CSSE 132 – Introduction to Computer Systems
Rose-Hulman Institute of Technology
Computer Science and Software Engineering Department

SOLUTIONS To Sample Exam 1

KEY

This exam is **closed book**. You are allowed to use one single-sided 8 1/2 by 11 inch sheet of hand-written notes and a calculator. You may not use a computer, smart phone, etc. during the examination.

Write all answers on these pages. Be sure to **show all work**.

All numbers are expressed in decimal unless specifically stated otherwise.

Write your name and circle your section number on this page, then write your initials on all remaining pages of this exam. You are encouraged to read the entire exam before you start.

	Points available	Your marks
1	9	
2	6	
3	15	
4	15	
5	4	
6	6	
7	6	
8	9	
9	15	
Coding	15	
Total	100	

Problem 1 (9 pts) Convert each of the following **unsigned** binary numbers to *both* hexadecimal *and* decimal. For full credit, be sure to show your work.

(a) `0000 0000 0001 0001`

$$\begin{aligned} Hexidecimal &= 0x0011 \\ Decimal: &= 2^4 + 2^0 = 16 + 1 = 17 \end{aligned}$$

(b) `0000 1000 1000 1000`

$$\begin{aligned} Hexidecimal &= 0x0888 \\ Decimal &= 2^{11} + 2^7 + 2^3 \\ &= 2048 + 128 + 8 \\ &= 2184 \end{aligned}$$

(c) `1000 0000 0000 1111`

$$\begin{aligned} Hexidecimal &= 0x800F \\ Decimal &= 2^{15} + 2^3 + 2^2 + 2^1 + 2^0 \\ &= 2^5 \times 1024 + 8 + 4 + 2 + 1 \\ &= 32768 + 8 + 4 + 2 + 1 \\ &= 32783 \\ or & \\ &= 0x8 \times 2^{12} + 0xF \\ &= 8 \times 4096 + 15 \\ &= 32768 + 15 \\ &= 32783 \end{aligned}$$

Problem 2 (6 pts) A 4 byte number to represent the number of words in a word-processor document is stored inside that document. The document is opened on two different computers (A and B). Computer A reports the word count as "1". Computer B reports the word count as "16777216".

The word count number as stored in the document:

...	0000 0000	0000 0000	0000 0000	0000 0001	...
address:	3	4	5	6	

(a) What would cause the two computers to interpret the value in memory so differently?

The two computers have different endianess and the loader does not adjust the value correctly.

(b) What can you infer about each computer given their behavior?

Computer A is:
Computer B is:

Computer A is Big Endian and B is Little Endian.

Problem 3 (15 pts) Perform the following 8-bit integer arithmetic operations in binary. The numbers are ***signed*** *in two's complement form.* Be sure to show your work for full credit and *check the box to indicate whether there is overflow or not.*

(a) 0001 0001 + 0000 1110 = 0001 1111
No overflow
17 + 14 = 31

☐ Overflow ☐ No overflow

(b) 0111 1111 - 1111 1111 =
0111 1111 + 0000 0001 = 1000 0000 (two's comp negation)
YES overflow
127 - -1 = 128 (not -128)

☐ Overflow ☐ No overflow

(c) 0001 0000 - 0000 1111 =
0001 0000 + 1111 0001 = 0000 0001 (two's comp negation)
No overflow
16 - 15 = 1

☐ Overflow ☐ No overflow

Problem 4 (15 pts) This problem is in three parts, read them carefully before you begin.

(a) For the following truth table, write the Sum-Of-Products boolean logic expressions for Y and for Z. DO NOT simplify the expressions.

A	B	C	Y	Z
0	0	0	1	0
0	0	1	0	0
0	1	0	1	1
0	1	1	0	0
1	0	0	1	1
1	0	1	0	0
1	1	0	0	0
1	1	1	0	0

$$Y = \bar{A}\bar{B}\bar{C} + \bar{A}B\bar{C} + A\bar{B}\bar{C}$$
$$Z = \bar{A}B\bar{C} + A\bar{B}\bar{C}$$

(b) For the following expression, write the truth table. Arrange the input values in the order we used in class.

$$X = A + \overline{(BC)}$$

A	B	C	X
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

(Part c is on the next page)

(c) Given the following boolean logic expression, draw the circuit. You may use standard two- or three-input AND gates, standard two- or three-input OR gates, and NOT gates (inverters). **Do not** simplify the expression and be sure your drawing is clear.

$$V = A\bar{C} + A\bar{B} + \bar{A}(\bar{C} + \bar{A}B)$$

Problem 5 (4 pts) What is the difference between a D Flip-Flop and a D Latch?

