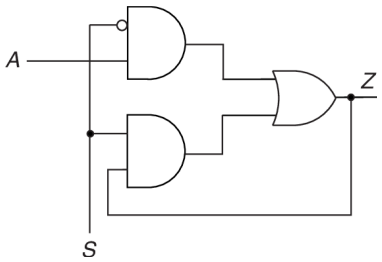
CS150: Computer Organization and Architecture
Final Exam

Name: _____

No books, notes, or electronic devices of any kind are to be used. This exam contains 10 questions and is worth 320 points.

1. (10 pts) A certain combinational circuit has two inputs. The values of the two inputs for the last five cycles were **01**, **10**, **11**, **00**, and **01**. The values of the two inputs are again **10**. What is the effect that the previous five inputs have had on the current output?

2. (10 pts) Consider the circuit below.



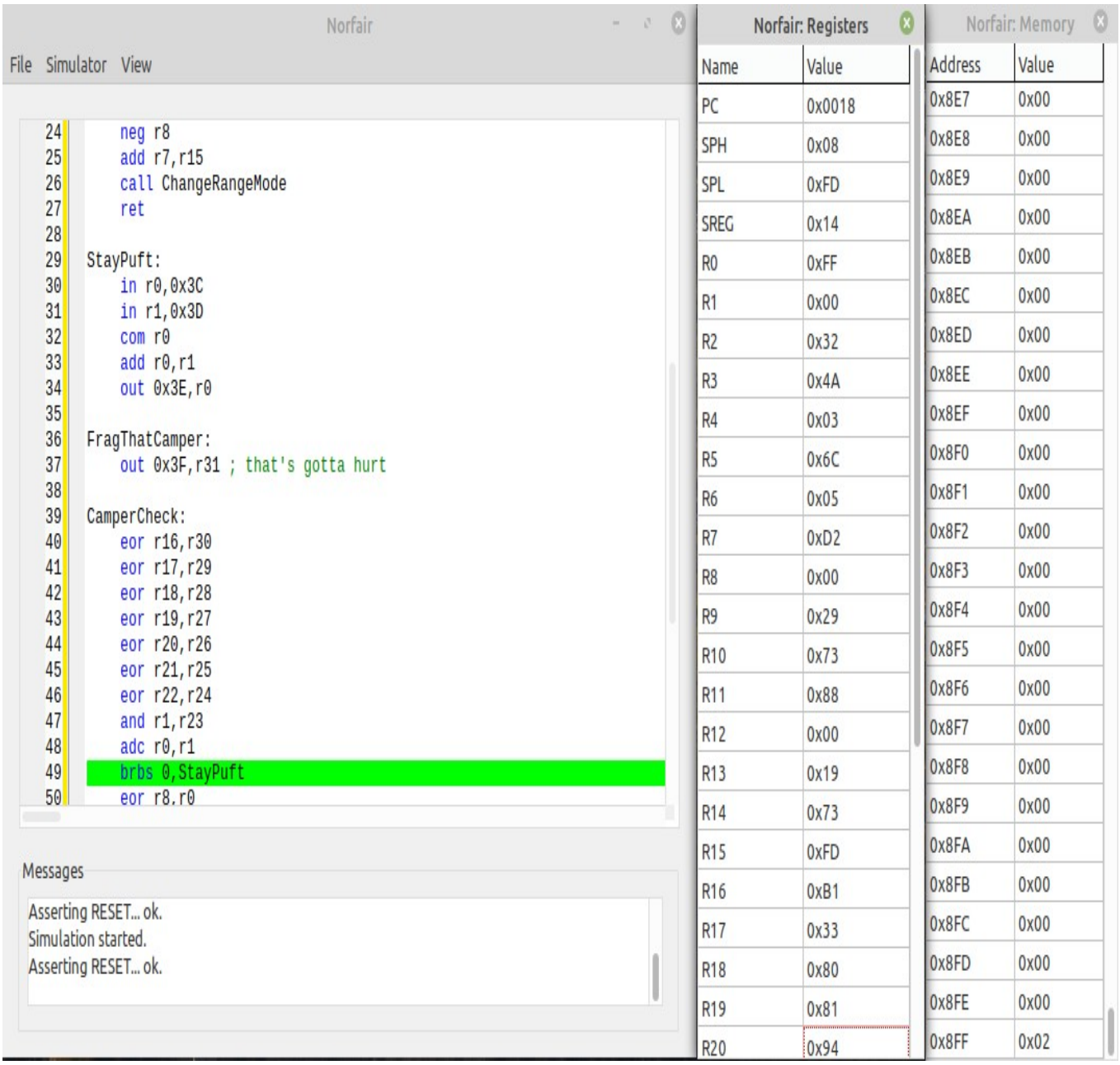
- What is the value of Z in this circuit when the input S is 0?

