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*Lecture 2

Number System 2

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* Hexadecimal Numbers

The **hexadecimal** number system has a base of sixteen. **Ten numeric digits and six alphabetic digits** make up the hexadecimal number system. each hexadecimal digit represents a **4-bit** binary number (as listed in **Table below**).

Decimal	Binary	Hexadecimal
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

* Counting in Hexadecimal

How do you count in hexadecimal once you get to F? Simply start over with another column and continue as follows:

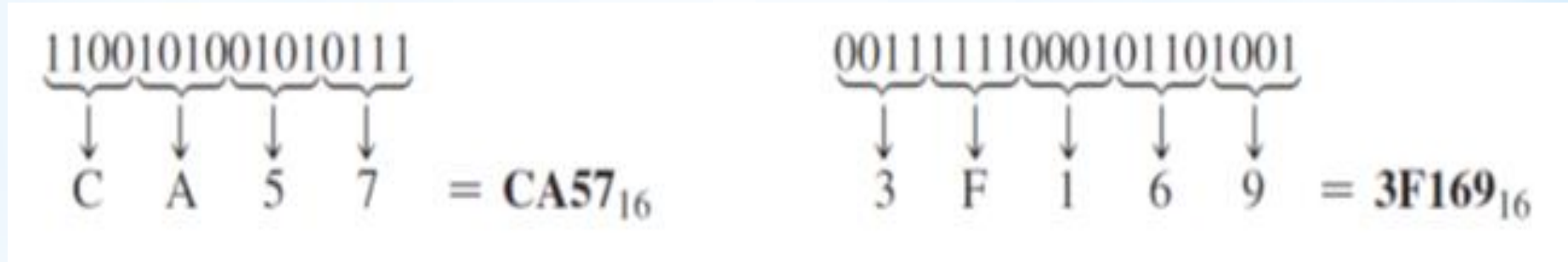
0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19,
1A, 1B, 1C, 1D, 1E, 1F, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 2A, 2B,
2C, 2D, 2E, 2F, 30, 31, ...

With two hexadecimal digits, you can count up to FF_{16} , which is decimal 255. To count beyond

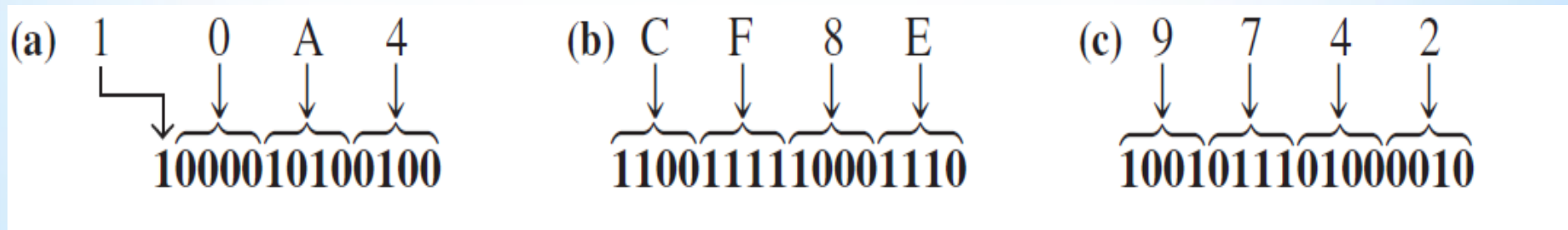
this, three hexadecimal digits are needed. For instance, 100_{16} is decimal 256, 101_{16} is decimal 257, and so forth. The maximum 3-digit hexadecimal number is FFF_{16} , or decimal 4095. The maximum 4-digit hexadecimal number is FFFF_{16} , which is decimal 65,535.

* Binary-to-Hexadecimal Conversion

Simply break the binary number into 4-bit groups, **starting** at the right-most bit (**LSB**) and replace each **4-bit** group with the equivalent hexadecimal symbol. **Zeros** can be add to complete a **4-bit** group at the left.



- **Hexadecimal-to-Binary Conversion:** Replace each hexadecimal
- symbol with the appropriate four bits.



