Name: _____ Entry number: _____

Verify that your exam has pages 1 to 12. Please fill the name and entry number on *every page* front and back. Do this first before starting the exam.

● You should not have any electronic equipment including laptop, mobile phone, tablet, etc. Calculator is allowed.

● The exam is closed book. You can keep one A4 formula sheet with you during the exam. Please write your name and entry number on the formula sheet.

● You are not allowed to write on the formula sheet during the exam. Instead, use the rough space available on Pages 4, 6, and 12.

● Please answer each question in the provided space.

Q1: [5 marks] True/False

A. [0.5 marks] According to DeMorgan's Law (AB)' = A'B'.

_____

B. [0.5 marks] A full adder takes three inputs and produces two outputs.

_____

C. [0.5 marks] The Boolean expression x+xy is equivalent to x.

_____

D. [0.5 marks] The output of a combinational circuit depends only on its current inputs, not on its previous inputs

_____

E. [0.5 marks] P-type dopants have one extra electron than silicon, i.e., valency of 5.

_____

F. [0.5 marks] In an n-channel transistor, when gate-to-source voltage > threshold (-2V), no current flows.

_____

G. [0.5 marks] CMOS circuits contain both p-channel and n-channel transistors.

_____

H. [0.5 marks] A bit contains 8 bytes.

_____

I. [0.5 marks] A 1MB file contains 2^{20} bytes.

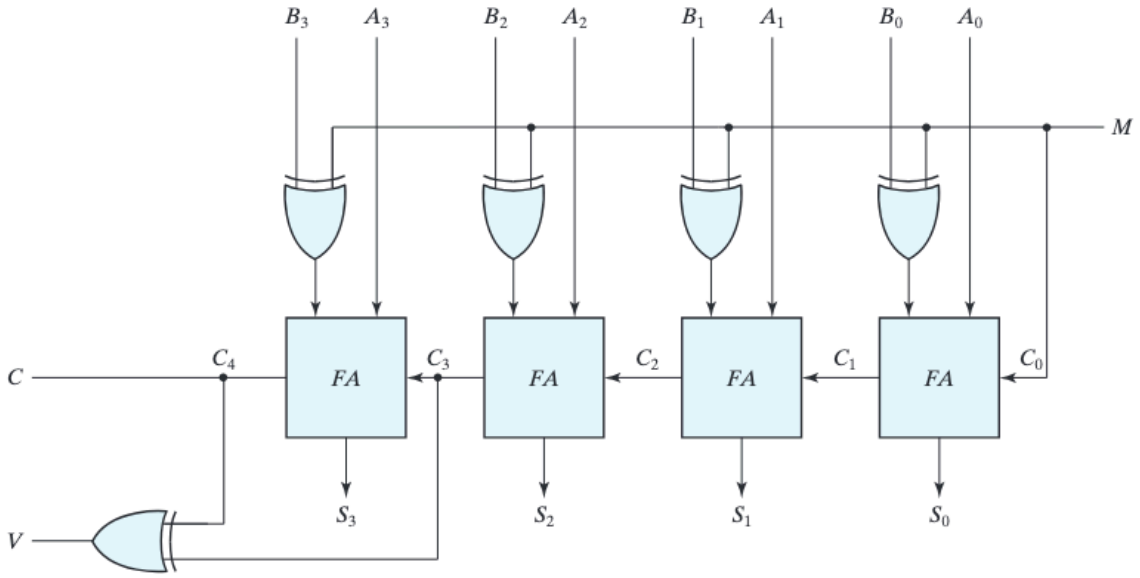
_____

J. [0.5 marks] NAND is both associative and commutative.

_____

Q2 [11 marks] True/False. Also justify your answer.

A. [3 marks] Setting M=1 in this circuit outputs S = A - B. The V bit is set to 1 if there is an overflow.



B. [2 marks] (R, +, *) is a Boolean Algebra, where R is the set of real numbers, + is the addition operation, and * is the multiplication operation.

C. [2 marks] Say a cassette player has two inputs and one output as follows.
Inputs:

1. Play: When the play button is pressed, this input is 1. Otherwise 0.
2. Stop: When the stop button is pressed, this input is 1. Otherwise 0.

Output:

1. Spin: When this output is 1, the motor of the cassette player rotates which plays the audio stored in the cassette. When this output is 0, the motor stops, stopping the audio playback.

After the play button is pressed, the player keeps spinning the motor and keeps playing the audio until the stop button is pressed. This cassette player controller circuit is combinational (True/False).

D. [2 marks] If two Boolean functions have equal number of minterms, then they will have the same number of terms in their minified sum-of-product forms.