- If the input S is 0 and is then switched to 1, how will the value of Z be effected after the switch?

3. (50 pts) Build an assembly language subroutine named `SetLowerNibble` that will take an argument on the stack and set the lower 4 bits of the value to be ones without affecting the upper four bits of the value. For example, if the value of the argument on the stack is 11010011 when your subroutine is called, the result should be 11011111 when your subroutine is finished. Your subroutine will place the computed result onto the stack in order to return it to the caller. Your subroutine must be placed at address 0x24 in program memory and must use only instructions that are contained in the CS150 AVR instruction subset. The following code shows how your subroutine will be used:

```
...
push R23            ; push R23 value onto stack
call SetLowerNibble ; set bits [3..0] of the value
pop R31             ; put result into R31
...
```

4. (20 pts) Consider the following Norfair screenshot:



After the processor fetches and executes the BRBS instruction that is highlighted on line 49 of the editor, what will be the value of the following items?

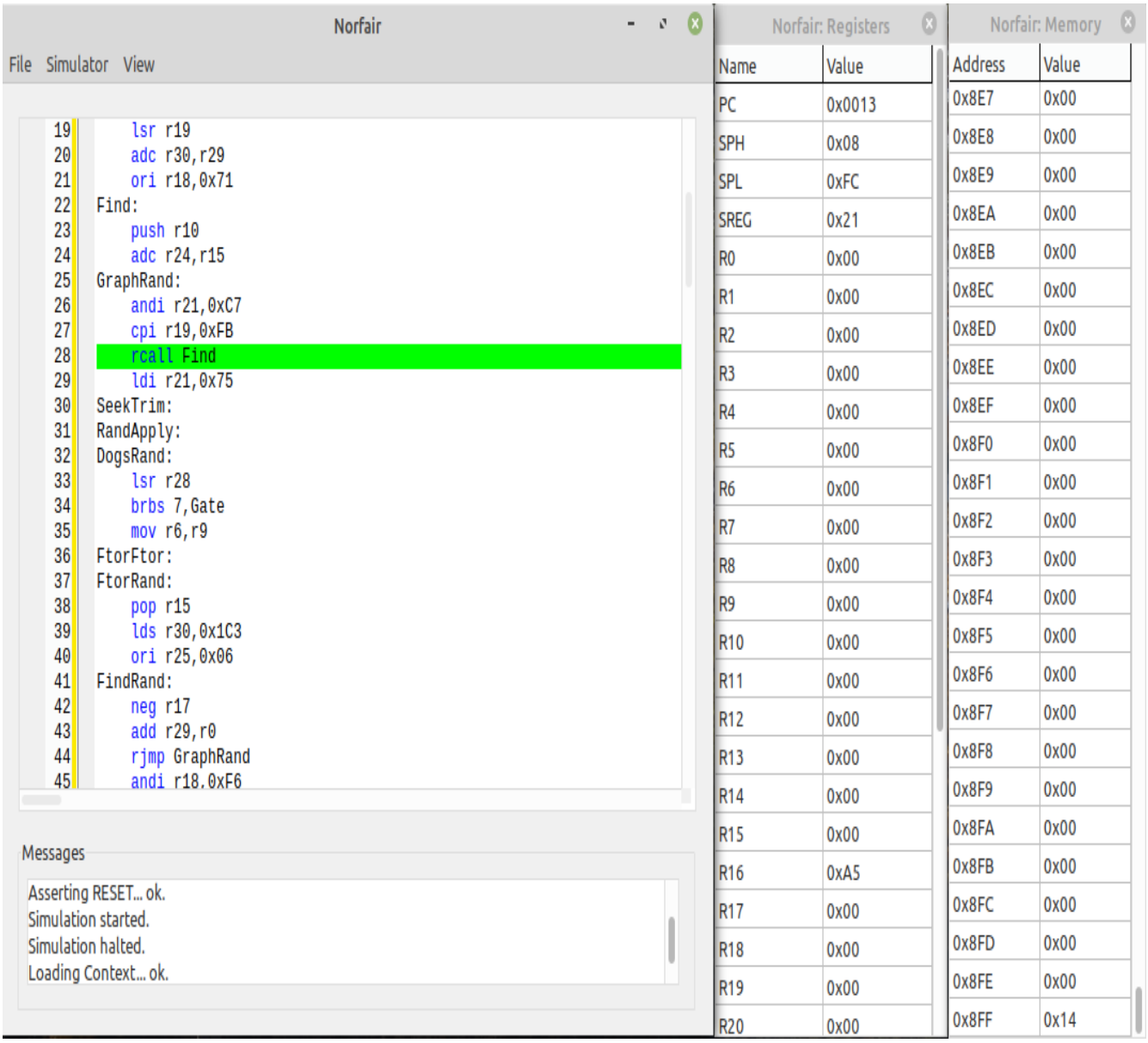
PC: _____

SREG: _____

SPL: _____

Memory Location 0x8FF: _____

5. (20 pts) Consider the following Norfair screenshot:



After the processor fetches and executes the RCALL instruction that is highlighted on line 28 of the editor, what will be the value of the following items?

