

L1 (CHAPTER 2)

Data Representation Exercises

Decimal, Binary and Hex

Decimal	Binary	Hex
0	0000	0x0
1	0001	0x1
2	0010	0x2
3	0011	0x3
4	0100	0x4
5	0101	0x5
6	0110	0x6
7	0111	0x7
8	1000	0x8
9	1001	0x9
10	1010	0xA
11	1011	0xB
12	1100	0xC
13	1101	0xD
14	1110	0xE
15	1111	0xF

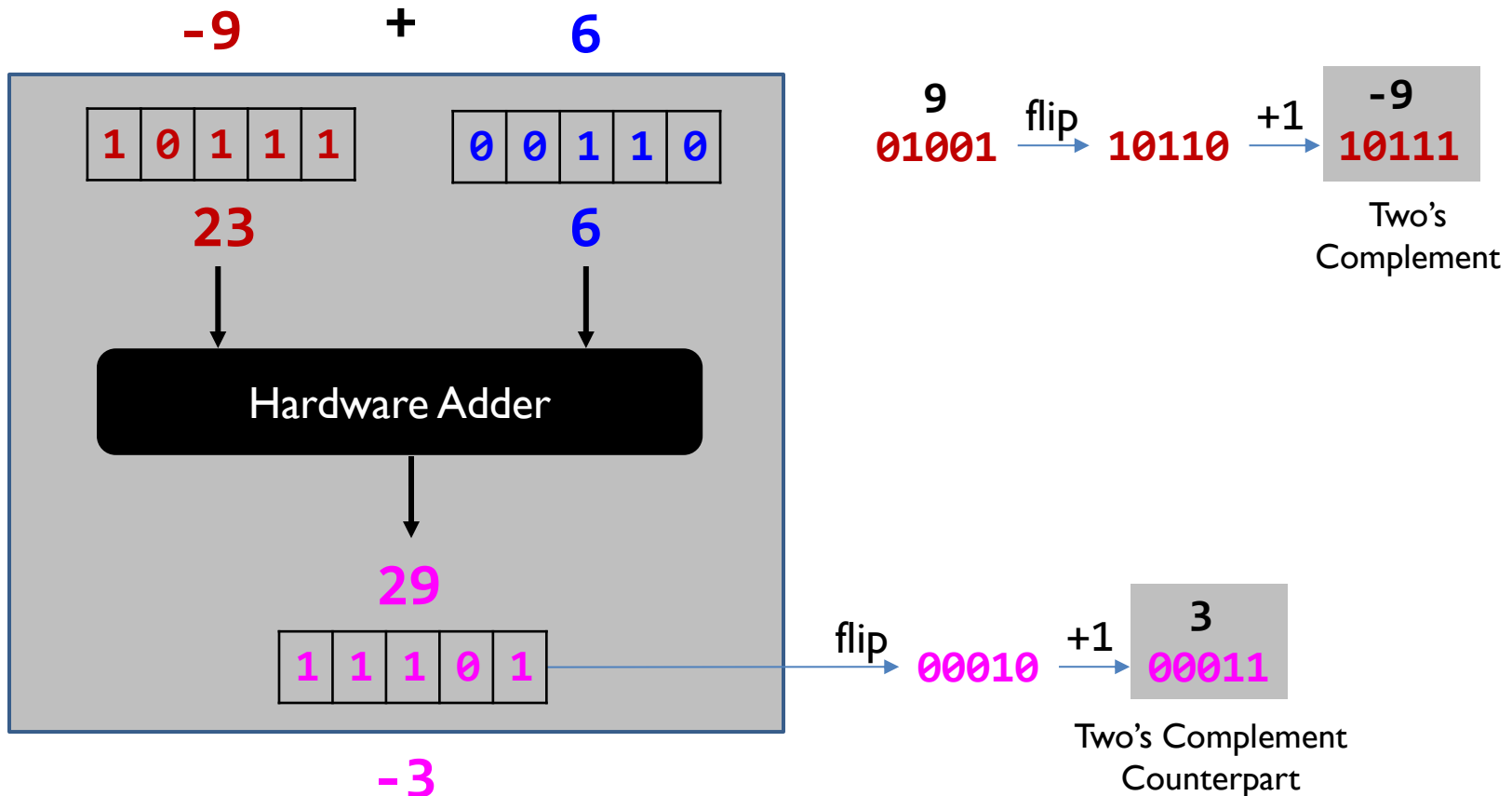
Prefix 0x denotes hex

Question: Number Conversion

- ▶ Q: Convert 0x3A56E2F8 into binary
- ▶ Q: Convert binary number 111010 into hex

Review

Adding two integers



