

CS/ECE 252: INTRODUCTION TO COMPUTER ENGINEERING

UNIVERSITY OF WISCONSIN—MADISON

Prof. Mark D. Hill

TAs: Sujith Surendran, Lisa Ossian

Midterm Examination 4

In Class (50 minutes)

Wednesday, May 6, 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. Trap Codes and Assembler directives are provided on page 10

LAST NAME: _____

FIRST NAME: _____

ID#: _____

Problem	Maximum Points	Points Earned
1	10	
2	8	
3	4	
4	6	
5	2	
Total	30	

Problem 1: Short answer questions

(10 points)

- a) **(1 point)** How many accesses to memory are made after the instruction fetch phase of a LDI instruction? Show your work.

2

- b) **(1 point)** For rare events, would you prefer interrupt-driven I/O or polling I/O? Justify your answer.

Interrupt-driven I/O, because polling I/O will waste a lot of time checking for the next input.

- c) **(1 point)** Briefly explain what the difference between asynchronous and synchronous I/O events.

Synchronous I/O events occur at fixed, predictable rates, so the processor can read or write at fixed time intervals. Asynchronous events occur at an unpredictable rate, such as a person typing on a keyboard.

d) (2 points) An LC-3 assembly program contains the following instruction:

```
MAIN    LD R5, MAIN
```

The symbol table entry for MAIN is $\times 4000$. What will be the value of R5 after the execution of the above instruction? Show your work.

Binary code for the instruction, 'LD R5, MAIN,' is 0010 101 11111111.

Therefore, R5 will be $\times 2BFF$.

e. (2 points) Briefly describe what happens during the linking and loading phases of an assembly program?

Loading: leads to copying an executable image into memory.

Linking: leads to resolving symbols between independent object files.

f. (3 points) Identify three **assembly** errors in the following code:

```
        .ORIG x3000

        LEA R1, NUMBER
        LD R1, NUMBER
LOOP    NOT R5, #2
        TRAP x29
        BRzp LOOP2
        AND R1, R1, FIVE
        LD R1, FIVE
        BRp LOOP

LOOP    HALT

FIVE    .FILL #5
NUMBER .FILL x60
        .END
```

- NOT with IMMEDIATE
- FIVE for AND
- Double declaration of LOOP

Problem 2: Two-pass assembly process

(8 points)

a) **(3 points)** Consider the following LC-3 assembly program.

```
.ORIG x3000

    LEA R2, STRING
    LD R3, NUMBER
HERE  ADD R1, R2, R3
    ADD R2, R1, #0
    LDR R0, R1, #0
    BRz DONE
    OUT
    BR HERE

THIS  .BLKW 5
STRING .STRINGZ "2down_3to_go"
NUMBER .FILL x4

DONE  HALT

.END
```

What would be the output on the console if you run the above code in Pennsim?

no

b) **(3 points)** In the first pass, the assembler creates the symbol table. Fill in the symbol table created by the assembler for this program

<u>Symbol</u>	<u>Address</u>
Here	3002
This	3008
String	300D
Number	301A
Done	301B

- c) **(2 points)** In the second pass, the assembler creates a binary version (.obj) of the program, using the entries from the symbol table shown below. Given that the following symbol table entries were generated in the first pass of assembly (for another program), fill in the binary code generated by the assembler for the two instructions located at x3000 and x3001.

Symbol Table:

Label	Address
ADDRESS	x3015
NEXT	x3016

Address	Assembly code	Binary Code
x3000	LD R0, ADDRESS	0010 000 000010100
x3001	BRnp NEXT	0000 101 000010100

Problem 3**(4 points)**

Consider the program below, the goal of which is to multiply the value in memory location corresponding to label Input1 with the value in memory location corresponding to label Input2 and store the result in the memory location corresponding to label RESULT.

```
.ORIG x3000
LD R2, ZERO
LD R0, Operand1
LD R1, Operand2

LOOP  BRn DONE
      ADD R2, R2, R0
      ADD R1, R1, -1
      BR LOOP

DONE  ST R2, RESULT
      HALT

RESULT .FILL    x0000
ZERO   .FILL    x0000
Input1 .FILL    x0008
Input2 .FILL    x0002
.END
```

a. **(2 points)** What is the value at RESULT after executing the HALT instruction? Write the answer in hexadecimal. Show your work.

