CS150 - Computer Organization and Architecture
Exam #2 - Spring 2015

Name: _____ _____

Time: 50 minutes. Closed Book. No Calculators. There are 5 pages and 11 questions on this exam.

1. (12 pts) In the following problems write the machine code (in binary) for an atmega328 instruction, to be placed in the memory location specified, that accomplishes the specified goal.

- a) At program memory location x100, write an instruction that will place the contents of R7 into I/O space location x3D.

- b) At program memory location x418, write an instruction that will unconditionally branch back to program memory location x40B.

- c) At program memory location x515, write an instruction that will branch to address x523 if the result of the last operation produced a negative value.

2. (10 pts) Write a numbered list of the operations that occur during the FETCH phase of the atmega328 instruction processing cycle.

3. (6 pts) The opcode BRZS means "branch if Z is set." Where is Z located, and what has to happen in order for Z to be set?

4. (6 pts) What is the difference between the CALL and JMP instructions on the atmega328?

5. (6 pts) Write a numbered list all phases of the atmega328 instruction processing cycle.

6. (3 pts) In which phase of the atmega328 instruction processing cycle is the addressing mode of an instruction used to determine the location of operands?

7. (12 pts) Write the atmega328 assembly language instruction(s) that perform the following operations:

- a) Add the contents of registers R3, R4, and R7, and place the result into R0.

- b) Clear (set to zero) the lower two bits (bits [1:0]) of register R7, leaving the upper six bits (bits [7:2]) unchanged.

- c) Take the one's complement of the value in R0 and place it in R31, then take the two's complement of the value in R1 and place it in R30.

8. (10 pts) Write atmega328 assembly language instructions that will swap the lower nibble (bits[3:0]) of R30 with the upper nibble (bits[7:4]) of R30.

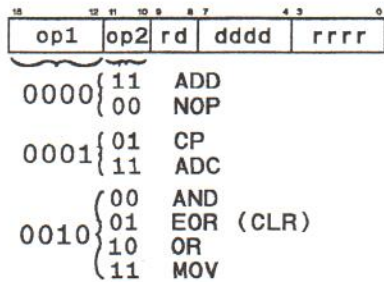9. (3 pts) In assembly language, what do labels represent?

10. (12 pts) Generate the symbol table for the following atmega328 assembly language program.

```
reset_vect: rjmp entry
            .org 0x38
entry:      ldi r16, 8
            ldi r17, 23
            ldi r18, -1
            eor r0, r0
sig_a:      add r0, r17
            add r16, r18
            brbc 1, sig_a
sig_b:      ldi r16, 5
sig_c:      add r16, r18
            brbc 0, sig_c
            in r17, 0x25
            rjmp sig_b
terminus:   rjmp terminus
```
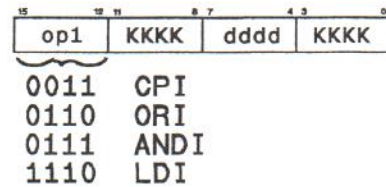
11. (20 pts) Write a complete program in atmega328 assembly language that will *rotate left* the value in R16 by the number of bits stored in R0. For example, if R16 contains the value 10000000 and R0 contains the value 1, your program should terminate with the value 00000001 in R16. The value in R0 will always be greater than 0 and less than 8. You can assume that R0 and R16 are already loaded with the necessary values when your program starts executing. Please use **only** intructions that are contained in the CS150 AVR subset.
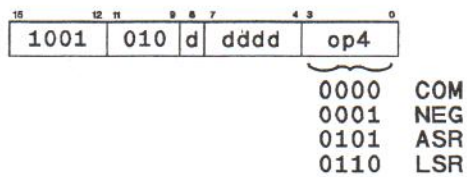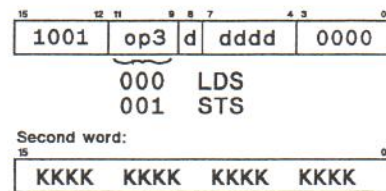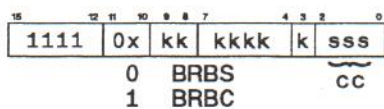
AVR Instruction Subset

ALU Instructions

op1	op2	rd	dddd	rrrr

```
0000 { 11  ADD
       00  NOP

0001 { 01  CP
       11  ADC

       00  AND
0010 { 01  EOR (CLR)
       10  OR
       11  MOV
```

Immediate Instructions

op1	KKKK	dddd	KKKK

```
0011  CPI
0110  ORI
0111  ANDI
1110  LDI
```

Unary Logical Instructions

1001	010	d	dddd	op4

```
0000  COM
0001  NEG
0101  ASR
0110  LSR
```

Load/Store Instructions

1001	op3	d	dddd	0000

```
000  LDS
001  STS
```

Second word:

KKKK	KKKK	KKKK	KKKK

Branch Instructions

1111	0x	kk	kkkk	k	sss

```
0  BRBS        cc
1  BRBC
```

Input/Output Instructions

1011	x	AA	r	rrrr	AAAA

```
0  IN
1  OUT
```

Call/Jump Instructions

1001	0100	0000	op4

```
1110  CALL
1100  JMP
```

Second word:

KKKK	KKKK	KKKK	KKKK

Return Instructions

1001	0101	000	x	1000

```
0  RET
1  RETI
```

Stack Instructions

1001	00	xd	dddd	1111

```
0  POP
1  PUSH
```
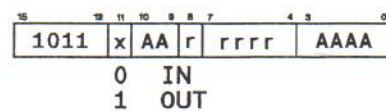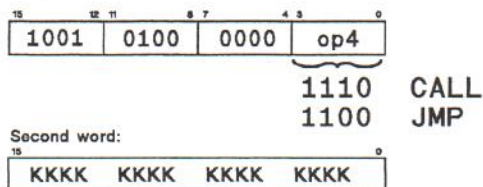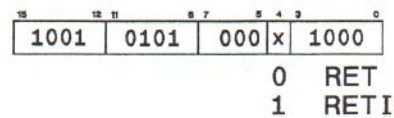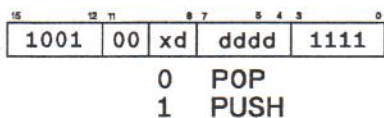
Relative Jump Instructions

110x	KKKK	KKKK	KKKK

```
0  RJMP
1  RCALL
```