

Lecture 3: More binary & overflow

CMPE 120: Computer Organization and Architecture

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Logistics

- HW0 due today!
- Next week's lectures will be async
 - Olivia's OH next week will be rescheduled

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Review: Binary representation

- What number is this?

1	1	0	0	1	1	0	1
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 = 205

Review: Demo

- `uint8_t bin8_to_dec(char bin_arr[])`

How do we **add** two binary numbers together?

How should we represent **negative** numbers in binary?

How should we represent **negative** numbers in binary?

- Two's complement
 - signed values

-128	64	32	16	8	4	2	1
-2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

- Min =

- Max =

What is the two's complement value?

- 1001

- 1111

- 0101

What is the two's complement value?

- $1001 = -7$

- $1111 = -1$

- $0101 = 5$

Two's complement

- **Signed** values in C are represented as **two's complement**
 - Lets us represent both positive and negative values
 - Example data types: `char`, `int`, `int8_t`
- **Unsigned** values in C only represent values ≥ 0
 - Example data types: `unsigned char`, `unsigned int`, `uint8_t`

What is the two's complement sum in binary and decimal?

- $1001 + 0001$
- $1010 + 0010$
- $0111 + 0001$

What is the two's complement sum in binary and decimal?

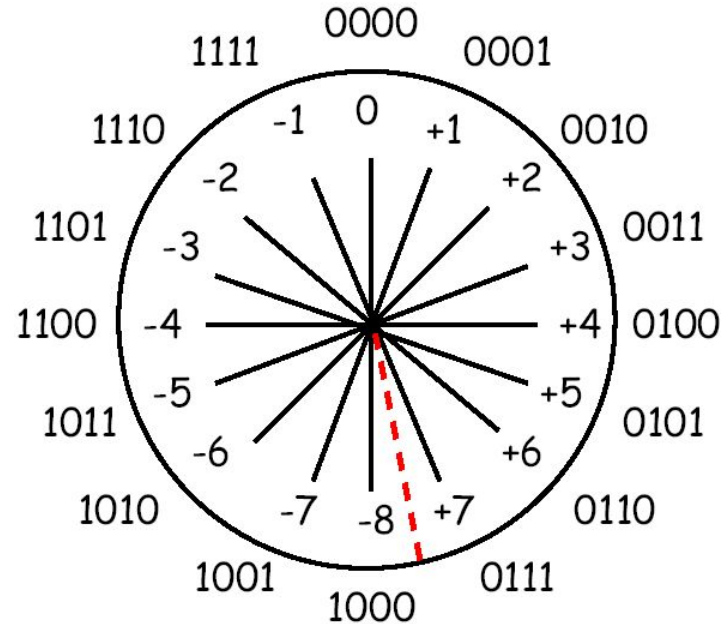
- $1001 + 0001 = -7 + 1 = 1010 \text{ (-6)}$
- $1010 + 0010 = -6 + 2 = 1100 \text{ (-4)}$
- $0111 + 0001 = 7 + 1 = 1000 \text{ (-8) overflow!}$

Why do we integer overflow?

- Two's complement makes addition in hardware easier

Why do we integer overflow?

- Two's complement makes addition in hardware easier
- Fixed number of bits
- Side effect: **overflow!**



Consequences of overflow

- Psy's Gangnam Style MV nearly overflowed Youtube's 32-bit view counter
- 1980 Pacman glitched when 8-bit level counter overflows
- Therac-25 radiation therapy machine would overflow, bypassing a safety mechanism, harming 6 patients



Common data types in C

- Integer data types

- `char = 'A'; // 1 byte signed`
- `unsigned char = 255; // 1 byte unsigned`

- `int/int32_t = -5; // 4 bytes signed`
- `unsigned int/uint32_t = 5; // 4 bytes unsigned`

- `long long int/int64_t = -10; // 8 bytes signed`
- `unsigned long long int/uint64_t = 10; // 8 bytes unsigned`

How to copy a **small int** into **larger sized int**?

- Need to handle copying a smaller two's complement into a larger one

```
int16_t a_s = -1; // 2 bytes
int a = a_s; // 4 bytes
printf("a = %d a_s = %d\n", a, a_s);
```

Practice

Assume a machine where the size of an integer is 1 byte. Assume two's complement to represent signed numbers.

1. What is the max value of an unsigned integer on this machine?
2. What is the max value of a signed integer on this machine?

Practice

Assume a machine where the size of an integer is 1 byte. Assume two's complement to represent signed numbers.

3. What is the minimum value of a signed integer on this machine?

4. How is the signed integer -1 represented on this machine?

Practice

Assume a machine where the size of an integer is 1 byte. Assume two's complement to represent signed numbers.

5. What is the value of the number 0b10000000 when it is interpreted as

- a. Unsigned integer
- b. Signed integer