CS 223 – Digital Logic and Design

Week 11 Lecture 1
Signed Binary Numbers

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Signed Binary Numbers

- Positive integers (including zero) can be represented as unsigned numbers.
- However, to represent negative integers, we need a notation for negative values. In ordinary arithmetic, a negative number is indicated by a minus sign and a positive number by a plus sign.
- Because of hardware limitations, computers must represent everything with binary digits.
- It is customary to represent the sign with a bit placed in the leftmost position of the number.
- Sign bit 0 for positive and 1 for negative.

Signed Binary Numbers (Contd.)

- It is important to realize that both signed and unsigned binary numbers consist of a string of bits when represented in a computer.
- The user determines whether the number is signed or unsigned.
- If the binary number is signed, then the leftmost bit represents the sign and the rest of the bits represent the number.
- If the binary number is assumed to be unsigned, then the leftmost bit is the most significant bit of the number.
- For example, the string of bits 01001 can be considered as 9 (unsigned binary) or as +9 (signed binary) because the leftmost bit is 0.
- The string of bits 11001 represents the binary equivalent of 25 when considered as an unsigned number and the binary equivalent of -9 when considered as a signed number.

Signed-magnitude convention

- In this notation, the number consists of a magnitude and a symbol (+ or -) or a bit (0 or 1) indicating the sign. This is the representation of signed numbers used in ordinary arithmetic.

Signed-complement system

- When arithmetic operations are implemented in a computer, it is more convenient to use a different system, referred to as the signed-complement system, for representing negative numbers.
- In this system, a negative number is indicated by its complement.
- Whereas the signed-magnitude system negates a number by changing its sign, the signed-complement system negates a number by taking its complement.
- Since positive numbers always start with 0 (plus) in the leftmost position, the complement will always start with a 1, indicating a negative number.
- The signed-complement system can use either the 1's or the 2's complement, but the 2's complement is the most common.

Signed-complement system – Example

- Consider the number 9, represented in binary with eight bits.
- +9 is represented with a sign bit of 0 in the leftmost position, followed by the binary equivalent of 9, which gives 00001001.
- Note that all eight bits must have a value; therefore, 0's are inserted following the sign bit up to the first 1.
- Although there is only one way to represent +9, there are three different ways to represent -9 with eight bits:

- signed-magnitude representation: 10001001
- signed-1's-complement representation: 11110110
- signed-2's-complement representation: 11110111

Signed-complement system – Example (Contd.)

- signed-magnitude representation: 10001001
- signed-1's-complement representation: 11110110
- signed-2's-complement representation: 11110111

- In signed-magnitude, -9 is obtained from +9 by changing only the sign bit in the leftmost position from 0 to 1.
- In signed-1's-complement, -9 is obtained by complementing all the bits of +9, including the sign bit.
- The signed-2's-complement representation of -9 is obtained by taking the 2's complement of the positive number, including the sign bit.

Table 1.3

- Table 1.3 lists all possible four-bit signed binary numbers in the three representations.
- The equivalent decimal number is also shown for reference.
- Note that the positive numbers in all three representations are identical and have 0 in the leftmost position.
- The signed-2's-complement system has only one representation for 0, which is always positive.
- The other two systems have either a positive 0 or a negative 0, something not encountered in ordinary arithmetic.
- Note that all negative numbers have a 1 in the leftmost bit position; that is the way we distinguish them from the positive numbers.

Table 1.3
Signed Binary Numbers

Decimal	Signed-2's Complement	Signed-1's Complement	Signed Magnitude
+7	0111	0111	0111
+6	0110	0110	0110
+5	0101	0101	0101
+4	0100	0100	0100
+3	0011	0011	0011
+2	0010	0010	0010
+1	0001	0001	0001
+0	0000	0000	0000
−0	—	1111	1000
−1	1111	1110	1001
−2	1110	1101	1010
−3	1101	1100	1011
−4	1100	1011	1100
−5	1011	1010	1101
−6	1010	1001	1110
−7	1001	1000	1111
−8	1000	—	—

- That’s end of the presentation ! ☺