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Unit 2: Data Storage

CS 101, Fall 2020

Learning Objectives

After completing this unit, you should be able to:

- Evaluate digital circuits that use AND, OR, XOR, and NOT.
- Convert binary integers to/from decimal, hexadecimal, ASCII.
- Identify the highest integer that can be represented with n bits.
- Implement a half adder, full adder, and 4-bit ripple carry adder.
- Add 8-bit binary numbers without converting to/from decimal.
- Describe how RAM is organized (e.g., 8-bit cells, addresses).
- Describe how hard drives, optical drives, and flash drives work.

Textbook Sections

1.1 Bits and Their Storage
1.2 Main Memory
1.3 Mass Storage
1.4 Representing Information as Bit Patterns
1.5 The Binary System

Video Lectures

- Binary and Hex
- Bless and Logisim
- How Computer Memory Works
- How Hard Drives Work

Assignments

Exercose02 Bits and Bytes; Chapter 1 Problems
Lab02 Logisim Tutorial; Ripple Carry Adder

[Based on #6] What is the largest 8-bit integer? What is the largest 10-bit integer? Describe a quick way to calculate the maximum value for a given number of bits.

255, 1023. Take the number of bits and use as the power of 2 and minus 1. $2^* - 1$

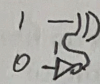
[Based on #32] Perform each of the following 5-bit additions without converting to/from decimal. Identify each case in which the answer is incorrect because of overflow.

```
  00101      11111      01111      10111      11111      00111
+ 01000    + 00001    + 00001    + 11010    + 11111    + 01100
-------    -------    -------    -------    -------    -------
  01101      100000     10000      10001      11110      10011
             Overflow                 Overflow   overflow
```

Chapter 1: Data Storage

Complete the following Chapter Review Problems on pages 73–77.

#1 (what is the output for each?)



a. 0, b. 0, c. 1

#5 (what is in memory at the end?)

Skip 02 → 00
01 → 06
53 → 02

02 53 01 53

#8 (what is the most significant bit?)

B. FF

#19 and #20 (ASCII in binary and hex)

What SP does SP air SP say?

#26 (binary to base 10) – *divide them up and do 3 each* 4 3 2 1 0 (base 2)

a. 15	b. 1	c. 21	d. 8
e. 19	f. 0	g. 9	h. 17
i. 33	j. 25	k. 26	l. 27

#27 (base 10 to binary) – *work on these ones together*

a. 0111	b. 1011	c. 10000
d. 10001	e. 11111	

d) What is 0xFAD in binary? 1111 1010 1101

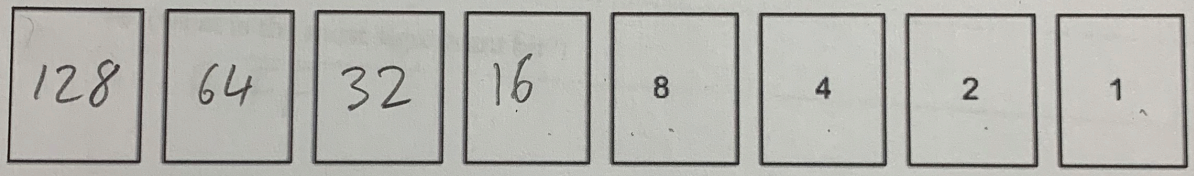
10. Based on the table in #8, explain why binary is sometimes referred to as base-2, decimal as base-10, and hexadecimal as base-16.

Binary increases in powers of 2 for each bit. Decimal increases from power of 10 and hexadecimal increases from the power of 16.

11. Explain the humor: "There are only 10 types of people in the world: those who understand binary, and those who don't."

10 in binary is 2.

12. Typically computers group 8 bits together at a time (8 bits are also called 1 ***byte***). Fill in the number of dots for the four new cards:



13. What is the largest number that can be represented by:

a) five bits? 31

b) six bits? 63

c) seven bits? 127

d) eight bits? 255

e) n bits? $2^n - 1$

$2^5 - 1$

14. Most computers built since the year 2000 have 64-bit processors. Before then, 32-bit processors were the norm. What is the advantage of having more bits?

Having more bits helps store more values.

15. In terms of logic gates and digital circuits, what is the disadvantage of having more bits?

There are more complex logic gates and digital circuits when having more bits.

c) How many possible decimal numbers can be represented by four bits? 10

7. Examine the binary notation below the cards. Explain in a full sentence what a 0 means about the card's dots and what a 1 means.

"0" will not use the value of the card's dots, "1" will use the card's dots.

8. Complete the following table by writing the binary representation of the decimal numbers 0 to 15 using four bits. (And check your answers for #6.)

2^3 2^2 2^1 2^0

Decimal	Binary	Hex
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

9. ***Hexadecimal*** is shorthand for binary. For example, 0xD5 in hex is 1101 0101.

