CSCI 240 - Computer Organization and Assembly Language Programming
Homework 9 - TRAP Routines and Subroutines

Problem 9.3. Refer to Figure 9.6, the `HALT` service routine.

(a) What starts the clock after the machine is `HALT`ed? Hint: How can the `HALT` service routine after bit [15] of the machine control register is cleared?

(b) Which instruction actually halts the machine?

(c) What is the first instruction executed when the machine is started again?

(d) Where will the `RET` of the `HALT` routine return to?

Problem 9.4. Consider the following LC-3 assembly language program:

```
        .ORIG x3000
  L1    LEA R1, L1
        AND R2, R2, x0
        AND R2, R2, x2
        LD R3, P1
  L2    LDR R0, R1, x0
        OUT
        ADD R3, R3, #-1
        BRz GLUE
        ADD R1, R1, R2
        BR L2
  GLUE HALT
  P1   .FILL xB
        .STRINGZ "HBoeoakteSmtHaotren!s"
        .END
```

(a) After this program is assembled and loaded, what bianry pattern is stored in memory location `x3005`?

(b) Which instruction (provide a memory address) is executed after instruction `x3005` is executed?

(c) Which instruction (provide a memory address) is executed prior to instruction `x3600`?

(d) What is the output of this program?

Problem 9.5. The following LC-3 program is assembled and then executed. There are no assemble time or run-time errors. What is the output of this program? Assume all registers are initialized to `0` before the program executes.

```
        .ORIG x3000
        ST   R0, x3007
        LEA  R0, LABEL
        TRAP x22
        TRAP x25
  LABEL  .STRINGZ "FUNKY"
  LABEL2 .STRINGZ "HELLO WORLD"
        .END
```

Problem 9.8. Assume that an integer greater than 2 and less than 32768 is deposited in memory location A by another module before the program below is executed.

```
        .ORIG x3000
        AND  R4, R4, #0
        LD   R0, A
        NOT  R5, R0
        ADD  R5, R5, #2
        ADD  R1, R4, #2
        ;
 REMOD  JSR  MOD
        BRz  STORE0
        ;
        ADD  R7, R1, R5
        BRz  STORE1
        ADD  R1, R1, #1
        BR   REMOD
        ;
 STORE1 ADD  R4, R4, #1
 STORE0 ST   R4, RESULT
        TRAP x25
        ;
 MOD    ADD R2, R0, #0
        NOT R3, R1
        ADD R3, R3, #1
 DEC    ADD R2, R2, R3
        BRp DEC
        RET
        ;
 A      .BLKW 1
 RESULT .BLKW 1
        .END
```

In 20 words or fewer, what does the above program do?

Problem 9.9. Recall the machine busy example. Suppose the bit pattern indicating which machines are busy and which are free is stored in memory location x4001. Write subroutines that do the following:

(a) Check if no machines are busy, and return 1 if none are busy.

(b) Check if all machines are busy, and return 1 if all are busy.

(c) Check how many machines are busy, and return the number of busy machines.

(d) Check how many machines are free, and return the number of free machines.

(e) Check if a certain machine number, passed as an argument in R5, is busy, and return 1 if that machine is busy

(f) Return the number of a machine that is busy.

Problem 9.12. Consider the following LC-3 assembly language program:

```
        .ORIG x3000
        LEA R0, DATA
        AND R1, R1, #0
        ADD R1, R1, #9
LOOP1 ADD R2, R0, #0
        ADD R3, R1, #0
LOOP2 JSR SUB1
        ADD R4, R4, #0
        BRzp LABEL
        JSR SUB2
LABEL ADD R2, R2 ,#1
        ADD R3, R3, #-1
        BRP LOOP2
        ADD R1, R1, #-1
        BRp LOOP1
        HALT
DATA  .BLKW 10 x0000
SUB1  LDR R5, R2, #0
        NOT R5, R5
        ADD R5, R5, #1
        LDR R6, R2, #1
        ADD R4, R5, R6
        RET
SUB2  LDR R4, R2, #0
        LOR R5, R2, #1
        STR R4, R2, #1
        STR R5, R2, #0
        RET
        .END
```

Assuming that the memory locations at `DATA` get filled in before the program executes, what is the relationship between the final values at `DATA` and the initial values at `DATA`.

Problem 9.15. Suppose we define a new service routine starting at memory location `x4000`. This routine reads in a character and echoes it to the screen. Suppose memory location `x0072` contains the value `x4000`. The service routine is shown below.

```
        .ORIG x4000
        ST R7, SaveR7
        GETC
        OUT
        LD R7, SaveR7
        RET
SaveR7 .FILL x0000
```

(a) Identify the instruction that will invoke this routine.

(b) Will this service routine work? Explain.

Problem 9.18. The program below, when complete, should print the following to the monitor: `ABCFGH`. Insert instructions at `(a)-(d)` that will complete the program.

```
        .ORIG x3000
        LEA    R1, TESTOUT
BACK_1  LDR    R0, R1, #0
        BRz    NEXT 1
        TRAP   x21
        ------------ (a)
        BRnzp BACK 1
NEXT_1  LEA    R1, TESTOUT
BACK_2  LDR    R0, R1, #0
        BRz    NEXT 2
        JSR    SUB 1
        ADD    R1, R1, #1
        BRnzp BACK 2
NEXT_2  ------------ (b)
SUB_1   ------------ (c)
K       LDI    R2, DSR
        ------------ (d)
        STI    R0, DOR
        RET
DSR     .FILL xFE04
DDR     .FILL xFE06
TESTOUT .STRINGZ "ABC"
        .END
```