

CS/ECE 252: INTRODUCTION TO COMPUTER ENGINEERING

UNIVERSITY OF WISCONSIN—MADISON

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Examination 4

In Class (50 minutes)

Friday, May 11, 2012

Weight: 17.5%

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

This exam has 9 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 11.

LAST NAME: _____

FIRST NAME: _____

SECTION: _____

CAMPUS ID# _____

EMAIL ID _____

| Question | Maximum Points | Points |
|-----------------|-----------------------|---------------|
| 1 | 6 | |
| 2 | 4 | |
| 3 | 5 | |
| 4 | 4 | |
| 5 | 2 | |
| 6 | 5 | |
| 7 | 4 | |
| Total | 30 | |

Problem 1 (6 points)

An LC-3 assembly language program is given below.

```

        .ORIG x3000
        LEA R0, STR1
        LEA R1, STR2
LOOP    LDR R2, R0, #0
        BRz DIFF
        LDR R3, R1, #0
        BRz DIFF
        ADD R0, R0, #1
        ADD R1, R1, #1
        BRnzp LOOP
DIFF    LDR R2, R0, #0
        LDR R3, R1, #0
        NOT R3, R3
        ADD R3, R3, #1
        ADD R3, R2, R3
        BRp OUT1
        BRn OUT2
        BRz OUT3
OUT1    LEA R0, STR1
        BRnzp DONE
OUT2    LEA R0, STR2
        BRnzp DONE
OUT3    LEA R0, STR3
DONE    PUTS
        HALT

```

```

STR1    .STRINGZ "Unsealed on a porch a letter sat"
STR2    .STRINGZ "I close my eyes only for a moment and the moment's gone"
STR3    .STRINGZ "There's a lady who's sure all that glitters is gold"

```

Note: there are 34 characters in the first string (including null)

- a. Fill in the symbol table created by the first pass of the assembler on the above program for the following labels / symbols (3 points)

| Label | Address |
|-------|---------|
| LOOP | 0x3002 |
| DIFF | 0x3009 |
| OUT1 | 0x3011 |
| OUT2 | 0x3013 |
| STR1 | 0x3018 |
| STR2 | 0x3039 |

- b.

- c. Assume we don't know anything about the strings stored in STR1, STR2, and STR3. What does the above program do? Give your answer in **one** or **two** sentences. (1 point)

It will compare STR1 and STR2 and output the longer string. Else it will display STR3.

- d. What is the output of this program? (2 points)

"I close my eyes only for a moment and the moment's gone"

Problem 2 (4 points) 1 point each

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

- a. What are the two methods for accessing I/O devices?

Memory mapped and special I/O instructions

- b. Define and contrast callee-save and caller-save.

Callee-save: the called subroutine will save any registers it will use during its execution

Caller-save: the caller of the subroutine will save any registers the subroutine will use before calling it.

The difference is when the registers are saved: before or within the subroutine

- c. Give one example of a syntax error using the ADD **immediate** instruction and explain the error.

AND R0, R0, #50 : Immediate value out of range

AND R0, R8, #0 : Invalid register

AND R0, R0, Label : Invalid input parameter

- d. Is there a problem with using AND as a label in an LC-3 assembly program? Why or why not?

Yes, AND is an instruction and cannot be used as a label.

Problem 3 (5 points)

The following LC-3 subroutine implements the PUTS service routine. This means it will output the string stored at the address stored in R0 and then return to normal execution.

```

        .ORIG x0301
        ST    R1, R1_TMP
        ST    R2, R2_TMP
L1     LDI    R2, DSR
        BRzp L1
        LDR    R1, R0, #0
        BRz   DONE
        STI    R1, DDR
        ADD    R0, R0, #1
        BRnzp L1
DONE   LD     R2, R2_TMP
        LD     R1, R1_TMP
        RET

DSR    .FILL    xFE04    ; Address of DSR
DDR    .FILL    xFE06    ; Address of DDR
R1_TMP .FILL    0
R2_TMP .FILL    0

```

- Fill in the blanks. **There should be one instruction per line and no NOPs.** (3 points)
- Assume the above assembly code is a service routine that is a part of the LC-3 OS. Suppose we can call it using TRAP xB0. Where is the address of the trap vector, and what are its contents? (2 points)

Give all answers in hex

| Address of TRAP vector | Contents at this memory location |
|------------------------|----------------------------------|
| 0xB0 | 0x0301 |

Problem 4 (4 points)

