Lab Experiment 1

Numeric System

COMPONENTS

Calculator

INTRODUCTION

Binary number and digital codes are fundamental to computers and digital electronics. Computers store information as “bits”, short for binary digit. A bit is a 0 or a 1, but can be represented in many ways. For example, as *true* or *false*, or a light being *on* or *off*. In a computer, a 1 bit is stored as an electrical voltage of 5V, and a 0 bit is 0 volts[1]. This representation of 1’s and 0’s are known as binary coding. The natural system for computers is to use base 2, which is the binary number of system. Binary numbers use only the digits 0 and 1, and each position corresponds to a power of 2.

The decimal system is important because it is universally used to represent quantities outside a digital system. In a decimal system, numbers are encoded in a positional number system. Each number is represented by a string of digits, where each digit position has an associated weight. For example: 3956 = (3×1000) + (9×100) + (5×10) + (4×1)

Since binary code are extremely long, one way to simplify a binary code is by grouping into a group of 4-bits or 3-bits. A group of 4-bit (nibbles) is called the hexadecimal number of system. It is a base 16 system because it has 16 digits, $2^4 = 16$. To represent a single hexadecimal digit, we use 0-9 and then A, B, C, D, E, F to represent the 10, 11, 12, 13, 14, 15, respectively.

Like the hexadecimal number system, the octal number system provides a convenient way to express binary number and codes. However, it is used less frequently than hexadecimal in conjunction with computers and microprocessors to express binary quantities. One octal digit is a decimal representation of a group of 3-bit. Therefore, the octal number system is a base of 8 system composed of eight digits, 0-7.

LAB EXPERIMENT PROCEDURE

Part 1.1 - Binary to decimal conversion

The decimal value of any binary number can be found by adding the weights of all bits that are 1 and discarding the weights of all bits that are 0. Since we are converting from binary, which is base of 2, then the exponent of the base will be weight position of each bit. The weight of each binary digit, bit, starts from right to left. The bit from the right-most has the lowest weight value and is known as **The Most Significant Bit,** MSB, and the bit from the left-most has the highest weight value and is known as **The Less Significant Bit,** LSB. For example, the weight value of an 8-bit code can written as the following:

Weight of each bit position							
$2^7 = 128$	$2^6 = 64$	$2^5 = 32$	$2^4 = 16$	$2^3 = 8$	$2^2 = 4$	$2^1 = 2$	$2^0 = 1$

Example 1.1

Convert the binary whole number **1101101**$_2$ to decimal

To make the conversion:

Step 1) Determine the weight value of each bit

Step 2) Multiply each bit with its weight value

Step 3) Sum all the product from Step 2.

Step 1	Weight	$2^6 = 64$	$2^5 = 32$	$2^4 = 16$	$2^3 = 8$	$2^2 = 4$	$2^1 = 2$	$2^0 = 1$
	Given Binary	**1**	**1**	**0**	**1**	**1**	**0**	**1**
Step 2	Weight × Given Binary	64	32	0	8	4	0	1
Step 3	Sum all product	64+32+0+8+4+0+1 = 109						
	Answer	**109_{10}**						

Exercise 1.1 Binary to decimal conversion

Make the following conversion from binary to decimal and fill up Table 1.1

Given Binary Number	Calculations	Decimal Number
11011_2		
101011_2		
10001_2		
1001010_2		

Table 1.1 – Binary to decimal conversions

Part 1.2 - Binary to hexadecimal conversion

Converting a binary number to hexadecimal is a straightforward procedure. Simply break the binary number into 4-bit groups, starting at the right-most bit, find the decimal equivalent of each 4-bit group, and replaces each group decimal value with the equivalent hexadecimal digit and shown in the following table:

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

Example 1.2

Convert the following binary numbers to hexadecimal: **$1100\ 1010\ 0101\ 0111_2$**

Given Binary number	**1100**	**1010**	**0101**	**0111**
Decimal equivalent	12	10	5	7
Hexadecimal equivalent	C	A	5	7
Answer	**$CA57_{16}$**			

Exercise 1.2 - Binary to hexadecimal conversions

Make the following conversion from binary to hexadecimal and fill up Table 1.2

Given Binary Code	Calculations	Hexadecimal equivalent
1110001001_2		
11100001010_2		
110110000001_2		

Table 1.2 – Binary to hexadecimal conversion

Part 1.3 - Binary to octal conversion

Octal is another way to represent binary code. It breaks the binary code into 3-bit groups, starting at the right-most bit, and find the decimal equivalent of each 3-bit group. This decimal equivalent becomes the equivalent octal digit.