* Hexadecimal-to-Decimal Conversion

A. Method One: First convert the **hexadecimal number to binary** and then convert from **binary to decimal**.

(a)
$$\begin{array}{cc} 1 & C \\ \downarrow & \downarrow \\ 0001 & 1100 \end{array} = 2^4 + 2^3 + 2^2 = 16 + 8 + 4 = 28_{10}$$

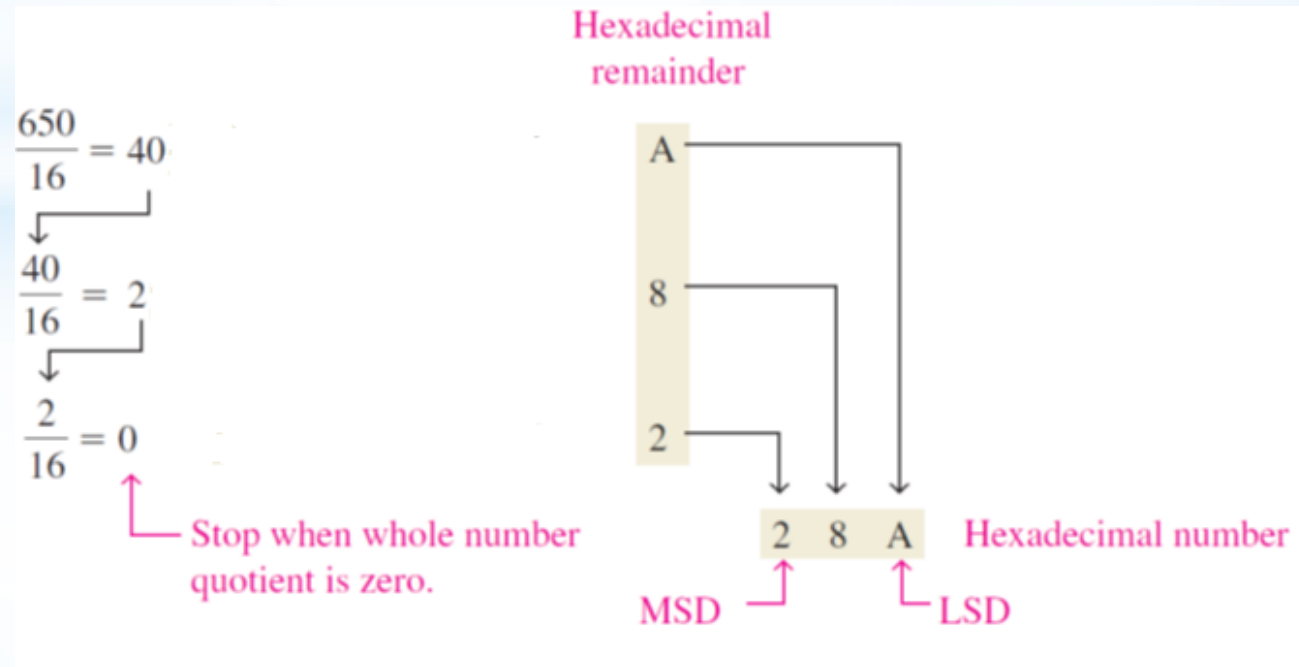
(b)
$$\begin{array}{ccc} A & 8 & 5 \\ \downarrow & \downarrow & \downarrow \\ 1010 & 1000 & 0101 \end{array} = 2^{11} + 2^9 + 2^7 + 2^2 + 2^0 = 2048 + 512 + 128 + 4 + 1 = 2693_{10}$$

B. Method Two: Multiply the decimal value of each hexadecimal digit by its weight and then take the sum of these products. For a **4-digit** hexadecimal number, the weights are:

$$\begin{aligned} B2F8_{16} &= (B \times 4096) + (2 \times 256) + (F \times 16) + (8 \times 1) \\ &= (11 \times 4096) + (2 \times 256) + (15 \times 16) + (8 \times 1) \\ &= 45,056 + 512 + 240 + 8 = 45,816_{10} \end{aligned}$$

* Decimal-to-Hexadecimal Conversion (Repeated Division by 16)

Repeated division by 16 will produce the equivalent hexadecimal number, formed by the remainders of the divisions. The **first remainder** produced is the least significant digit (**LSD**).