The following program reads two inputs from memory locations A and B and compares their contents. If $M[A] > M[B]$, the program terminates with the value 1 in memory location COMPARE_RESULT, otherwise it stores zero in COMPARE_RESULT and terminates. What is the problem with the following code? How can you resolve it? Answer in **one** or **two** sentences in the box provided.

```

                .ORIG      x3000
                LD         R0, A
                LD         R1, B
                JSR        COMPARE
                HALT

COMPARE        ST         R7, R7_TMP
                JSR        NEG          ; compute -R0
                ADD        R0, R0, R1  ; compute R1-R0
                BRN        STORE_ZERO
STORE_ZERO    LD         R0, ZERO
                ST         R0, COMPARE_RESULT
                BR         END_COMP
STORE_ONE     LD         R0, ONE
                ST         R0, COMPARE_RESULT
END_COMP      LD         R7, R7_TMP
                RET

NEG           ST         R7, R7_TMP
                NOT        R0, R0
                ADD        R0, R0, #1
                LD         R7, R7_TMP
                RET

A             .BLKW      1
B             .BLKW      1
R7_TMP       .BLKW      1
COMPARE_RESULT .BLKW      1

ZERO         .FILL      0
ONE          .FILL      1
                .END
```

Problem: R7_TMP is used for storing the return address of two subroutines that one of them is called inside the other. This causes the return address for COMPARE subroutine that is stored in R7_TMP to be overwritten when the NEG subroutine is being called.

Solution: Store R7 for COMPARE(NEG) subroutine in R7_TMP but for the NEG(COMPARE) subroutine in a memory location other than R7_TMP.

Problem 5 (2 points)

A programmer decides to design a variant of the LC-3 that does not need a keyboard status register. Instead, he creates a readable/writable keyboard data and status register (KBDSR). With the KBDSR, a program requiring keyboard input waits until a nonzero value appears in the KBDSR and reads this value into R0. The nonzero value is the ASCII value of the last key pressed. Then the program writes a zero into the KBDSR indicating that it has read the data. **Fill in the following blanks to implement this new scheme. (1 instruction per line)**

```
ZERO      LDI      R0, B
          BRz     ZERO

NONZERO    AND    Ri, Ri, #0
          STI    Ri, B

          BRnzp  NEXT_TASK

B         .FILL  xFE00      ; Address of KBDSR
```

Ri could be any register other than R0

Problem 6 (5 points)

Select **only one answer** choice for the following questions about LC-3:

1. Suppose JSRR R5 is stored at memory location x400F and R5 contains x3002. The execution of JSRR instruction will cause:
 - a. ***R7 to be loaded with x4010 and the PC to be loaded with x3002***
 - b. R7 to be loaded with x3003 and the PC to be loaded with x400A
 - c. R7 to be loaded with x3003 and the PC to be loaded with x400F
 - d. R7 to be loaded with x4010 and the PC to be loaded with x3003
2. Which of the following is **not true** about interrupt driven I/O?
 - a. It has built in priority levels for different device requests
 - b. The device controls the interaction by sending a special signal to the processor when it is ready
 - c. ***The processor must routinely check the status register for the device until new data arrives or the device is ready***
 - d. It is more efficient than polling
4. At the end of which phase of instruction cycle does an interrupt-driven I/O processor test for an interrupt signal?
 - a. Execute
 - b. Decode
 - c. ***Store result***
 - d. Fetch
5. In LC-3, in what range of addresses are the trap vectors stored?
 - a. xFDFF - xFFFF
 - b. ***x0000 - x00FF***
 - c. xFE00- xFFFF
 - d. xFF00 - xFFFF
5. Which one is the highest priority level?
 - a. PL0
 - b. ***PL7***
 - c. PL1
 - d. They are all equal in priority

Problem 7 (4 points)

Suppose the LC-3 is modified such that the TRAP vector table exists in the range of addresses from 0x0000 to 0x0007. The following tables show the TRAP vector table and the relevant system service routines.

TRAP vector table:

| Address | Memory Content |
|---------|----------------|
| 0x0000 | 0x000A |
| 0x0001 | 0x000F |
| 0x0002 | 0x000E |
| 0x0003 | 0x000A |
| 0x0004 | 0x000B |
| 0x0005 | 0x000D |
| 0x0006 | 0x000F |
| 0x0007 | 0x000C |

Service routines:

| Address | Label | Instruction |
|---------|-------|-----------------|
| 0x000A | | LD R0, L2 |
| 0x000B | | ADD R0, R0, #10 |
| 0x000C | | RET |
| 0x000D | L1 | LD R0, L3 |
| 0x000E | | BRn L1 |
| 0x000F | | RET |
| 0x0010 | L2 | .FILL x100A |
| 0x0011 | L3 | .FILL x100B |

Suppose we are running a program and we reach to TRAP x5 instruction at memory location xABCD. Show the MAR trace for a TRAP x5 call. **Give all the answers in HEX.**

You may not need to use all the blank boxes.

| MAR Trace |
|-----------|
| xABCD |
| 0x0005 |
| 0x000D |
| 0x0011 |
| 0x000E |
| 0x000F |