**Midterm Exam**
**CSC 252**
**7 March 2025**
**Computer Science Department**
**University of Rochester**

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**Name**: _____

| | |
|---|---|
| Problem 0 (2 points): | _____ |
| Problem 1 (12 points): | _____ |
| Problem 2 (21 points): | _____ |
| Problem 3 (27 points): | _____ |
| Problem 4 (28 points): | _____ |
| Total (90 points): | _____ |

Remember "**I don't know**" is given 15% partial credit, but you must erase everything else. This does not apply to extra credit questions (if any).

Your answers to all questions must be contained in the given boxes. Use spare space to show all supporting work to earn partial credit.

You have 75 minutes to work.

Please sign the following. I have not given nor received any unauthorized help on this exam.

Signature:_____

**Have a good spring break and GOOD LUCK!!!**

**Problem 0: Warm-up (2 Points)**

What's the most surprising thing you've learned so far?

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**Problem 1: Fixed-Point Arithmetics (12 points)**

**Part a) (2 points)** Represent decimal number 31 in the hexadecimal form.

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| 1F |

**Part b) (4 points)** Represent octal (base 8) number 73 in the decimal form **and** binary form.

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| Base 10 = 59 Base 2 = 111011 |

**Part c) (6 points)** Consider two signed binary numbers A = 10101 and B = 11001, both are represented using two's complement representation. Do the math below.

**(2 points)** What's the result of !A || B (! is NOT and || is OR)?

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| 11011 |

**(2 points)** What's the result of A^B (^ is XOR)?

| |
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| 01100 |

**(2 points)** How to write A in base 7?

| |
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| -14 |

**Problem 2: Floating-Point Arithmetics (21 points)**

**Part a) (4 points)**

**(2 points)** Write $10\frac{7}{8}$ using the normalized scientific notation.

$1.010111 \times 2^3$

**(2 points)** Write $32\frac{5}{16}$ using the normalized scientific notation.

$1.000000101 \times 2^5$

**Part b) (8 points)** The engineering team is designing a new **12 bit floating point** standard. The format follows the principles of the IEEE-style floating point representation we discussed in the class. The engineering team is considering two possible standard:

- Standard A: 6 fraction bits
- Standard B: 9 fraction bits

**(4 points)** What are the biases for Standard A and Standard B?

Standard A: 15
Standard B: 1

**(4 points)** Given the requirement that the smallest gap between two representable numbers is at most $\frac{1}{2^{24}}$, which of the two options meets the requirement? Show your work.

Neither.

Standard A: the smallest gap between two representable number is $2^{-14} \times 2^{-6} = 2^{-20} > 2^{-24}$.

Standard B: the smallest gap between two representable number is $2^{-9} > 2^{-24}$.

Neither of them satisfy the requirement

**Part c) (9 points)** Now the engineering team wants to design another 12-bit floating point representation. They want the representation to be able to precisely represent -100 and 100.

**(5 points)** What is the representation that meets this requirement while having the smallest gap between two consecutive, representable numbers?

Turn 100 into binary scientific form, we have $1.1001 \times 2^6$. We need at least 4 fraction bits to precisely represent 100 and -100. Let F be the number of fraction bits and E be the number of exponent bits. The have smallest gap between two consecutive representable numbers with F and E, we have $2^{-Bias(E)+1} \times 2^{-F}$. The increase of Bias is much larger than the increase of F. So we want as many exponent bits as possible. So answer will be 4 fraction bits and 7 exponent bits.

**(4 points)** What is the smallest positive number that can be precisely represented in this format?

For 7 fraction bit, we have bias $2^6 - 1 = 63$. Then answer will be $2^{-63+1} \times 2^{-4} = 2^{-66}$

**Problem 3: Logic Design (27 points)**

**Part a) (4 points)**

**(2 points)** What is the result of a bitwise XOR operation between 01100 and 00111?

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| 01011 |

**(2 points)** What is the result of a bitwise NAND operation between 01000 and 01010?

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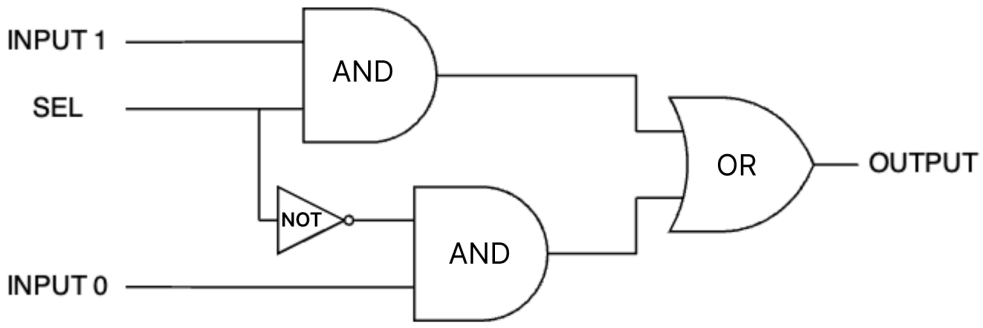
| 10111 |

