FILL

2. Which of the following is true about “callee-save”?
   a. Used by calling routine to save and restore registers that will be used in the routine
   b. Save R7 before calling TRAP
   c. Save R0 before calling TRAP x23
   d. Used by called routine to save registers used by the routine

3. Suppose the instruction JSR label is stored at memory location x3000. After the instruction is executed, which of the following is true if label=x3050 and R7=x4000 before execution?
   a. R7 = x3050
   b. R7 = x3001
   c. R7 = x3000
   d. R7 = x4000

4. Which bit in the KBSR is the interrupt enable bit?
   a. 15
   b. 14
   c. 13
   d. 12

5. Which of the following is not true about interrupt driven I/O?
   a. The device controls the interaction by sending a special signal to the processor when it is ready
   b. It is more efficient than polling
   c. It has built in priority levels for different device requests
   d. The processor must routinely check the status register for the device until new data arrives or the device is ready