Digital Electronic

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Chapter One

Lecture 3

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1.3.5 Hexadecimal numeration system:

- **The hexadecimal numeration system is a place weighted system with a base of sixteen.**
- **Valid ciphers include the normal decimal symbols "0","1","2","3","4","5","6","7";"8";9"**
- **Plus six alphabetical characters A, B, C, D, E, and F.**
- To convert from binary to hexadecimal numeration,
- we group bits in fours.
- Each group of four bit is replaced by its hexadecimal equivalent.
- **The following table summarizes the equivalence between decimal, binary, octal and hexadecimal systems.**

Decimal	Binary	Octal	Hexadecimal
0	0000	0	0
1	0001	1	1
2	0010	2	2
3	0011	3	3
4	0100	4	4
5	0101	5	5
6	0110	6	6
7	0111	7	7
8	1000	10	8
9	1001	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
15	1111	17	F

- Example 1.6:
- Convert the following binary numbers in hexadecimal.
- A = 1101011101
- B = 11101011101.11
- As explained above,
- We just have to group the binary number in groups of four bits each:

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As explained above, we just have to group the binary number in groups of four bits each:

A = **00**11 0101 1101

3 5 D_{16}

$1101011101_2 = 35D_{16}$

The binary number has been grouped is groups of four bits each, from the right to the left two implied zeros have been added at the extreme left. In the same way the number B can also be converted.

B = 0111 0101 1101 .1100

7 5 D C_{16}

$11101011101.11_2 = 75DC_{16}$

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Changing of base:

We have already seen in the previous section **how to change from binary to decimal, octal or hexadecimal systems of numeration.** The present section is intended to show how to move from a given system of numeration to any other system.

From octal and hexadecimal to binary and decimal:

- The octal and hexadecimal systems are actually used by computer engineer just to obtain a "shorthand" representation of binary numbers (because octal and hexadecimal representations take a few numbers of ciphers or symbols as compared to binary system).
- Only binary system is implemented in the electronic circuits of digital systems (through two levels of voltages or currents: high (1) and low (0)), the others systems being used by engineers just for simplification issues.
- However, we sometimes have the need to convert either of those systems to binary or decimal forms.

Octal and hexadecimal to binary:

- It is obvious that, to convert from octal to binary,
- We just have to convert each octal cipher to its binary equivalent in **3 bits**.
- In the same way, to convert from hexadecimal to binary, we should convert each hexadecimal symbol into its binary equivalent in **4 bits**.

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Example 1.7:

- Convert the following octal number to digital 5238.
- Convert the following hexadecimal number to binary 4DC216.

$523_8 = 101\ 010\ 011_2$ (groups: 101 → 5, 010 → 2, 011 → 3)

$523_8 = 101010011_2$

$4DC2_{16} = 0100\ 1101\ 1100\ 0010_2$ (groups: 0100 → 4, 1101 → D, 1100 → C, 0010 → 2)

$4DC2_{16} = 100110111000010_2$

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1.4.1.2 Octal to decimal:

- Because octal is a base of eight numeration system, each place weight value differs from either adjacent place by factor of eight.

- **Example 1.8:**
- Let us convert the following octal number to decimal: A = 264.748

$$\begin{array}{l} \quad\ \ 2\ 1\ 0\ {-1}\ {-2} \\ A = 2\ 6\ 4.7\ 4_8 \end{array}$$

$$A = 2 \times 8^2 + 6 \times 8^1 + 4 \times 8^0 + 7 \times 8^{-1} + 4 \times 8^{-2}$$

$$A = 180.9375_{10}$$

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Exercise 1.3:

Convert the following octal number to decimal:

- A = 4562.368
- B = 523411.2328
- C= 264.3658
- D = 4516328
- Is the number 12586 an octal number?

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Hexadecimal to decimal:

The technique for converting hexadecimal notation to decimal is the same as the one used above, except that each successive place weight changes by a factor of sixteen.

