Signed Integer Representations

- All representations: **0/1 in the high bit position indicates +/-**

Sign-Magnitude Representation

- High bit stores 0/1 to represent +/-
- Remaining n-1 bits store the magnitude of the integer
- Example (1 Byte): **59** = b**0011 1011** = x**3B**
  -59 = b**1011 1011** = x**BB**

One's Complement Representation

- $1C_n(X) = (2^n - 1) - X$ Equivalent to **complementing** the bits of X
- Example (1 Byte): **59** = b**0011 1011** = x**3B**
  -59 = b**1100 0100** = x**C4**

Two's Complement Representation

- $2C_n(X) = 2^n - X$ Equivalent to $1C_n(X) + 1$ **Complement and Increment**
- Example (1 Byte) **59** = b**0011 1011** = x**3B**
  -59 = b**1100 0101** = x**C5**

- In practice, Sign-Magnitude representation is seldom used.
- 1's Complement was used in some older machines. What is b**1111 1111** ?
- 2's Complement is pretty much standard

2's Complement Arithmetic

- Evaluate 30 – 59 (signed byte arithmetic)

30	b**0001 1110**	x**1E**
-**59**	b**1100 0101**	x**C5**
====	===========	===
-**29**	b**1110 0011**	x**E3**

- Check: - (-59) = 59?
- Check: 59 + (-59) = 0?

59	b**0011 1011**	x**3B**
-**59**	b**1100 0101**	x**C5**
====	===========	===
	b**1 0000 0000**	x**100**

- In signed addition, a **high-end carry has no significance**

Important to know:

- The range of **unsigned integer values** that can be stored in n bits is $\mathbf{0..2^{n}-1}$
  Byte : 0 .. $2^8 - 1 = 255$ Word : 0 .. $2^{16} - 1 = 65535$.
- The range of **signed integer values** that can be stored in n bits is $\mathbf{-2^{n-1}..2^{n-1}-1}$
  Byte : $-2^7..2^7-1$ = -128..127 Word : $-2^{15}..2^{15}-1$ = -32768..32767.

Overflow

When performing integer arithmetic, overflow occurs if the arithmetic produces a result that is outside of the range of the intended storage (see above). For example, suppose that we are performing **byte** arithmetic. The sum 125 + 125 will produce signed overflow but not unsigned overflow. The sum, 250, is within the unsigned byte range, but outside the signed byte range.

	Binary	Hex	Condition Codes		Unsigned	Signed
			Carry	o**V**erflow		
(1)	b**1010 1000**	x**A8**			168	-88
	b**0010 1101**	x**2D**			45	45
	=============	====			===	===
	b**1101 0101**	x**D5**	**C = 0**	**V = 0**	213	-43
(2)	b**1101 0011**	x**D3**			211	-45
	b**1111 0100**	x**F4**			244	-12
	=============	====			===	===
	b**1 1100 0111**	x**1C7**	**C = 1**	**V = 0**	455	-57
(3)	b**0010 1101**	x**2D**			45	45
	b**0101 1000**	x**58**			88	88
	=============	====			===	===
	b**1000 0101**	x**85**	**C = 0**	**V = 1**	133	133
(4)	b**1101 0011**	x**D3**			211	-45
	b**1010 1000**	x**A8**			168	-88
	=============	====			===	===
	b**1 0111 1011**	x**17B**	**C = 1**	**V = 1**	379	-133

- Producing a carry, C = 1, indicates **unsigned** overflow.
- Producing a carry, C = 1, does **not** indicate **signed** overflow.
- To recognize **signed overflow**, two conditions must be present:
  1. the **augend** and **addend** must have the **same sign**, and
  2. the **sum** must have the **opposite sign**.