PC: _____

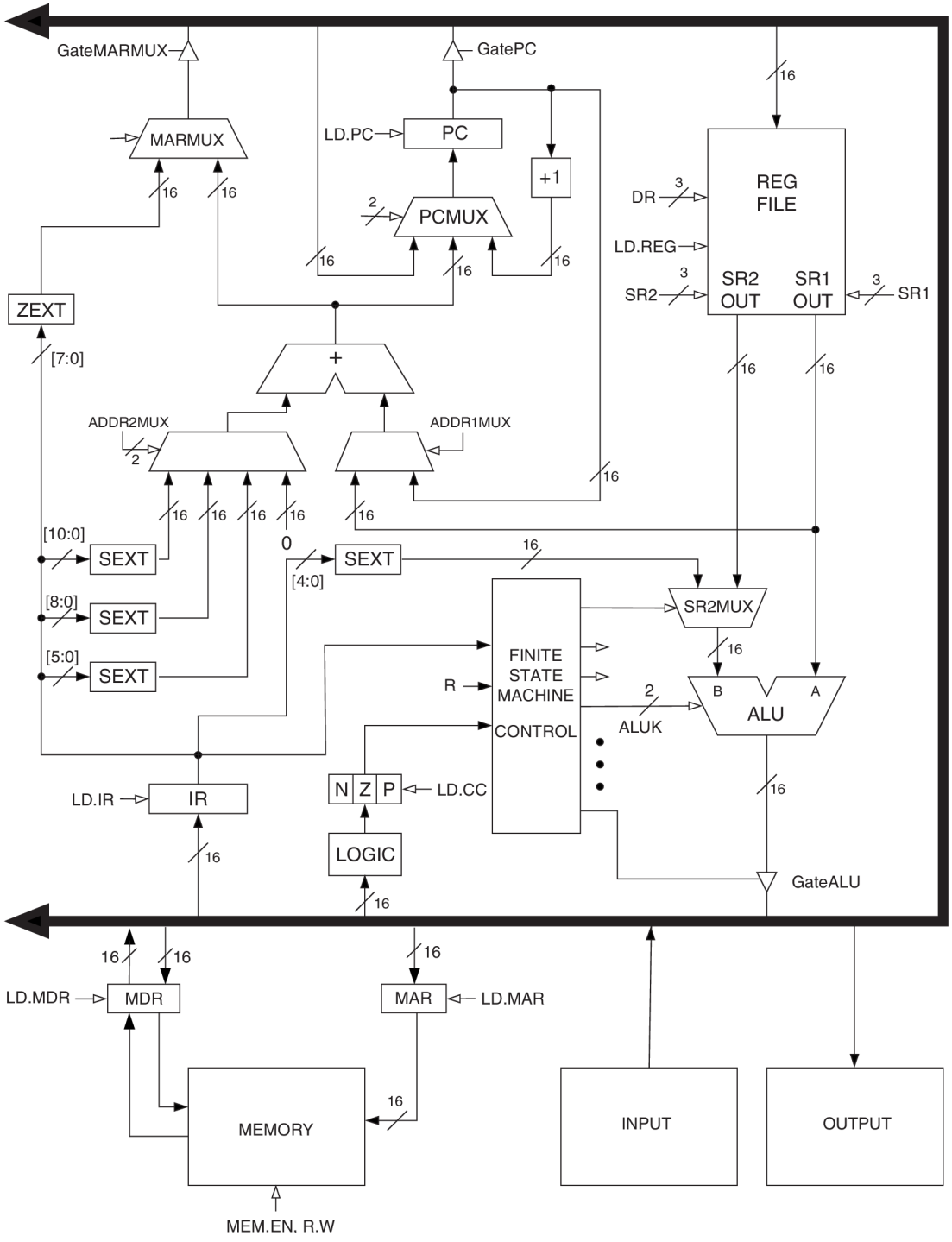
SPL: _____

Memory Location 0x8FC: _____

Memory Location 0x8FF: _____

6. (50 pts) Build an assembly language subroutine named `SuperfyR0` that will find the largest of the values in the registers R0, R1, R2, and R3 and copy that value into R0. For example, if R0 contains 28, R1 contains 15, R2 contains 3, and R4 contains 77 when your subroutine is called, when your subroutine is finished R0 will contain 77, R1 will contain 15, R2 will contain 3, and R4 will contain 77. Your subroutine must be placed at address 0x30 in program memory and must use only instructions that are contained in the CS150 AVR instruction subset. Your subroutine cannot use any data memory locations or any registers other than R0, R1, R2, and R3 to solve this problem.