* Octal Numbers

Like the hexadecimal number system, the octal number system provides a convenient way to express binary numbers and codes. However, it is used less frequently than hexadecimal in conjunction with computers and microprocessors to express binary quantities for input and output purposes.

The octal number system is composed of eight digits, which are

0, 1, 2, 3, 4, 5, 6, 7

To count above 7, begin another column and start over:

10, 11, 12, 13, 14, 15, 16, 17, 20, 21, ...

* Octal-to-Decimal Conversion

Since the octal number system has a base of eight, each successive digit position is an increasing power of eight, beginning in the right-most column with 8^0 . The evaluation of an octal number in terms of its decimal equivalent is accomplished by multiplying each digit by its weight and summing the products, as illustrated here for 2374_8 .

Weight: 8^3 8^2 8^1 8^0

$$2374_8 = (2 \times 8^3) + (3 \times 8^2) + (7 \times 8^1) + (4 \times 8^0)$$

$$= (2 \times 512) + (3 \times 64) + (7 \times 8) + (4 \times 1)$$

$$= 1024 + 192 + 56 + 4 = 1276_{10}$$

* Decimal-to-Octal Conversion (Repeated Division by 8 Method)

Each successive **division by 8** yields a remainder that becomes a digit in the equivalent octal number. The **first remainder** generated is the least significant digit (**LSD**).

$$\begin{array}{r} 359 \\ 8 \overline{) 359} \\ \underline{320} \\ 44 \\ 8 \overline{) 44} \\ \underline{40} \\ 5 \\ 8 \overline{) 5} \\ \underline{0} \end{array}$$

Stop when whole number quotient is zero.

Remainder

7
4
5

5 4 7

MSD

Octal number

LSD

* Octal-to-Binary Conversion

Because each octal digit can be represented by a **3-bit** binary number, it is very easy to convert from octal to binary. **Each octal digit is represented by three bits** as shown in **Table below**.

Octal/binary conversion.

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

(a) 1 3
 ↓ ↓
 └─┘ └─┘
 001011

(b) 2 5
 ↓ ↓
 └─┘ └─┘
 010101

(c) 1 4 0
 ↓ ↓ ↓
 └─┘ └─┘ └─┘
 001100000

(d) 7 5 2 6
 ↓ ↓ ↓ ↓
 └─┘ └─┘ └─┘ └─┘
 111101010110

* Binary-to-Octal Conversion

Start with the **right-most group of three bits** and, moving from right to left, convert each **3-bit group** to the equivalent octal digit. If there are **not three** bits available for the left-most group, **add** either one or two zeros to make a complete group. These leading zeros do not affect the value of the binary number.

$$(a) \quad \begin{array}{ccc} 110101 \\ \downarrow \quad \downarrow \\ 6 \quad 5 = 65_8 \end{array}$$

$$(b) \quad \begin{array}{ccc} 101111001 \\ \downarrow \quad \downarrow \quad \downarrow \\ 5 \quad 7 \quad 1 = 571_8 \end{array}$$

$$(c) \quad \begin{array}{cccc} 100110011010 \\ \downarrow \quad \downarrow \quad \downarrow \quad \downarrow \\ 4 \quad 6 \quad 3 \quad 2 = 4632_8 \end{array}$$

$$(d) \quad \begin{array}{cccc} 011010000100 \\ \downarrow \quad \downarrow \quad \downarrow \quad \downarrow \\ 3 \quad 2 \quad 0 \quad 4 = 3204_8 \end{array}$$

* Binary Coded Decimal (BCD)

Binary coded decimal (BCD) is a way to express each of the decimal digits with a binary code. There are **only ten code** groups in the BCD system.

Decimal/BCD conversion.

Decimal Digit	0	1	2	3	4	5	6	7	8	9
BCD	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001