- ▶ Same bit patterns, different interpretation.

- ▶ Unsigned addition: $23+6=29$

- ▶ Signed addition: $-9+6=-3$

- ▶ This example shows that the hardware adder for adding unsigned numbers, also works correctly for adding signed numbers.

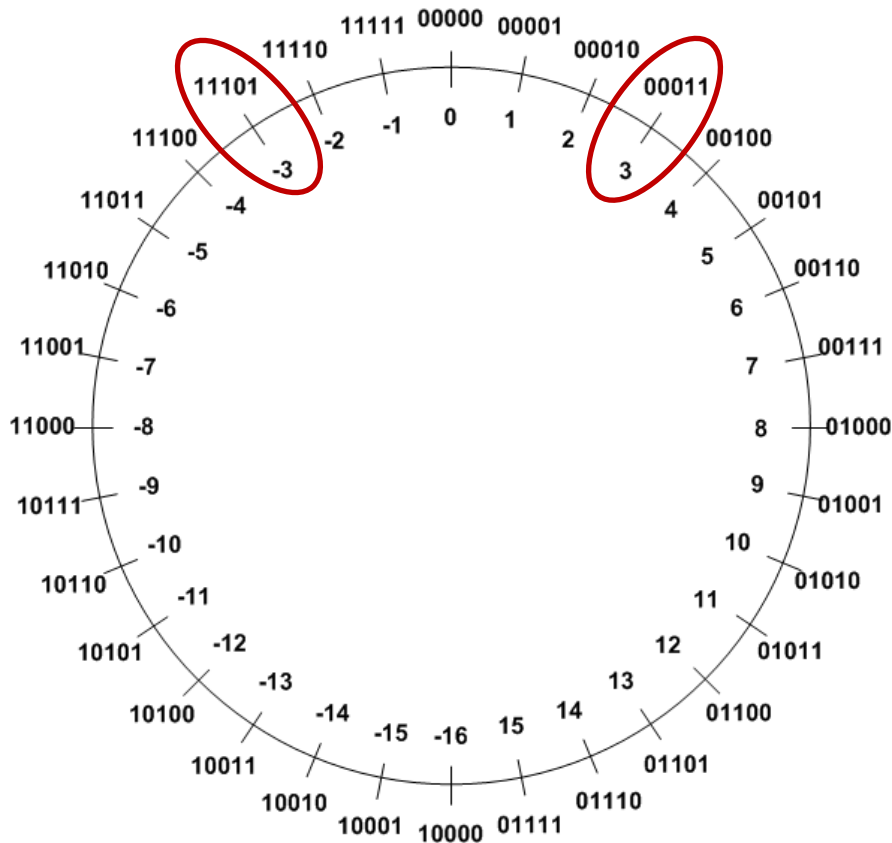
Review

Signed Integers

Method 3: Two's Complement

Two's Complement ($\bar{\alpha}$):

$$\alpha + \bar{\alpha} = 2^n$$



TC of a number can be obtained by its bitwise NOT plus one.