Binary code	Octal equivalent
000	0
001	1
010	2
011	3
100	4
101	5
110	6
111	7

Example 1.3

Convert the following binary numbers to octal: **10111000101_2**

Given Binary number	**10**	**111**	**000**	**101**
Octal equivalent	2	7	0	5
Answer	**2705_8**			

Exercise 1.3 - Binary to octal conversion

Solve the following conversion from binary to octal and fill up Table 1.3

Given Binary Code	Calculations	Octal equivalent
110101_2		
101111001_2		
100110011010_2		

Table 1.3 – Binary to octal conversion

Part 1.4 - Hexadecimal to binary conversion

To convert from hexadecimal number to binary number, we replace each hexadecimal digit with the appropriate four bits.

Example 1.4

Convert the following hexadecimal number to binary number: $8F5B_{16}$

Given Hexadecimal number	**8**	**F = 15**	**5**	**B = 11**
Binary equivalent	1000	1111	0101	1011
Answer	**1000111101011011_2**			

Exercise 1.4 – Hexadecimal to binary conversion

Make the following conversion from hexadecimal to binary and fill up Table 1.4

Hexadecimal Code	Calculations	Binary equivalent
$35D_{16}$		
$E082_{16}$		
$4B1_{16}$		

Table 1.4 – Hexadecimal to binary conversion

Part 1.5 - Octal to binary conversion

To convert from octal number to binary number, we replace each octal digit with the appropriate three bits. Each octal digit is represented by grouping three bits

Example 1.5

Convert the following hexadecimal number to binary number: **3516_8**

Given Octal digit	**3**	**5**	**1**	**6**
Binary equivalent	011	101	001	110
Answer	**$11\ 101\ 001\ 110_2$**			

Exercise 1.5 – Octal to binary conversion

Perform the following conversion from octal to binary and fill up Table 1.5

Given Octal Code	Calculations	Binary equivalent
732_8		
501_8		
64_8		

Table 1.5 – Octal to binary conversion

Part 1.6 - Hexadecimal to decimal conversion

One way to convert a hexadecimal code to its decimal equivalent is by using its weight value:

- Multiply the decimal value of each hexadecimal digit (in its decimal equivalent) by its weight position and then take the sum of these products. The weight of a hexadecimal number are increasing powers of 16 (from right to left)

Example 1.6

Convert the following hexadecimal number to decimal number: **$F2A7_{16}$**

Given Hexadecimal digit	**F = 15**	**2**	**A =10**	**7**
Step 1) Weight position value	$16^3 = 4096$	$16^2 = 256$	$16^1 = 16$	$16^0 = 1$
Step 2) Given hex digit × weight position value	15×4096 = 61440	2×256 = 512	10×16=160	7×1 = 7
Step 3) Sum all products from Step 2	**61440+512+160+7 = 62119_{10}**			
Answer	**62119_{10}**			

Exercise 1.6 – Hexadecimal to decimal conversion

Make the following conversion from hexadecimal to decimal and fill up Table 2.6

Hexadecimal Code	Calculations	Decimal equivalent
$C3_{16}$		
178_{16}		
$9D_{16}$		

Table 1.6 – Hexadecimal to decimal conversion

Part 1.7 - Octal to decimal conversion

To convert an octal number to its decimal equivalent, we multiply each octal digit by its weight position and then take the sum of these products. The weight of an octal number are increasing powers of 8 (from right to left)

Example 1.7

Convert the following octal number to decimal number: **7251_8**

Given Octal digit	**7**	**2**	**5**	**1**
Step 1) Weight position value	$8^3 = 512$	$8^2 = 64$	$8^1 = 8$	$8^0 = 1$
Step 2) Given hex digit × weight position value	7×512 = 3584	2×64 = 128	5×8 = 40	1×1 = 1
Step 3) Sum all products from Step 2	**3584+128+40+1 = 3753_{10}**			
Answer	**3753_{10}**			

Exercise 1.7 – Octal to decimal conversion

Make the following conversion from octal to decimal and fill up Table 1.7

Given Octal Code	Calculations	Decimal equivalent
703_8		
62_8		
154_8		

Table 1.7 – Octal to decimal conversion

Part 1.8 - Decimal to binary conversion

One way to convert a decimal number to binary equivalent is by identifying each remainder of a chain division. In this case, the given decimal number becomes the dividend, and the base that the decimal number is converting to become the divisor.

