

CS2100

<http://www.comp.nus.edu.sg/~cs2100/>

COMPUTER ORGANISATION

## Lecture #3d

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# Data Representation and Number Systems



**NUS**  
National University  
of Singapore

School of  
Computing



# Questions?

IMPORTANT: DO NOT SCAN THE QR CODE IN THE VIDEO RECORDINGS. THEY NO LONGER WORK

Ask at

<https://sets.netlify.app/module/676ca3a07d7f5ffc1741dc65>

**OR**

**Scan** and ask your questions here!  
(May be obscured in some slides)



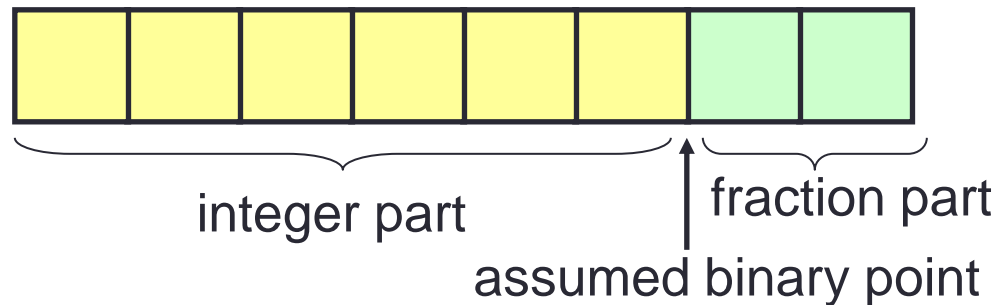
# 11. Real Numbers

- Many applications involve computations not only on integers but also on real numbers.
- How are real numbers represented in a computer system?
- Due to the finite number of bits, real numbers are often represented in their approximate values.



# 11.1 Fixed-Point Representation

- In **fixed-point representation**, the number of bits allocated for the whole number part and fractional part are fixed.
- For example, given an 8-bit representation, 6 bits are for whole number part and 2 bits for fractional parts.



- If 2s complement is used, we can represent values like:

$$011010.11_{2s} = 26.75_{10}$$

$$111110.11_{2s} = -000001.01_2 = -1.25_{10}$$



## 11.2 Floating-Point Representation (1/4)

- Fixed-point representation has limited range.
- Alternative: **Floating point numbers** allow us to represent very large or very small numbers.
- Examples:
  - $0.23 \times 10^{23}$  (very large positive number)
  - $0.5 \times 10^{-37}$  (very small positive number)
  - $-0.2397 \times 10^{-18}$  (very small negative number)



## 11.2 IEEE 754 Floating-Point Rep. (2/4)

- 3 components: **sign**, **exponent** and **mantissa (fraction)**



- The base (radix) is assumed to be 2.
- Two formats:
  - Single-precision (32 bits)**: 1-bit sign, 8-bit exponent with bias 127 (excess-127), 23-bit mantissa
  - Double-precision (64 bits)**: 1-bit sign, 11-bit exponent with bias 1023 (excess-1023), and 52-bit mantissa
- We will focus on the single-precision format
- Reading
  - DLD pages 32 - 33
  - IEEE standard 754 floating point numbers:  
<http://steve.hollasch.net/cgindex/coding/ieeefloat.html>



## 11.2 IEEE 754 Floating-Point Rep. (3/4)

- 3 components: **sign**, **exponent** and **mantissa (fraction)**



- Sign bit: 0 for positive, 1 for negative.
- Mantissa is **normalised** with an implicit leading bit 1
  - $110.1_2 \rightarrow \text{normalised} \rightarrow 1.101_2 \times 2^2 \rightarrow$  only **101** is stored in the mantissa field
  - $0.00101101_2 \rightarrow \text{normalised} \rightarrow 1.01101_2 \times 2^{-3} \rightarrow$  only **01101** is stored in the mantissa field



## 11.2 IEEE 754 Floating-Point Rep. (4/4)

- Example: How is  $-6.5_{10}$  represented in IEEE 754 single-precision floating-point format?

$$-6.5_{10} = -110.1_2 = \underbrace{-1}_{\text{sign}} \cdot \underbrace{101}_{\text{mantissa}} \times 2^{\underbrace{2}_{\text{exponent}}}$$

$$\text{Exponent} = 2 + 127 = 129 = 10000001_2$$



- We may write the 32-bit representation in hexadecimal:

$$1\ 10000001\ 10100000000000000000000000000000_2 = \text{C0D00000}_{16}$$

(Slide 4)

As an 'int', it is -1060110336

As an 'float', it is -6.5





# Quiz

- Please complete the “CS2100 C Number Systems Quiz 4” in Canvas.
- Access via the “Quizzes” tool in the left toolbar and select the quiz on the right side of the screen.

The screenshot displays the Canvas LMS interface. On the left, the sidebar contains various navigation tools, with 'Quizzes' highlighted by a red box. The main content area shows a list of quizzes under the heading 'Assignment quizzes'. The quiz 'CS2100 Number Systems Quiz 4' is highlighted with a red box, indicating it is the target of the instruction. The interface also includes a search bar at the top and a '+ Quiz' button.

[2210] 2022/2023 Semester 1		
Search for quiz		
+ Quiz		
▼ Assignment quizzes		
CS2100 Number Systems Quiz 1	Not available until 8 Aug at 0:00   Due 16 Aug at 15:55	✓
CS2100 Number Systems Quiz 2	Not available until 8 Aug at 0:00   Due 16 Aug at 15:55	✓
CS2100 Number Systems Quiz 3	Available until 16 Aug at 16:00   Due 16 Aug at 15:55	✓
CS2100 Number Systems Quiz 4	Available until 16 Aug at 16:00   Due 16 Aug at 15:55	✓
CS2100 Programming Quiz 1	Not available until 8 Aug at 0:00   Due 16 Aug at 15:55	✓
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