E. [2 marks] Any Boolean function F(x,y,z) can be written as x.F(1, y, z) + x'.F(0,y,z).

Intentionally left blank for rough work

Q3: [5 marks] Binary numbers and arithmetic

A. [1 mark] Convert the following binary number to decimal: 11010.11

B. [1 mark] Convert the decimal number 135 to octal.

C. [1 mark] Perform the following binary addition. Show all carries.

```
  101101
+ 100111
```

D. [2 marks] Calculate 13-25 using 2's complement arithmetic. Use 8-bit binary representation for both numbers. Show how the subtraction is performed and convert the final result back into decimal.

Q4. [6 marks] XOR gate

For the following questions, assume that you only have access to *2-input* XOR gates and NOT gates.

A. [0.5 mark] What is the even parity of 0110?

_____

B. [2 mark] Show a circuit that computes the even parity from the four input bits. We can call the four input bits as w, x, y, z.

C. [2 marks] Show a circuit that outputs an error bit when it takes four input bits and the even parity bit. We can call the parity bit as P.

D. [0.75 marks] Demonstrate how you can tweak the circuit built in part B above to output an odd parity bit instead. Try to make minimal modifications to the circuit built in part B.

E. [0.75 marks] Demonstrate how you can tweak the circuit built in part C above to output the error when the input is an odd parity bit instead. Try to make minimal modifications to the circuit built in part C.

Intentionally left blank for rough work

Name: _____ Entry number: _____

Q5. [23 marks] Floating point numbers and comparators

Say we are representing our floating points using just 4 bits.

s	Sign bit: 0 for positive, 1 for negative
e	Two exponent bits, stored with a bias of 1.
m	Fractional mantissa bit

A floating point number is $(-1)^{s}(1.m)_2 2^{e-1}$.

Notice that the mantissa bit m appears after the decimal point with a 1 always before the decimal point. We reserve 0000 for representing 0. This makes 1000 represent -0, which is equivalent to 0.

Therefore, the following shows the decimal numbers corresponding to some four-bit representations. Recall that 1.1 in base 2 is 1.5 in decimal.

Representation	**Calculation**	**Decimal value**
0000	Reserved	0
0001	$(-1)^{0}(1.1)_2 2^{0-1}$	0.75
0010	$(-1)^{0}(1.0)_2 2^{1-1}$	1
0011	$(-1)^{0}(1.1)_2 2^{1-1}$	1.5
0100		
0101		
0110		
0111		
1000	Reserved	0
1001		
1010		
1011		
1100		
1101	$(-1)^{1}(1.1)_2 2^{2-1}$	-3
1110		
1111		

Ensure that you thoroughly understand the representation and calculation in the above table before proceeding.

A. [5 marks] Fill the calculation and decimal value for all the remaining entries in the table above.

B. [1.5 marks] Mention two 4-bit representations which when added together will not give their exact mathematical sum because we require rounding to capture the addition's output in the same 4-bit representation. Mention the four-bit representation and value of what that addition might be reasonably rounded to by an adder circuit.

C. [1.5 marks] Mention two 4-bit representations which when added together will not give their exact mathematical sum because of overflow. Mention the four-bit representation and value of that addition which might be output by a reasonable adder circuit.

D. [3 marks] Design an equality comparator that takes two four bit floating point numbers $A = A_0A_1A_2A_3$ and $B = B_0B_1B_2B_3$ and outputs 1 if the two numbers are equal and outputs zero otherwise. We expect you to write this output E as a Boolean expression containing $A_0A_1A_2A_3$ and $B_0B_1B_2B_3$.

Tip: 0000 and 1000 are equal.

E. [3 marks] Design a "exactly-sums-to-zero comparator" that takes two four bit floating point numbers $A = A_0A_1A_2A_3$ and $B = B_0B_1B_2B_3$ and outputs 1 if the two numbers will exactly add to zero i.e., without any rounding, and otherwise outputs 0. We expect you to write this output Z as a Boolean expression containing $A_0A_1A_2A_3$ and $B_0B_1B_2B_3$.

Tip: 0000 and 1000 exactly add to zero. 0000 and 0000 also add to zero.

E. [2 marks] Draw a circuit that takes $A_0A_1A_2A_3$ and $B_0B_1B_2B_3$ as inputs and outputs E and Z from the previous questions. Try to reuse circuit elements as much as you can.

F. [4 marks] Design a greater-than comparator that takes two four-bit floating point numbers $A = A_0A_1A_2A_3$ and $B = B_0B_1B_2B_3$ and outputs 1 if A>B and zero otherwise. We expect you to write this output G as a Boolean expression containing $A_0A_1A_2A_3$ and $B_0B_1B_2B_3$.

*Tip: 0000 is **not** greater than 1000.*

G. [3 marks] Draw the circuit diagram for the above expression and connect it appropriately to a 4-bit multiplexer such that it outputs Y = $Y_0Y_1Y_2Y_3$ which is the maximum of A ($A_0A_1A_2A_3$) or B ($B_0B_1B_2B_3$).

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