

- ① Binary representation of Negative Numbers  
 — Negative numbers are represented in 2<sup>n</sup> complement form.  
 — Range of numbers:  $[-2^{n-1} \text{ to } 2^n - 1]$   
 (n is number of bits)  
 — Steps to get 2<sup>n</sup> complement:  
 (i) invert all bits  
 (ii) Add 1  
 $\text{Result formula} = 2^n - x$

- Why 2<sup>n</sup> complement form?  
 → other options  
 → signed bit  
 → 1's complement
- 1) We have only one representation of zero.
  - 2) The arithmetic operations are easier to perform. Actually 2<sup>n</sup> complement form is derived from the idea of 0-x.
  - 3) The leading bit is always 1. ( $2^{n-1} \rightarrow$  leading bit always 0) for negative numbers

- Note: 1) The first bit in a signed representation is the sign of number, 0 for non-negative numbers and 1 for negative numbers, and the remaining ( $n-1$ ) bits contains the magnitude of the number.  
 2) Two's complement is used for negative numbers.  
 3) In an unsigned representation, only non-negative numbers can be used, but the upper bound for values is higher.  
 — contains integers between 0 to  $2^n - 1$ .  
 Connection between two representations:  
 A signed -x equals to an unsigned  $2^n - x$ .

- 4) If a number is larger than the upper bound of bit representation, the number will overflow.  
 — In a signed representation, next no after  $2^{n-1}$  is  $-2^{n-1}$ .  
 — In an unsigned representation, next no after  $2^{n-1}$  is 0.

## ② Bitwise Operators in Python

print(`b10(18)`) → 0b10010  
 print(`b10(22)`) → 0b1100  
 print(`int("0b10010", 2)`) → 18

Special prefixes for all bases:  
 → for integer/decimal representation  
 → for binary representation  
 → for octal  
 → for hexadecimal  
 → 0b  
 → 0o  
 → 0x

Bitwise AND (&)  
 Bitwise OR (|)  
 Bitwise XOR (^)

LeftShift operator (<<)  
 RightShift operator (>>)  
 Bitwise Not (~)

operator	operator	Result
XOR	$X \wedge 0s$	X
XOR	$X \wedge 1s$	$\sim X$
XOR	$X \wedge X$	0

Here, 0s or 1s mean a sequence of 0 or 1.

operator	operator	Result
AND	$X \& 0s$	0
AND	$X \& 1s$	X
AND	$X \& X$	X

operator	operator	Result
OR	$X   0s$	X
OR	$X   1s$	1s
OR	$X   X$	X

eg:  $X=6 \Rightarrow 0110$       eg:  $X=7 \Rightarrow 0111$       eg:  $X=5 \Rightarrow 0101$

$0110$        $0111$        $0101$

$0000$        $0000$        $0000$

$0110$        $0111$        $0101$

$\underline{\underline{X}}$        $\underline{\underline{X}}$        $\underline{\underline{X}}$

$\underline{\underline{X}}$        $\underline{\underline{X}}$        $\underline{\underline{X$