Example 1.9:

Let us convert the following hexadecimal number to decimal:

$A = 34DF.AC2_{16}$

3 2 1 0 -1-2-3

$A = 3\ 4\ D\ F.A\ C\ 2_{16}$

$$A = 3\times16^{3} + 4\times16^{2} + 13\times16^{1} + 15\times16^{0} + 10\times16^{-1} + 12\times16^{-2} + 2\times16^{-3}$$

$$A = 12288 + 1024 + 208 + 15 + 0.625 + 0.046875 + 0.000488281$$

$$A = 13535.67236_{10}$$

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Exercise 1.4:

- Convert from hexadecimal to decimal.
- X = A23C.DF16
- Y = 7D3E16
- Z= D96EC.FA16

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1.4.2 Conversion from decimal numeration system to others systems:

- The conversion from decimal numeration system to others systems of numeration is an important task for everyone dealing with computer science, because it permits to move from daily world to digital world.
- To convert a number from decimal numeration system to binary, octal or hexadecimal, we use repeated cycles of divisions to break the decimal numeration down into multiples of binary, octal or hexadecimal place weight values.
- In the first cycle of division, we take the original decimal number and divide it by the base of the numeration system that we are converting to:
- It meant that for binary, we should divide by 2, for octal we should divide by 8, for hexadecimal we should divide by 16. Then we take the whole number portion of the division result and divide it by the result again, and so on, until we end up with a quotient of less than the base value.

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Decimal to binary conversion:

- Let us convert the decimal number 87_{10} to binary, using the principle described above.
- It meant that the decimal number should be repeatedly divided by 2.

87	2	
43	2	1
21	2	1
10	2	1
5	2	0
2	2	1
1		0

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- The coloured ciphers are the reminders of repeated division of the decimal number by 2.
- To obtain the binary number, we just have to take those reminders, beginning with the last one, as indicated by the arrow. Then we have:

$$87_{10} = 1010111_2$$

- In short, the binary bits are assembled from the reminders of the successive division steps, beginning with the LSB (Least Significant Bit) and proceeding to the MSB (Most significant Bit).

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Exercise 1.5:

- Convert the following decimal numbers to binary
- A = 15310
- B = 25510
- C = 4610
- D = 3810

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Conversion of decimal numbers less than 1 to binary:

- For converting a decimal number less than 1 to binary.
- we use repeated multiplication by 2, taking the integer portion of the product in each step as the next digit of our converted number.
- Let us convert the decimal number 0.37510 to binary:

0.375x2 = **0**.75	Integer portion of the product = **0**
0.75x2 = **1**.5	Integer portion of the product = **1**
0.5x2 = **1**	Integer portion of the product = **1** (we stop when the product is a pure integer)

- Each step gives us the next bit further away from the binary point, so the binary number is obtained taking the bits from up to down.

$$0.375_{10} = 0.011_2$$

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Remark 1.3:

- With integer division, worked from the LSB to the MSB (down to up)
- But with repeated multiplication, we worked from up to down.

Exercise 1.6:

- Convert from decimal to binary:
- A = 0.812510
- B= 0.62510
- C = 0.87510
- D = 0.4062510

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Remark 1.4:

- To convert a decimal number greater than 1 with a less than 1 component,
- we should use both techniques, one at time.

- Let us convert the decimal number 23.125_{10} to binary.
- Step one: repeated division for the integer portion 23_{10}.

23	2	
11	2	**1**
5	2	**1**
2	2	**1**
1		**0**

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- Let us convert the decimal number 23.125_{10} to binary.
- Step one: repeated division for the integer portion 23_{10}.

23	2	
11	2	**1**
5	2	**1**
2	2	**1**
1		**0**

Partial answer:

$23_{10} = 10111_2$

Step two: repeated multiplication for the less than 1 portion 0.125_{10}

0.125x2 = 0.25	Integer portion of the product = 0
0.25x2 = 0.5	Integer portion of the product = 0
0.5x2 = 1	Integer portion of the product = 1

Partial answer:

$0.125_{10} = 0.001_2$

Complete answer:

$10111_2 + 0.001_2 = 10111.001_2$

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Exercise 1.7:

- Convert from decimal to binary
- A = 17.37510
- B = 43.62510
- C = 27.87510
- D = 49.4062510

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1.4.2.3 Decimal to octal conversion:

- Let us convert the number 123_{10} from decimal to octal numeration system. As explained before, we just have to divide the decimal number successively by 8.

123	8	
15	8	**3**
1		**7**

$123_{10} = 173_8$

- The octal digits are determined by the reminders left over by each division step. These reminders are between 0 and 7.

Exercise 1.8:

- Convert the following numbers from decimal to octal:
- A = 32310
- B = 45210
- C = 12810
- D = 9910

1.4.2.4 Decimal to hexadecimal conversion:

- Let us convert the number 456_{16} from decimal to hexadecimal. This conversion is obtained by repeated division of the decimal number by 16.

456	16	
28	16	**8**
1		**12 (C_{16})**

$456_{16} = 1C8_{16}$

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Exercise 1.9:

- Convert from decimal to hexadecimal:
- A = 452310
- B = 86710
- C = 99710
- D = 123810

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