UNIVERSITY OF WISCONSIN—MADISON

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Examination 4
In Class (50 minutes)
Wednesday, Dec 14
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>
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<tbody>
<tr>
<td>1</td>
<td>3</td>
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<td>6</td>
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<td>7</td>
<td>5</td>
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<td>Total</td>
<td>30</td>
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</tbody>
</table>
Q1. Syntax Error in LC-3 Assembly Codes (3 points)

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

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 R3, COUNT
AND R3, R3, M1

LOOP
  LEA R5, x2FF
  ADD R5, R3, R4
  BRz LOOP
  NOT R3, R3, R3

HALT
M1 .FILL x5000
COUNT .FILL #100
.END
```

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>AND R3, R3, M1</td>
<td>AND reg, reg, label is illegal</td>
</tr>
<tr>
<td>LOOP LEA R5, x2FF</td>
<td>x2FF is &gt; POffset9 field for LEA</td>
</tr>
<tr>
<td>NOT R3, R3, R3</td>
<td>NOT reg, reg, reg is illegal</td>
</tr>
</tbody>
</table>
Q2. Two-Pass Assembly Process (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 “HGioeTolhdceboryme”
.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)
   HiThere
Q3. Logical Error (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.

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

1. How many times does the instruction labeled LOOP get executed? (2 points)
   \[16 + 1 = 17\text{ times}\]

2. What is wrong with this program? (2 points)
   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.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>x0092</td>
<td>x06A0</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 ; Save ?? upon call of trap
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. .BLKW
   b. .STRINGZ
   c. .FILL
   d. .ORIG

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

3. Suppose the instruction JSR label is stored at memory location x4000. 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 = x4000
   d. R7 = x4001

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

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. The processor must routinely check the status register for the device until new data arrives or the device is ready
   c. It has built in priority levels for different device requests
   d. It is more efficient than polling