0x18

b. **(2 points)** From your answer from 3a, you would have noticed that the answer is not the result of multiplication of input1 and input2. Identify what caused this error, and how do you fix it?

Instead of computing (the value in M0) x (the value in M1), the program above computes (the value in M0) x (the value in M1 + 1). We could fix that by changing "BRn DONE" to "BRz DONE" or "BRnz DONE".

Problem 4: Traps and Subroutines**(6 points)**

Suppose we want to write a new TRAP subroutine, TRAP x02. This subroutine takes an input from the caller of the subroutine through register R2. R2 has the memory address of the first character of a string. The subroutine then prints all characters that are not 'a'. Fill in the missing blanks to complete this subroutine code. Assume that we are implementing a callee-save subroutine. Save only those registers that are necessary.

Assume that the trap vector table (also known as the system control block) is shown below:

Address	Value
x0001	x2400
x0002	x2500
x0003	x2600

```

.ORIG x2500 _____

STORE    ST R0 __, SAVEREG1
         ST R2 __, SAVEREG2
         ST R5 __, SAVEREG3
         ST R7 __, SAVEREG4

LOOP     LDR R0, R2, #0 ;Load a character from the string.
         BRz RESTORE_  ;If there are no more characters, goto RESTORE
         LD R5, neg_aASCII ;Load negative of ASCII of 'a' into R5.
         ADD R2, R2, #1   ;Increment pointer to get next character.
         ADD R5, R5, R0   ;Determine if current character equals 'a'.
         BRz_ LOOP       ;If character is 'x', go load next character.
         OUT              ;Print the extracted character.
         BR LOOP         ;Branch to LOOP.

RESTORE LD __, SAVEREG1
         LD __, SAVEREG2
         LD __, SAVEREG3
         LD __, SAVEREG4
         RET

SAVEREG1 .BLKW 1
SAVEREG2 .BLKW 1
SAVEREG3 .BLKW 1
SAVEREG4 .BLKW 1
neg_aASCII .FILL 0xFF9D ; This is the negative of ASCII of 'a'
.END

```


Problem 5: I/O**(2 points)**

The following code segment should display the string specified at the “STRING” label on to the console. Write the missing assembly instructions of the program (without using PUTS/PUTC/OUT/TRAP instructions).

Hint: Make use of DSR, DDR

```
                .ORIG x3000

                LEA R3, STRING
NEXT            LDR R0, R3, #0

                _____ ;BRz END
POLL           _____ ;LDI R1, DSR
                _____ ;BRzp POLL
                _____ ;STI R0, DDR, #0

                ADD R3, R3, #1 ; Point to the next character
                BR NEXT
END            HALT

STRING .STRINGZ "Enjoy_your_holidays!" ; String to display
DSR    .FILL xFE04 ; Display status register location
DDR    .FILL xFE06 ; Display data register location

                .END
```

LC 3 Instruction Set to be provided here

TRAP CODES

<i>Code</i>	<i>Equivalent</i>	<i>Description</i>
HALT	TRAP x25	Halt execution and print message to console.
IN	TRAP x23	Print prompt on console, read (and echo) one character from keybd. Character stored in R0[7:0].
OUT	TRAP x21	Write one character (in R0[7:0]) to console.
GETC	TRAP x20	Read one character from keyboard. Character stored in R0[7:0].
PUTS	TRAP x22	Write null-terminated string to console. Address of string is in R0.

ASSEMBLER DIRECTIVES

<i>Opcode</i>	<i>Operand</i>	<i>Meaning</i>
.ORIG	address	starting address of program
.END		end of program
.BLKW	n	allocate n words of storage
.FILL	n	allocate one word, initialize with value n
.STRINGZ	n-character string	allocate n+1 locations, initialize w/characters and null terminator