7. (10 pts). Consider the diagram below that depicts a stored-program computer. Does this computer implement the Harvard model or the Von Neumann model? Please justify your answer.



8. (50 pts). Build an assembly language subroutine named `IsEightTendie` that will determine if the value in R8 is evenly divisible by 8. If the value in R8 is evenly divisible by 8, your subroutine should place the value 0xFF on the stack, and if the value in R8 is not evenly divisible by 8, your subroutine should place the value 0x00 on the stack. Your subroutine must be placed at address 0x26 in program memory and must use only instructions that are contained in the CS150 AVR instruction subset. You can use any registers that you want, but the value of all registers must be preserved for the caller. The following code shows how your subroutine will be used:

```
...
call IsEightTendie ; check to see if R8 has what we're after
pop R1             ; put result into R1
...
```

9. (50 pts). Build an assembly language subroutine named `Normalize` that will take an argument on the stack and transform it as per the following description. If the value of the argument is odd, your subroutine should just return the original argument on the stack. If the value of the argument is greater than the value in R0, your subroutine should subtract the value in R1 from the value of the argument and return the new value of the argument by placing it on the stack. If the value of the argument is less than the value in R1, your subroutine should add the value of R0 to the value of the argument and return the new value of the argument by placing it on the stack. Your subroutine must be placed at address 0x20 in program memory and must use only instructions that are contained in the CS150 AVR instruction subset. The following code shows how your subroutine will be used:

```
...
push R30       ; push R30 value onto stack
call Normalize ; Normalize the value
pop R30        ; put result into R30
...
```

10. (50 pts). Build an assembly language subroutine named `ExportR1Bits` that copy bits from R1 into other registers. Your subroutine will copy bits 7, 5, and 0 of R1 into R31, and will copy bits 6, 3, and 1 of R1 into R30, and will copy bits 4 and 2 of R1 into R29. The bits found in R1 must occupy the same places in the destination register as they did in R1. A diagram of where each bit in R1 must go is shown below:

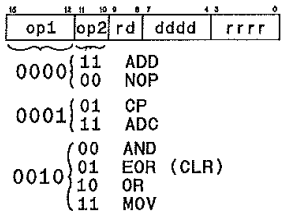
R1 [R31 R30 R31 R29 R30 R29 R30 R31]

For example, suppose that R1 contains the value 11111111 and that R29, R30, and R31 all contain 0 when your function is called. When your function finishes, R31 will contain 10100001, R30 will contain 01001010, and R29 will contain 00010100. As another example, suppose that R1 contains the value 10011101 and that R29, R30, and R31 all contain 0 when your function is called. When your function finishes R31 will contain the value 10000001, R30 will contain the value 00001000, and R29 will contain the value 00010100. Your subroutine must use only instructions that are contained in the CS150 AVR instruction subset. The next page is blank if you need more space to work.

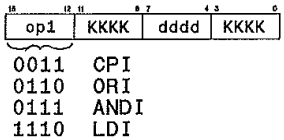
This page intentionally left blank.

AVR Instruction Subset

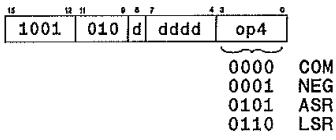
ALU Instructions



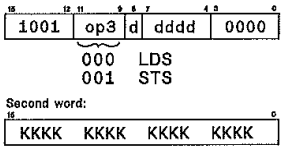
Immediate Instructions



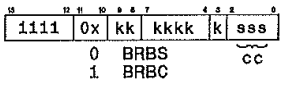
Unary Logical Instructions



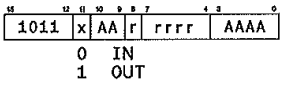
Load/Store Instructions



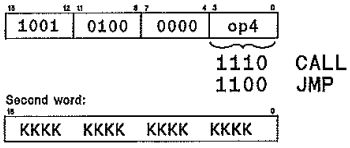
Branch Instructions



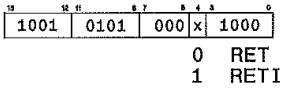
Input/Output Instructions



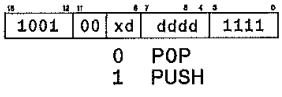
Call/Jump Instructions



Return Instructions



Stack Instructions



Relative Jump Instructions