**Part b) (13 points)**




**(8 points)** Given the circuit above, complete the following truth table. Additional columns are provided to show your partial work (for partial credit).

| INPUT 0 | INPUT 1 | SEL | OUTPUT | | | | |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | | | | |
| 0 | 0 | 1 | 0 | | | | |
| 0 | 1 | 0 | 0 | | | | |
| 0 | 1 | 1 | 1 | | | | |
| 1 | 0 | 0 | 1 | | | | |
| 1 | 0 | 1 | 0 | | | | |
| 1 | 1 | 0 | 1 | | | | |
| 1 | 1 | 1 | 1 | | | | |

**(2 points)** Briefly describe the behaviour of the circuit above in words.

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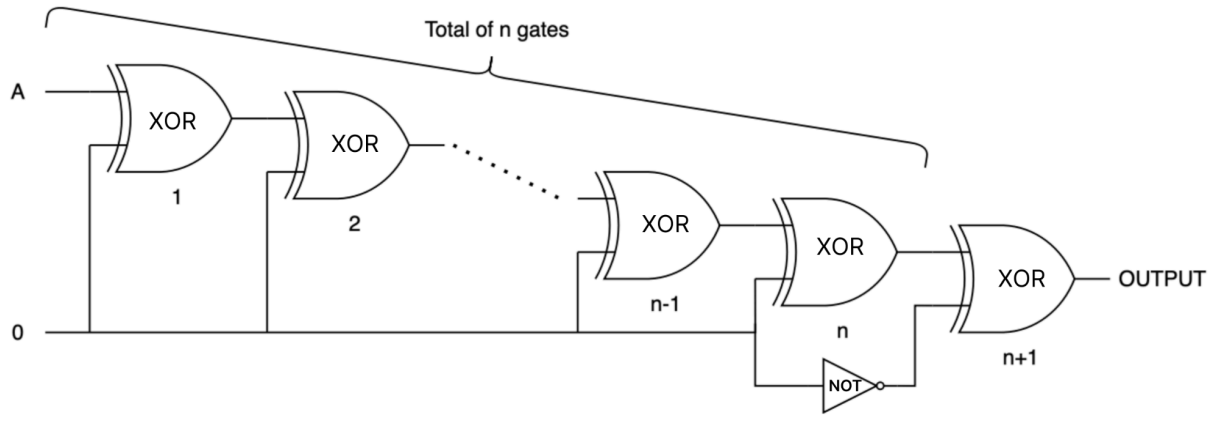
| 2 pts: "If `SEL` is `0`, output the value from `INPUT0`, otherwise output the value from `INPUT1`."<br>1 pt: Express the diagram in a logical expression. |

**(3 points)** Using the same circuit, it is possible to implement the equivalent of an AND gate. Complete the following table by assigning each of the three input wires to variables `A`, `B` or constants `0`, `1` such that `OUTPUT = A AND B`.

| Input | Assigned variable/constant |
|---|---|
| `INPUT 0` | 0 |
| `INPUT 1` | A (B) |
| `SEL` | B (A) |

**Part c) (8 points)**

Consider the circuit below, which consists of N+1 XOR gates cascaded with a single NOT gate placed immediately before the $(N+1)^{th}$ XOR gate.




**(6 points)** What is the output of the circuit for the following values of N? You can write the output as a function of A.

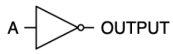
N = 50

Any of: !A / NOT(A) / ¬A / 0 if A=1, 1 if A=0.

N = 63

Any of: !A / NOT(A) / ¬A / 0 if A=1, 1 if A=0.

