

# Binary Arithmetic

## Binary Addition

Rules:

- $0 + 0 = 0$
- $1 + 0 = 1$
- $0 + 1 = 1$
- $1 + 1 = 10$  (0 with carry 1)
- $1 + 1 + 1 = 11$  (1 with carry 1)

Carrying just like in decimal:

Ignore if overflows

$$0000\ 0011 = 3_{10}$$

+

$$0000\ 0101 = 5_{10}$$

=

$$0000\ 1000 = 8_{10}$$

Could also convert from binary to decimal then add:

$$0111\ 1000 = 64 + 32 + 16 + 8 = 120_{10}$$

+

$$0101\ 0101 = 64 + 16 + 4 + 1 = 85_{10}$$

=

$$1100\ 1101 = 128 + 64 + 8 + 4 + 1 = 205_{10}$$

## Unsigned vs Signed

Unsigned numbers always positive or zero

Leftmost bit in signed number is sign; 0 = positive, 1 = negative

$$1000\ 0000 = -128$$

$$0111\ 1111 = +127$$

## Binary Subtraction (Two's Complement Notation)

Steps:

1. Take the 2nd number, convert with 2's complement
2. Add 1st number to 2's complement of 2nd

$$= 01 - 10$$

$$= 10_{10} - 13_{10}$$

$$= 10_{10} + (-13_{10})$$

## How to take 2's Complement

Steps:

1. Flip every bit to its opposite
2. Add 1 to the binary

0011 0011

1.  $\rightarrow$  1100 1100

2.  $\rightarrow$  1100 1101

## Convert 2's Complement to Decimal

Leftmost bit is  $-128$  (1) or  $+127$  (0)

Add the same way:

$\rightarrow$  1100 1101

$\rightarrow -128 + 64 + 8 + 4 + 1$

$= -51_{10}$

## Subtraction

**Example 1:**

0000 1011  $-$  0000 0010

1. Second to complement: 0000 0010  $\rightarrow$  1111 1101
2. Add to first: 0000 1011  $+$  1111 1101

$=$  0000 1001

**Example 2:**

0000 1100  $-$  0000 1001

1. Second to complement: 0000 1001  $\rightarrow$  1111 0111
2. Add to first: 0000 1100  $+$  1111 0111

$=$  0000 0011