Example 1.8

Convert the following decimal number to binary number: 23_{10}

$$\frac{23}{2} = 11.5 \rightarrow Remainder\ 0.5 \times 2 = \mathbf{1}\ \rightarrow The\ first\ remainder\ is\ the\ LSB$$

$$\frac{11}{2} = 5.5 \rightarrow Remainder\ 0.5 \times 2 = \mathbf{1}$$

$$\frac{5}{2} = 2.5 \rightarrow Remainder\ 0.5 \times 2 = \mathbf{1}$$

$$\frac{2}{2} = 1.0 \rightarrow Remainder\ 0 \times 2 = \mathbf{0}$$

$$\frac{1}{2} \rightarrow Stop\ division\ because\ the\ dividend\ which\ is\ 1, is\ less\ than\ the\ divisor\ which\ is\ 2.$$

$$Then\ the\ last\ remainder\ is\ 1, which\ is\ the\ MSB \rightarrow Remainder\ = \mathbf{1}$$

$$\rightarrow The\ last\ remainder\ is\ the\ MSB$$

Answer: **10111_2**

Exercise 1.8 – Decimal to binary conversion

Make the following conversion from decimal to binary and fill up Table 2.8

Given Decimal number	Calculations	Binary code
190_{10}		
38_{10}		

471_{10}		
Table 1.8 – Decimal to binary conversion		

Part 1.9 - Decimal to hexadecimal conversion

Repeated division of a decimal number by 16 will produce the equivalent hexadecimal number, formed by the remainders of the division. The first remainder produced is the Least Significant Digit (LSD). Each successive division by 16 yields a remainder that becomes a digit in the equivalent hexadecimal number.

Example 1.9

Convert the following decimal number to hexadecimal number: **780_{10}**

$$\frac{780}{16} = 48.75 \ldots.(Remainder = \ 0.75 * 16 = 12 = C). In\ this\ case\ \mathrm{C}\ is\ the\ LSD$$

$$\frac{48}{16} = 3.0 \ldots.(Remainder = \ 0 * 16 = 0)$$

$$\frac{3}{16} = 0.1875 \ldots.(Remainder = \ 0.1875 *= 3).$$

Stop the division when the quotient is less than the divisor. In this case 3 is the MSD

The answer is **$30C_{16}$**

Exercise 1.9 – Decimal to hexadecimal conversion

Make the following conversion from decimal to hexadecimal and fill up Table 1.9

Given Decimal number	Calculations	Hexadecimal code
773_{10}		
200_{10}		
1530_{10}		

Table 1.9 – Decimal to hexadecimal conversion

Part 1.10 - Decimal to octal conversion

Repeated division of a decimal number by 8 will produce the equivalent octal number, formed by the remainders of the division. The first remainder produced is the Least Significant Digit (LSD). Each successive division by 8 yields a remainder that becomes a digit in the equivalent octal number.

Example 1.10

Convert the following decimal number to octal number: **92_{10}**

$$\frac{92}{8} = 11.5 \ldots.(Remainder = 0.5 * 8 = 4).\ In\ this\ case\ "4"\ is\ the\ LSD$$

$$\frac{11}{8} = 1.375 \ldots.(Remainder = 0.375 * 8 = 3)$$

$$\frac{1}{8} = 0.125 \ldots . (Remainder = \ 0.125 * 8 = 1)$$

$$Stop\ the\ division\ when\ the\ quotient\ is\ less\ than\ the\ divisor. In\ this\ case\ 1\ is\ the\ MSD$$

The answer is 134_8

Exercise 1.10 – Decimal to octal conversion

Make the following conversion from decimal to octal and fill up Table 2.10

Given Decimal number	Calculations	Octal code
96_{10}		
205_{10}		
185_{10}		

Table 1.10 – Decimal to octal conversion

Student's name: ________________________ Lab Instructor's signature: _____________________

------------------ LAB EXPERIMENT 1 ENDS HERE --------------------