A latch will follow the value of d whenever the enable input is high and will hold otherwise and a flip flop will change only on one edge of the clock (usually rising edge).

Problem 6 (6 pts) Answer the following questions about addressing memory. Be sure to show your work for full credit when you need to compute answers.

(a) What is the smallest addressable unit of data in modern computer systems?
8 bits, or one byte

(b) If your computer uses 16-bit addresses, how many unique addresses can it access?
2^{16} *Bytes, or* 2^6 *Kilobytes, or* 64 *Kilobytes.*

(c) How many address bits do you need to address 100,000 unique things?
$2^{16} = 65536$ *and* $2^{17} = 131072$*, so you need 17 bits*

Problem 7 (6 pts) A friend of yours gives you a free hard disk with the following specifications:

Capacity:	30 Terabytes
Average Access Time:	10ms

You've purchased a cache for this hard disk. The cache takes 500 ns to access. Your computer puts often–accessed data from the hard disk into the cache and 99.99% of time, the desired data is ready in the cache. If the data is not found in the cache it must be read off the disk, which takes on average 10ms to access.

If you always check the cache before attempting to load the data from disk, what is the new average access time for data using this hard drive with the cache? Show your work for full credit.

$$\begin{aligned} avgtime &= 1.0 \times time_{cache} + 0.0001 \times time_{disk} \\ &= 500ns + 0.0001 \times 10.0ms \\ &= 500ns + 0.0001 \times 10,000,000ns \\ &= 500ns + 1000ns \\ &= 1500ns \\ &= 1.5\mu s \end{aligned}$$

Problem 8 (9 pts) The following table shows information about multiple types of memory.

	Avg. Access Time	Price
SRAM	< 1 ns	\$200/GB
DRAM	10 ns	\$5.00/GB
Flash Memory	0.5 ms	\$0.50/GB
Hard Disk	10 ms	\$0.10/GB
Cloud Storage	100 ms–2 s	\$0.01/10 GB

(a) Modern computer processors issue billions of small read and write operations per second. Which type of memory would you choose to build a register file in your CPU? Justify your answer.

SRAM since the writes are small, but require very fast access.

(b) Uncompressed video often requires 50GB-100GB of total storage, but is usually accessed in smaller, easy to manage blocks. Which type of memory would you choose as the primary storage for such video (where most of it will stay)? Justify your answer.

Flash or hard disk since the total size is large, but the data can be accessed in convenient chunks.

(c) Interactive programs like web browsers and video games require often fast access to large amounts of memory (2GB-5GB). What type of memory would be best for interactive applications? Justify your answer.

DRAM, since the size is large, but fast access is still required.

Problem 9 (15 pts) Modify (a) the Operation code table, (b) 1-bit ALU, and (c) 8-bit ALU diagrams below to support a new operation called ONCE in addition to the existing operations. ONCE generates a `Result` that is `1` if for all 8 bits in `a` and `b` (`i` = $0, 1, \ldots, 7$), exactly one of the input bits `a(i)` and `b(i)` is a 1. Otherwise, it generates a `Result` of 0.

For example:

`a`	`b`	`Result`	reason
`1111 0000`	`0000 1111`	`0000 0001`	Condition satisfied
`1111 0000`	`0000 1011`	`0000 0000`	`a(2)` = `b(2)` = `0`
`1111 0000`	`0010 1111`	`0000 0000`	`a(5)` = `b(5)` = `1`
`1010 0101`	`0101 1010`	`0000 0001`	Condition satisfied

Add or modify any components, IO pins, wires and busses required to add this operation to the one-bit and eight-bit ALU. The OP code for ONCE should be `11`.

Op Code	Operation
00	AND
01	OR
10	ADD
1 1	ONCE