

Basic Concepts

Base 2 integer encoding

- Suppose we want the computer to store a number 3. How do you think the computer will store it? Store it as “3” or other format?
 - Everything stored in a computer is encoded in a sequence of 0’s and 1’s.
 - Computers will store 3 in binary, 11, using base 2 integer encoding.
 - To represent 3 in binary, a computer needs at least 2 bits. Each “1” here is a bit.
- What is base 2?
 - Base 2 is just like base 10 except you have only two digits to work with on your odometer.
 - Let’s start counting: 0, 1, 2, 3, 4, 5, ... (decimal) $\longleftrightarrow$ 0, 1, 10, 11, 100, 101, ... (binary)
 - We use the following array to assist the transition from a binary to a decimal.

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
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- So, to calculate the decimal “1101” represent, we can use

$$1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 = 13$$

- This also means that a computer needs at least 4 bits to store 13.

- Exercise:

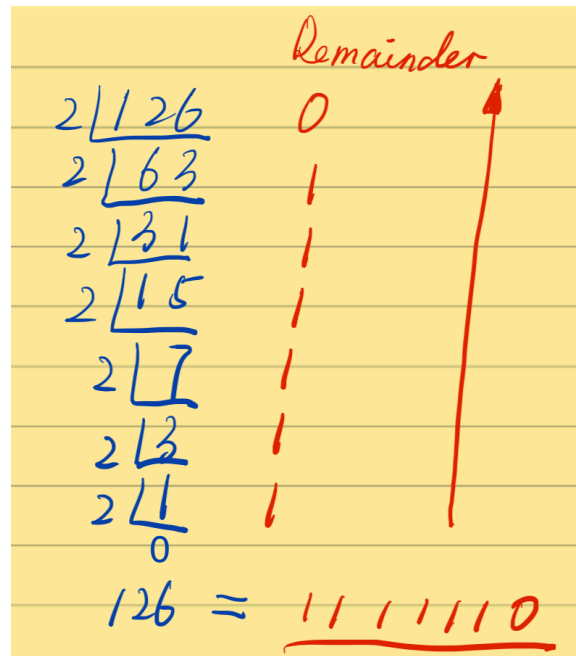
- 11010

- $1 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 0 \times 2^0 = 26$

- What is a bit?
 - Bit is a basic unit.
 - It’s the smallest piece of information a computer can work with.
 - A bit represents a logical state with one of two possible values, 0 and 1. Just like a light bulb, it can be either on or off.
- Another term used a lot in computer science is **Byte**.
 - A byte is 8 bits.
 - What is the smallest number a byte can represent? [0]
 - What is the largest number a byte can represent?

$$1 \times 2^7 + 1 \times 2^6 + 1 \times 2^5 + 1 \times 2^4 + 1 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 = 2^8 - 1 = 255$$
 - If use a byte to represent a number that needs less than 8 bits, the left bits are filled with 0s. E.g., 26 will be 00011010.

- How do we convert a decimal to binary? Convert 126 into 1 byte binary.



- Suppose we are going to use 1 byte to represent 126, then the binary is **01111110**

2's Complement

- So far so good. But what if we want to store a negative number? [2's complement]
- Representation for signed binary numbers

-2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
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- The value of the leftmost bit is $-2^{(N-1)}$, if given the fixed size N.
- To represent -126 in binary, there are three steps:
 - Step1: Convert 126 to binary (like what we did above)
 - Step2: Invert each bit
 - $01111110 \rightarrow 10000001$
 - Step3: Add one to the result of Step2
 - $10000001 + 1 = 10000010$
 - To verify:
 - $1 \times -2^7 + 1 \times 2^1 = -128 + 2 = -126$
- The largest negative value represented by 8 bits in 2's complement is $1000\ 0000 = -2^7$
- The largest positive value represented by 8 bits in 2's complement is $0111\ 1111 = 127 = 2^7-1$
- The range represented by N bits in 2's complement is $-2^{(N-1)} \sim 2^{(N-1)}-1$