EEE104 – Digital Electronics (I) Lecture 3

Dr. Ming Xu, Dr. Filbert Juwono

Dept of Electrical & Electronic Engineering

XJTLU

In This Session

- Binary Arithmetic
- Hexadecimal Numbers.
- Binary Coded Decimal (BCD)

Binary Arithmetic

1's Complement

- This is to change all 1s to 0s and all 0s to 1s in a binary number.
- It is important to the representation of negative numbers.

1 (1	1	0	0	1	0	Binary number
1	1	\downarrow	1	1	\downarrow	1	
0 1	. 0	0	1	1	0	1	1's complement

Binary Arithmetic

2's Complement

- This is to add 1 to the 1's complement.
- It is important to the representation of negative numbers.

10110	010	Binary number
01001	1101	1's complement
+	1	Add 1
01001	 110	2's complement

- Long binary numbers are difficult to read and write.
- So hexadecimal number system is introduced as a compact way of writing binary numbers.
- It is widely used in computers and microprocessors.

- The hexadecimal number system has 16 digits: 10 numeric digits (0-9) and 6 alphabetic characters (A-F).
- Each digit represents a 4-bit binary number.
- A hexadecimal number may have a subscript 16 or be followed by an "h".

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	В
12	1100	C
13	1101	D
14	1110	E
15	1111	F

Counting in Hexadecimal

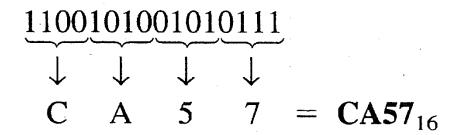
Once you get to F, add another digit and continue.

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0, 1, ....., 9, A, B, C, D, E, F
10, 11, ....., 19, 1A, 1B, 1C, 1D, 1E, 1F
.....
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F0, F1,, F9, FA, FB, FC, FD, FE, FF 100, 101,109, 10A, 10B, 10C, 10D, 10E, 10F

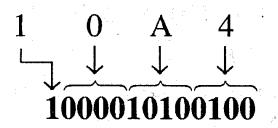
Binary-to-Hexadecimal Conversion

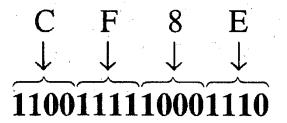
- Starting at the right-most bit, break the binary number into 4-bit groups.
- Replace each 4-bit group with the equivalent hexadecimal symbol.



Hexadecimal-to-Binary Conversion

- Replace each hexadecimal symbol with the appropriate 4 bits.
- The leftmost 0's can be removed.





Hexadecimal-to-Decimal Conversion

 The weights of hexadecimal digits are increasing powers of 16 (from right to left).

$$16^3$$
 16^2 16^1 16^0 4096 256 16 1

 Multiply the decimal value of each hexadecimal digit by its weight and then take the sum of these products.

$$B2F8_{16} = (B \times 4096) + (2 \times 256) + (F \times 16) + (8 \times 1)$$

$$= (11 \times 4096) + (2 \times 256) + (15 \times 16) + (8 \times 1)$$

$$= 45,056 + 512 + 240 + 8 = 45,816_{10}$$

Decimal-to-Hexadecimal Conversion

Repeated Division by 16 method

- Divide a decimal number or the previous quotient by 16.
 The remainder is a digit in the hexadecimal number.
- The first remainder is the LSD.
- Repeat this process until the whole number quotient becomes zero.

	quotient	remainder	
$\frac{650}{16}$	40	10 = A	$650 = 28A_{16}$
$\frac{40}{16}$	2	8 = 8	
$\frac{2}{16}$	0	2	

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Hexadecimal Addition

- If the sum of two digits is less than 16, bring down the corresponding hexadecimal digit.
- If the sum of these two digits is greater than or equal to 16, bring down the amount of the sum that exceeds 16 and carry a 1 to the next column.

right column:
$$8_{16} + 2_{16} = 8_{10} + 2_{10} = 10_{10} = A_{16}$$

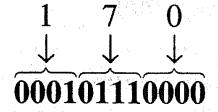
 $+ 22_{16} \over 7A_{16}$ left column: $5_{16} + 2_{16} = 5_{10} + 2_{10} = 7_{10} = 7_{16}$
DF₁₆ right column: $F_{16} + C_{16} = 15_{10} + 12_{10} = 27_{10}$
 $+ AC_{16} \over 18B_{16}$ left column: $C_{16} + C_{16} = 11_{10} = C_{10} = C_{10}$
 $C_{16} + C_{16} = C_{10} = C_{10} = C_{10} = C_{10}$
 $C_{16} + C_{16} = C_{10} = C_$

- Binary coded decimal (BCD) is an easy way to express decimal digits with a binary code.
- The BCD system has only 10 code groups.
- It is mainly used in user interface such as keypads and digital displays.
- The **8421 code** is a type of BCD, where the weights of the four bits are 8, 4, 2 and 1.

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

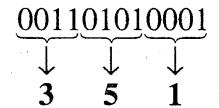
Decimal-to-BCD Conversion

Replace each decimal digit with the appropriate 4-bit.



BCD-to-Decimal Conversion

- Start at the right-most bit and break the code into groups of four bits.
- Write the decimal digit for each 4-bit group.



BCD Addition

- Add two BCD numbers using the rules for binary addition.
- If a 4-bit sum is less than 10, it is a valid BCD number.
- If a 4-bit sum is greater than or equal to 10, or if a carry out of the 4-bit group is generated, it is an invalid result. Add 6 (0110) to the 4-bit sum to skip the six invalid states.

BCD Addition

