CS/ECE 252: INTRODUCTION TO COMPUTER ENGINEERING
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Midterm Examination 4
In Class (50 minutes)
Friday, December 14, 2007
Weight: 15%

CLOSED BOOK, NOTE, CALCULATOR, PHONE, & COMPUTER.

The exam in two-sided and has **TEN** pages, including two blank pages and a copy of the ***Standard ASCII Table***, some ***Trap Service Routines*** description and the ***LC-3 Instruction Set handout*** on the final page (please feel free to detach this final page, but insert it into your exam when you turn it in).

Plan your time carefully, since some problems are longer than others.

NAME: _____

SECTION:_____

ID# _____

Problem Number	Maximum Points	Points Awarded
1	4	EH
2	2	SR
3	7	SJ
4	8	NEJ
5	7	GJ
6	2	SR
Total	30	

Problem 1 (4 points): Short Answers

a. What is the problem with using the string AND as a label in an LC-3 assembly language program?

Using an instruction as a label confuses the assembler because it treats the label as the opcode itself so the label AND will not be entered into the symbol table. Instead the assembler will give an error in the second pass.

b. What single instruction is equivalent to the following two LC-3 instructions?

```
LEA R7, #1
JMP R3, #0
```

JSRR R3

c. The LC-3 assembly process is done in two complete passes through the entire assembly language program. What is the objective of the first pass?

To identify the actual binary addresses corresponding to the symbolic names (or labels). This set of correspondences is known as the symbol table.

d. What is the purpose of .FILL pseudo-op?

.FILL tells the assembler to set aside the next location in the program and initialize it with the value of the operand.

Problem 2 (2 points): Memory-Mapped I/O

Suppose an ISA has a 16-bit address space. All addresses wherein bits[15:13] = 111 are allocated to I/O device registers.

a. What is the minimum address of I/O device registers?

1110000000000000

b. What is the maximum address of I/O device registers?

1111111111111111

Problem 3 (7 points): Two-Pass Assembly Process

An assembly language LC-3 program is given below:

```
1           .ORIG x3100
2     ONE   LD    R0, A
3           ADD   R2, R2, R0
4     TWO   LD    R0, B
5           ADD   R2, R2, R0
6           ST    R2, SUM
7           TRAP  x25
8     A     .FILL x0002
9     B     .FILL x0003
10    C     .FILL x0004
11          .END
```

a. Fill in the symbol table for the program:

Symbol	Address
ONE	x3100
TWO	**x3102**
A	**x3106**
B	**x3107**
C	**x3108**

b. Assuming that both passes of the assembler were to execute, write the binary word (machine language instruction) that would be generated by the assembler for the first instruction of the program.

0010 010 000000101

c. The programmer intended the program to add the values stored in memory locations A and B, and store the result into memory. There are two errors in the code. For each, describe the error and indicate whether it will be detected at assembly time or at run time.

Error 1:
Line 6: ST R2, SUM
SUM is an undefined label. This error will be detected at assembly time.
Error 2:
Line 3: ADD R2, R2, R0
R2 was not initialized before it was used; therefore, the result of this ADD instruction may not be correct. This error will be detected at run time.

Problem 4 (8 points): Trap Routines and Save/Restore Problem

Suppose we define a new service routine starting at memory location x4100. This routine reads in a character and echoes it to the screen. Suppose memory location x0071 contains the value x4100. The service routine is shown below.

```
01                .ORIG   x4100
02                ST      R0,     SAVERA
03                ST      R7      ,SAVERB
04                GETC
05                OUT
06                LD      R0,     SAVERA
07                LD      R7      ,SAVERB
08                RET
09      SAVERA    .FILL   x0000
10      SAVERB    .FILL   x0000
```

a. Fill the blanks in the above program.

b. Identify the instruction that will invoke this routine.

TRAP x71

c. Line 10 is the RET instruction, will a BR (Unconditional branch) instruction work instead? Why or why not?

No. TRAP routines need to be able to return to the instruction after the TRAP initiation. The location of this instruction will differ between TRAP instances, and could be anywhere. The RET instruction solves this problem by using the address stored in R7, which is the next PC address that was saved when the TRAP occurred. The BR instruction will always jump to the same PC-relative address, which cannot work in the general case. Also note that the RET instruction is base + offset and the BR instruction is PC-relative, so the BR instruction might have insufficient reach (partial credit answer).

d. What do instructions in line 02 and 06 do? Will the service routine work without these two lines? Why or why not?

Save and Restore R0.

