

CS/ECE 252: INTRODUCTION TO COMPUTER ENGINEERING

UNIVERSITY OF WISCONSIN—MADISON

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Examination 4

In Class (50 minutes)
Wednesday, May 3rd, 2017
Weight: 17.5%

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

The exam has eleven pages. You must turn in the pages 1-9. Circle your final answers. Plan your time carefully since some problems are longer than others. Use the blank sides of the exam for scratch work.

LAST NAME: _____
FIRST NAME: _____
ID#: _____

Problem	Maximum Points	Points Earned
1	4	
2	5	
3	5	
4	5	
5	5	
6	4	
7	4	
Total	32	

1. The following LC-3 assembly code contains assembly syntax errors. Identify and fix at least 4 such errors. (4 points)

```
.ORIG x3000
    AND R5, R5, ZERO
    LD R5, STRING
NEXT  ADD R5, R5, #32
      BRz NEXT
MAIN  LD R4, MAIN
      SUB R4, R4, #1
      ST R4, STRING
NEXT  HALT
ZERO  .FILL #0
      .BLKW 4
      .BLKW 3
STRING .STRINGZ "ABC"
      .END
```

2. a) Fill in the symbol table for following LC-3 assembly code. You may not need to fill all rows. (5 points)

```

        .ORIG x3000
        AND R3, R3, #0
        LD R4, VAL1
LOOP    BRZ DONE
        JSR INC1
        JSR INC2
DONE    ST R3, ANS
        OUT
        HALT
INC1    ADD R3, R3, #1
        RET
INC2    ADD R4, R4, #-1
        RET ; Storage area for variables below:
ANS     .BLKW #4
VAL0    .STRINGZ "CS"
VAL1    .STRINGZ "252"
        .END

```

SYMBOL	Value (in hex)

b) Convert the instruction stored at memory location 0x3006 into binary.

3. An LC-3 assembly program is given below: (5 points)

```
        .ORIG x3000
        LD R0, DATA
ADD     R0, R0, #10
PRINT1 OUT
        AND R0, R0, #0
        ADD R0, R7, R0
PRINT2 OUT
        HALT
DATA    .FILL 0xFFFF
```

a. What is the output (in hex) after the OUT statement at the symbol PRINT1 finishes execution?

b. What is the output (in hex) after the OUT statement at the symbol PRINT2 finishes execution?
Explain your answer.

c. Complete the following incomplete code snippet that uses the memory-mapped LC-3 registers KBSR and KBDR to take input from the keyboard instead of the GETC instruction. Your code should store the value entered from keyboard in register R1.
(Assume KBSR is mapped to address xFE00 and KBDR is mapped to address xFE02.)

```
ECHO:  _____, _____, KBSR
        _____
        _____, R1, KBDR
```

```
KBSR .FILL xFE00
KBDR .FILL xFE02
```

4. Short answer questions (5 points)

a. Briefly describe what happens in the **linking** phase of an assembly program.

b. How are the Display Data Register (DDR) and Display Status Register (DSR) used when TRAP x21 (OUT) is called?

c. What is a **service routine** in LC-3? Give an example.

d. **Briefly** describe the difference between synchronous and asynchronous I/O.

5. The following LC-3 assembly code implements a **subroutine**. After taking input, it outputs a lowercase letter (a-z) if the input was uppercase (A-Z), and a “N” otherwise. (5 points)

SUBR GETC

```
ADD R5, R0, 0
NOT R5, R5
ADD R5, R5, 1
```

```
LD R1, LBOUND
LD R2, UBOUND
```

```
ADD R3, R5, R2
BRn PNOT
ADD R3, R5, R1
BRp PNOT
```

```
LD R3, DIFF
```

```
ADD R0, R0, R3
OUT
BRnzp FINISH
```

```
PNOT LD R0, N
OUT
FINISH RET
```

```
UBOUND .FILL x5A ; ASCII value for "Z"
LBOUND .FILL x41 ; ASCII value for "A"
N      .FILL x4E ; ASCII value for "N"
DIFF   .FILL x20
```

a. Is this code able to successfully return? Explain why or why not.

b. Add lines to the code above to make this subroutine **callee-saved**. You should not modify any existing lines. **Clearly indicate which lines you have added and where.**

6. Examine the code below. You may assume that at the start of the program, all registers are set to 0. (4 points)

```
.ORIG x3000
GETC
AND R3, R3, 0
ADD R3, R3, R0

LD R1, ONE
NOT R1, R1
ADD R1, R1, 1

PRINT LD R0, C
OUT
LD R0, A
OUT
LD R0, T
OUT

ADD R0, R3, R1
BRZ FINISH

LD R0, S
OUT

FINISH HALT
C .FILL x63 ; ASCII 'c'
A .FILL x61 ; ASCII 'a'
T .FILL x74 ; ASCII 't'
S .FILL x73 ; ASCII 's'
ONE .FILL x31 ; ASCII '1'
```

a. If the input is the decimal number "1", what is output on the screen at the end of the program?

b. OUT only prints out one character at a time. Instead of printing individually, we decide to replace the code stored at memory locations **x3006 to x300B** with the following, much shorter block of code:

```
PRINT LD R0, C
PUTS
```

Will this output the same result as a)? Why or why not? **You must explain your answer for credit.**

7. Multiple choice questions. Circle **one** answer for each question. (4 points)

(i) Which of the following can **not** be used multiple times in a single assembly program?

- a) .FILL
- b) .ORIG
- c) .BLKW
- d) .STRINGZ

(ii) Assume that a LC-3 processor receives interrupts from 3 I/O devices (A, B and C) simultaneously. The priority levels for the interrupts are given below:

A) PL4 B) PL2 C) PL6

Assuming that no other interrupts come in, which of the above interrupts is serviced **last**?

- a) A
- b) B
- c) C
- d) Any selected at random

(iii) Our program begins at memory location x4000. We want to load the value x4020 into R3. Which LC-3 instruction can we use to accomplish this in a **single** line?

- a) LEA
- b) LD
- c) ST
- d) LDI

(iv) Which register is used to store **input data** after IN is called?

- a) R1
- b) R0
- c) R7
- d) R4

Assembler Directives

<i>Opcode</i>	<i>Operand</i>
.ORIG	address
.END	
.BLKW	n
.FILL	n
.STRINGZ	n-character string

Trap Codes

<i>Code</i>	<i>Equivalent</i>
HALT	TRAP x25
IN	TRAP x23
OUT	TRAP x21
GETC	TRAP x20
PUTS	TRAP x22