Representation of Numbers

DSC 315: Computer Organization & Operating Systems

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Unsigned Integers

Unsigned Integer Representation

Unsigned integers represent **non negative integers only** and use **all bits for magnitude**.

For an n bit unsigned integer:

$$\text{Value} = \sum_{i=0}^{n-1} b_i \, 2^i$$

- No sign bit is used
- Each bit contributes a positive power of two
- All bit patterns correspond to valid values

Range:

$$0 \leq \text{Value} \leq 2^n - 1$$

Example (8 bit unsigned integer):

- Minimum: $00000000_2 = 0$
- Maximum: $11111111_2 = 255$

Signed Integers

Signed Integer Representations

- Signed Integer
  - Sign-Magnitude
  - One's Complement
  - Two's Complement
  - Biased (Excess)

Sign-Magnitude Representation

- The most significant bit (MSB) represents the sign
  - 0 indicates a positive number
  - 1 indicates a negative number
- The remaining bits store the magnitude in unsigned binary
- Example using 8-bit representation:
  - $+5 \to 00000101$
  - $-5 \to 10000101$
- Drawbacks:
  - Two representations of zero: $+0$ and -0
  - `Arithmetic operations are complex` on hardware. Why?
  - Rarely used in modern computer systems

One's Complement Representation

- Positive numbers are represented using standard binary notation
- Negative numbers are obtained by taking the bitwise complement of the positive value
- Example using 8-bit representation:
  - $+5 \rightarrow 00000101$
  - $-5 \rightarrow 11111010$
- Key properties:
  - Two representations of zero: 00000000 and 11111111
  - Addition may require an end-around carry
- Largely obsolete, replaced by two's complement in modern systems

Signed Integer Representation (Two's Complement)

Signed integers represent **both positive and negative integers** using **two's complement**.

For an n bit signed integer:

$$\text{Value} = \begin{cases} \sum_{i=0}^{n-1} b_i\, 2^i, & \text{if } b_{n-1} = 0 \\ -2^{n-1} + \sum_{i=0}^{n-2} b_i\, 2^i, & \text{if } b_{n-1} = 1 \end{cases}$$

- Most significant bit is the sign bit
- Positive numbers are represented as usual binary
- Negative numbers are represented using two's complement

Range: $-2^{n-1} \leq \text{Value} \leq 2^{n-1} - 1$

Example (8 bit signed integer):

- Maximum: $01111111_2 = +127$; Minimum: $10000000_2 = -128$

Conversion Table with 2's Complement

Decimal	Bin	Flipped Bits	2's Complement	-ve
0	0000 0000	1111 1111	0000 0000	0
1	0000 0001	1111 1110	1111 1111	-1
2	0000 0010	1111 1101	1111 1110	-2
64	0100 0000	1011 1111	1100 0000	-64
126	0111 1110	1000 0001	1000 0010	-126
127	0111 1111	1000 0000	1000 0001	-127
128	~~1000 0000~~	0111 1111	1000 0000	-128

Table: Conversion Table with 2's Complement

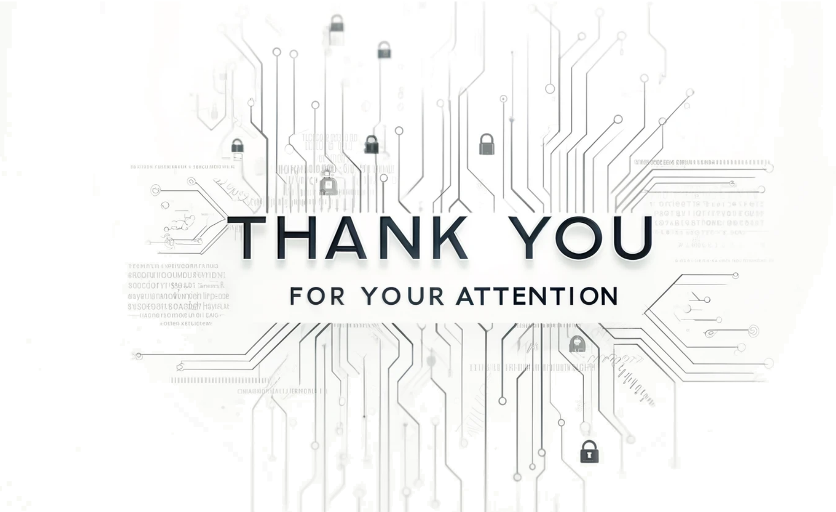
Homework

- Consider the decimal values 123, -123, 73, -73, 0, -0 (or number of your choice). Finds their
  1. Unsigned representation
  2. Sign-Magnitude representation
  3. 1's complement representation
  4. 2's complement representation

  Find their representations in both 8-bits and 32-bits.

- Consider the following binary numbers (or number of your choice)
  - a) 1100 1010 ; b) 0101 0101 c) 0111 0010 d) 1111 1010
  - f) 0000 0000 0000 0000 0000 0000 1100 1010
  - g) 1111 1111 1111 1111 1111 1111 1111 1010

  Find their decimal values considering them as a) Unsigned representation, b) Sign-Magnitude representation, c) 1's complement representation and d) 2's complement representation



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