**(4 points)** Draw a simpler circuit that will achieve the same output as the circuit above.



**Problem 4: Assembly Programming (28 points)**

**Conventions:**

1. For this section, the assembly shown uses the AT&T/GAS syntax **opcode src, dst** for instructions with two arguments where **src** is the source argument and **dst** is the destination argument. For example, this means that **mov a, b** moves the value **a** into **b.**
2. All C code is compiled on a **64-bit machine**, where arrays grow toward higher addresses.
3. We use the x86 calling convention. That is, for functions that take two arguments, the first argument is stored in **%edi (%rdi)** and the second is stored in **%esi (%rsi)** at the time the function is called; the return value of a function is stored in **%eax (%rax)** at the time the function returns.
4. We use the **Little Endian** byte order when storing multi-byte variables in memory.

**Part a) (10 points)**

Consider the following function `fibonacci` and the assembly code that implements the C function.

```
int fibonacci(int n) {
     if (n <= 1)   return n;
     return   fibonacci(n - 1)  +  fibonacci(n - 2);
}
```

```
0000000000401106 <fibonacci>:
401106:    push   %rbp
401107:    mov    %rsp,%rbp
40110a:    push   %rbx
40110b:    sub    $0x18,%rsp
40110f:    mov    %_A_, -0x14(%rbp)
401112:    _B_    $0x1, -0x14(%rbp)
401116:    _C_    40111d <fibonacci+0x17>
401118:    mov    -0x14(%rbp), %eax
40111b:    jmp    40113b <fibonacci+0x35>
40111d:    mov    -0x14(%rbp), %eax
401120:    sub    $0x1, %eax
401123:    mov    %eax, %edi
401125:    call   401106 <fibonacci>
40112a:    mov    %eax, %ebx
40112c:    mov    _D_(%rbp), %eax
40112f:    __________E__________
401132:    mov    %eax, %edi
401134:    call   401106 <fibonacci>
401139:    add    %ebx, %eax
40113b:    mov    -0x8(%rbp), %rbx
40113f:    leave
401140:    ret
```

**Your Task:** Fill in the missing instructions A, B, C, D, and E to complete the assembly code.

**(2 points) A**:

| |
|---|
| edi/ rdi |

**(2 points) B:**

| |
|---|
| cmp/cmpl/cmpg |

**(2 points) C:**

| |
|---|
| jg |

**(2 points) D:**

| |
|---|
| -0x14 |

**(2 points) E:**

| |
|---|
| sub $0x2,%eax |

**Part b) (18 points)**

Consider the following unknown x86_64 assembly function:

```
000055555555516d <unknown>:
0x55555555516d:      mov   $0x1,%eax
0x555555555172:      cmp   $0x1,%rsi
0x555555555176:      jbe   0x5555555551aa
0x555555555178:      mov   %rdi,%rdx
0x55555555517b:      lea   -0x4(%rdi,%rsi,4),%r8
0x555555555180:      mov   $0x1,%r9d
0x555555555186:      mov   $0x0,%edi
0x55555555518b:      jmp   0x555555555199
0x55555555518d:      mov   %edi,%r9d
0x555555555190:      add   $0x4,%rdx
0x555555555194:      cmp   %r8,%rdx
0x555555555197:      je    0x5555555551a7
0x555555555199:      mov   0x4(%rdx),%esi
0x55555555519c:      mov   (%rdx),%ecx
0x55555555519e:      cmp   %ecx,%esi
0x5555555551a0:      jg    0x55555555518d
0x5555555551a2:      cmovl  %edi,%eax
0x5555555551a5:      jmp   0x555555555190
0x5555555551a7:      or    %r9d,%eax
0x5555555551aa:      ret
```

At the start of the function, the first argument is set to a pointer to the following integer array: [1, 1, 3, 2]. The second argument is set to 0x4.

The `cmovl` instruction conditionally moves a value from the source register to the destination register only if the sign flag is not equal to the overflow flag.

**(3 points)** Which line of assembly sets the condition codes for the `cmovl` operation on line `0x555555551a2`?

| `0x55555555519e:      cmp   %ecx,%esi` |
|---|

**(3 points)** How many times is the jump at `0x5555555551a5` taken?:

| 2 |
|---|

**(3 points)** How many times is the jump at `0x555555551a0` taken?

| |
|---|
| 1 |

**(3 points)** Assume that the following line of assembly was executed immediately after the first execution of the instruction located at `0x55555555517b`:

```
mov (%r8), %r9
```

What would the value in `r9` be after this instruction?

| |
|---|
| 2 |

**(3 points)** What is the meaning of the second argument of the function?

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| The second argument represents the length of the input array (first argument) |

**(3 points)** Describe the function. What does it do?

| |
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| The function returns 1 if all of the elements within an array are either strictly increasing or strictly decreasing. The function returns 0 if this is not the case. |