Yes, this routine will work. But whatever value was in R0 before TRAP x71 is executed will be overwritten during the subroutine, so caller needs to save and restore R0 if the value in R0 will be used by caller after TRAP x71.

Problem 5 (7 points): I/O Basic

An assembly language LC-3 program is given below:

```
        .ORIG x3000
        LD    R0, ASCII
        LD    R1, NEG
LOOP    LDI   R2, DSR
        BRzp  LOOP
        STI   R0, DDR
        ADD   R0, R0, #1
        ADD   R3, R0, R1
        BRnz  LOOP
        HALT
ASCII   .FILL x0050
NEG     .FILL xFFA8
DSR     .FILL xFE04       ; Address of DSR
DDR     .FILL xFE06       ; Address of DDR
        .END
```

a. What does this program do?

The program displays the letters PQRSTUVWX in the screen (LC3 Console).

b. What is the purpose of the Display Status Register (DSR)?

The Display Status Register (DSR) controls the synchronization of the fast processor and the slow monitor display. Bit[15] of the DSR is 1 when the device is ready to display another character on screen. When data is written to DDR, DSR[15] is set to 0 and remains at 0 until monitor finishes processing the character on screen.

c. What problem could occur if the display hardware does not check the DSR before writing to the DDR?

If DSR[15] is 1, the data contained in the DDR has not been displayed by the monitor. Thus, if the display hardware does not check the DSR before writing to the DDR, the previous value in DDR could be lost.

d. Circle the correct combination that describes this program?
a. Special opcode for I/O and interrupt driven
b. Special opcode for I/O and polling
c. Memory mapped and interrupt driven
ⓓ. Memory mapped and polling

Problem 6 (2 points): Professional Ethics

Regarding the assigned reading "RFID Inside" on RFID implants, do you support RFID implants? Why or why not? Give two different reasons to support your position.

Support. RFID implants can be used as a life saving device in an emergency. RFID implants can be used as a source of authentication for security.

Do not support. RFID implants are Invasion of employee's privacy. An employee should have the right to bodily integrity.

Scratch Sheet 1 (in case you need additional space for some of your answers)

ASCII Table

Character	*Hex*	*Character*	*Hex*	*Character*	*Hex*	*Character*	*Hex*
nul	00	sp	20	@	40	`	60
soh	01	!	21	A	41	a	61
stx	02	"	22	B	42	b	62
etx	03	#	23	C	43	c	63
eot	04	$	24	D	44	d	64
enq	05	%	25	E	45	e	65
ack	06	&	26	F	46	f	66
bel	07	'	27	G	47	g	67
bs	08	(	28	H	48	h	68
ht	09	)	29	I	49	i	69
lf	0A	*	2A	J	4A	j	6A
vt	0B	+	2B	K	4B	k	6B
ff	0C	,	2C	L	4C	l	6C
cr	0D	-	2D	M	4D	m	6D
so	0E	.	2E	N	4E	n	6E
si	0F	/	2F	O	4F	o	6F
dle	10	0	30	P	50	p	70
dc1	11	1	31	Q	51	q	71
dc2	12	2	32	R	52	r	72
dc3	13	3	33	S	53	s	73
dc4	14	4	34	T	54	t	74
nak	15	5	35	U	55	u	75
syn	16	6	36	V	56	v	76
etb	17	7	37	W	57	w	77
can	18	8	38	X	58	x	78
em	19	9	39	Y	59	y	79
sub	1A	:	3A	Z	5A	z	7A
esc	1B	;	3B	[	5B	{	7B
fs	1C	<	3C	\	5C	|	7C
gs	1D	=	3D	]	5D	}	7D
rs	1E	>	3E	^	5E	~	7E
us	1F	?	3F	_	5F	del	7F

Trap Service Routines

Trap Vector	Assembler Name	Description
x20	GETC	Read a single character from the keyboard. The Character is not echoed onto the console. Its ASCII code is copied into R0. The high eight bits of R0 are cleared.
x21	OUT	Write a character in R0[7:0] to the console display.
…	…	…
x25	HALT	Halt execution and print a message on the console.

LC-3 Instruction Set (Entered by Mark D. Hill on 03/14/2007; last update 03/15/2007)

PC': incremented PC. setcc(): set condition codes N, Z, and P. mem[A]:memory contents at address A.
SEXT(immediate): sign-extend immediate to 16 bits. ZEXT(immediate): zero-extend immediate to 16 bits.
Page 2 has an ASCII character table.