Example 1: TC(3)

	Binary	Decimal
Original number	00011	3
Step 1: Invert every bit	11100	
Step 2: Add 1	+ 00001	
Two's complement	11101	-3

Signed Integer Representation

Overview

- Three ways to represent signed binary integers:
 - Signed magnitude
 - $value = (-1)^{sign} \times \text{Magnitude}$
 - One's complement ($\tilde{\alpha}$)
 - $\alpha + \tilde{\alpha} = 2^n - 1$
 - Two's complement ($\bar{\alpha}$)
 - $\alpha + \bar{\alpha} = 2^n$

	Sign-and-Magnitude	One's Complement	Two's Complement
Range	$[-2^{n-1} + 1, 2^{n-1} - 1]$	$[-2^{n-1} + 1, 2^{n-1} - 1]$	$[-2^{n-1}, 2^{n-1} - 1]$
Zero	Two zeroes (± 0)	Two zeroes (± 0)	One zero
Unique Numbers	$2^n - 1$	$2^n - 1$	2^n

Question: 2's Complement

- For each of the following binary numbers, give the corresponding binary number of the negative of its value, for 2's-complement system
- (a) $x=01010101$
- (b) $x=10101010$
- (c) $x=10000000$

Question: Number Conversion

- Q: What is the decimal value of binary number $x=10100111$ as either unsigned int, or signed int in 2's complement representation?
- What about $x=11100001$?
- What about $x=10000000$?

Question: Number Conversion

- Q: Which number is larger: 1001 or 0011 in binary?
- Q: Which number is larger: 0xFFFFFFFF or 0x00000001 in hex?

Question: Number Range

- Which range of decimals can be expressed with a 6-bit number (assuming Two's complement representation)?

Answer	Range
A	-32 ... 32
B	-64 ... 63
C	-31 ... 32
D	-16 ... 15
E	-32 ... 31

Question: Number Range

- Which range of decimals can be expressed with a 6-bit unsigned integer?

Answer	Range
A	-32 ... 32
B	-64 ... 63
C	-31 ... 32
D	-16 ... 15
E	-32 ... 31

Question: Integer arithmetic

- Q: Consider a 4-bit system. What is the result of $1001 + 0011$?

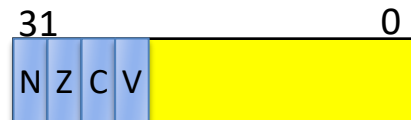
Summary of Carry and Overflow Flags

Bit	Name	Meaning after add or sub
N	negative	result is negative
Z	zero	result is zero
V	overflow	signed overflow
C	carry	unsigned overflow

Carry flag C = 1 upon an **unsigned** addition if the answer is wrong (true result $> 2^n - 1$)

Carry flag C = 0 (Borrow flag = 1) upon an **unsigned** subtraction if the answer is wrong (true result < 0)

Overflow flag V = 1 upon a **signed** addition if the answer is wrong (true result $> 2^{n-1} - 1$ or true result $< -2^{n-1}$)



Signed or unsigned

- Whether the carry flag or the overflow flag should be used depends on the programmer's intention.

```
uint a;  
uint b;  
...  
c = a + b  
...
```

C Program

Check the carry flag
for unsigned addition

```
int a;  
int b;  
...  
c = a + b  
...
```

C Program

Check the overflow flag
for signed addition

Question: Addition

- ▶ Q: Consider a 4-bit system. What is the result of addition $1011 + 0110$, assuming either unsigned integers, or signed integers in 2's-complement representation?

Question: Subtraction

- ▶ Q: Q: Consider a 4-bit system. What is the result of subtraction $1011 - 0110$, assuming either unsigned integers, or signed integers in 2's-complement representation?

Question: Subtraction

- ▶ Q: Consider a 4-bit system. What is the result of subtraction $0110 - 1011$, assuming either unsigned integers, or signed integers in 2's-complement representation?

Question: True or False

- ▶ 1. Borrow=1 is impossible when subtracting one unsigned number from another.
- ▶ 2. Overflow=1 is impossible when subtracting two signed operands of the same sign.
- ▶ 3. There are two representations of zero in 2's complement representation.
- ▶ 4. In 2's complement, the absolute values of full-scale negative and full-scale positive are identical