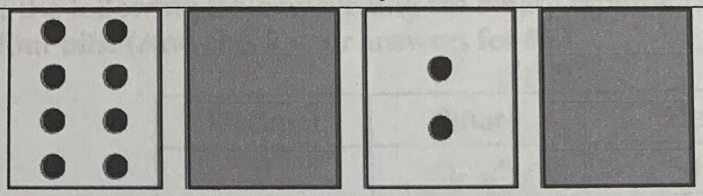
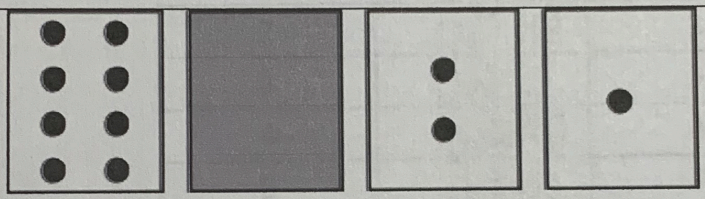
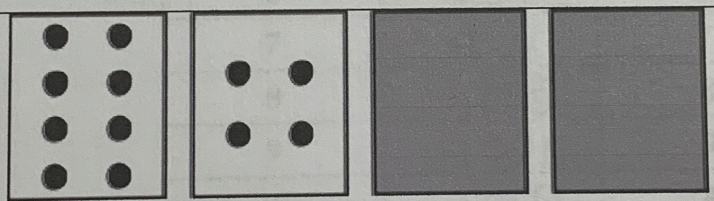
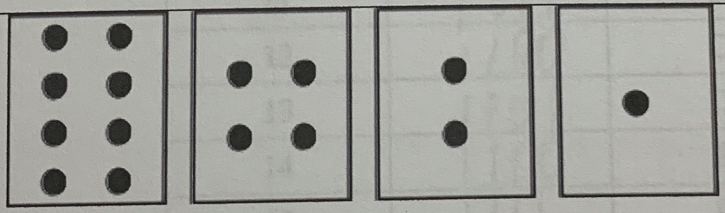
a) What is 0x2E in binary? 0010 1110

b) What is 0x74 in binary? 0111 0100

c) What is 0xB00 in binary? 1011 0000 0000

Model 2 Binary Numbers

Assume there are four cards, one card with 8 dots, one card with 4 dots and one card with 2 dots and one card with 1 dot. Also assume the cards are ordered from left to right with the card with the most dots (8) to the card with the least dots (1). These are base 2 numbers, i.e., 2^3, 2^2, 2^1, and 2^0. Below where the "1" appears means to use the card value and where the "0" appears to not use the value. The cards represent four binary digits, or in other words, a 4-bit number. What is the decimal number (base 10) each row represents?

Binary	Decimal
 1 0 1 0	10
 1 0 1 1	11
 1 1 0 0	12
 1 1 1 1	15

Questions

6. In the table above, write the decimal value for each row by counting the number of dots.

   a) What is the largest decimal number that can be represented by four bits? 15

   b) What is the smallest decimal number that can be represented by four bits? 10

Questions

1. In the circuit diagrams, what does the color (brightness) of the the lines represent?

The color of the lines represent that the wires are connected in the circuit.

2. For each type of gate, describe the circumstances when it will output the value 1.

AND: Both inputs must be 1.

OR: At least 1 input must be 1.

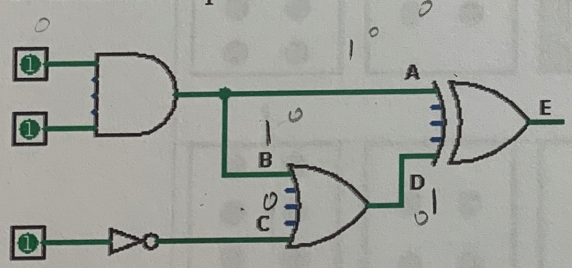
XOR: Only 1 input must be 1.

NOT: Input must be 0.

3. What do you think a "logic gate" represents?

It represents how the Boolean Logic is formed.

4. In the example circuit below, what are the values of *A*, *B*, *C*, *D*, and *E*?



A=1, B=1, C=0, D=1, E=0

5. How would *A*, *B*, *C*, *D*, and/or *E* change if the top input were zero?

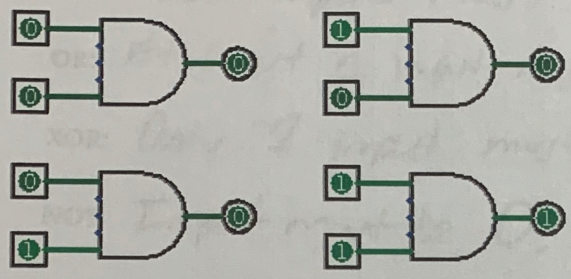
A, B, and D would change to zero. C and E would stay the same.

Exercise 2: Bits and Bytes

Computer hardware is made up of billions of tiny electronic circuits that use low and high voltages to represent the values 0 and 1. These binary digits, or "bits" for short, are the building blocks of all digital technology.

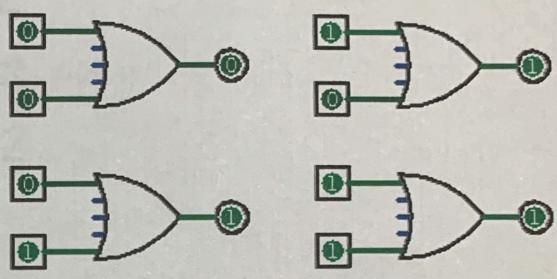
Model 1 Logic Gates

Complete the following tables based on the diagrams.



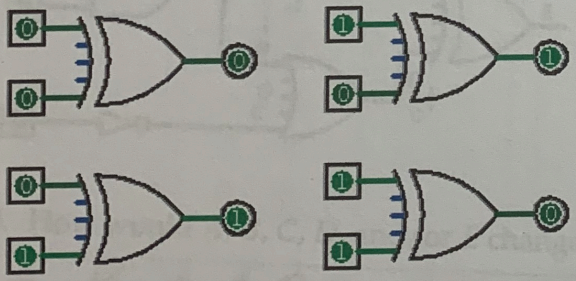
AND

Inputs	Output
0 0	0
0 1	0
1 0	0
1 1	1



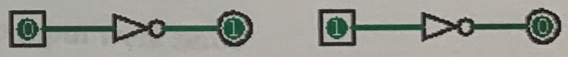
OR

Inputs	Output
0 0	0
0 1	1
1 0	1
1 1	1



XOR

Inputs	Output
0 0	0
0 1	1
1 0	1
1 1	0



NOT

Input	Output
0	1
1	0