Bit-wise Operators, Git

CS 2130: Computer Systems and Organization 1

September 5, 2022

Announcements

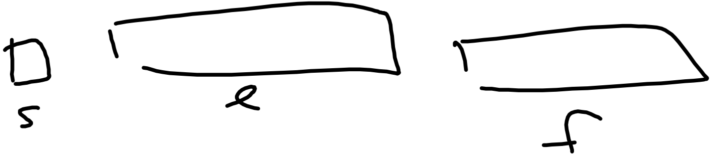
- Homework 1 due Monday 9/12/2022
- TA office hours
    - **In-person**: Olsson 001, Wed-Sun, 5-7pm
    - **Online**: Discord, Wed-Sun, varies
    - Discord is now available
- My office hours
    - Tuesday, 4-5pm, Discord/Zoom
    - Wednesday, 4:30-6pm, Rice 210 (masks requested)
    - Thursday, 11am-12pm, Discord/Zoom

Floating Point in Binary

1.101001×2^3

We must store 3 components

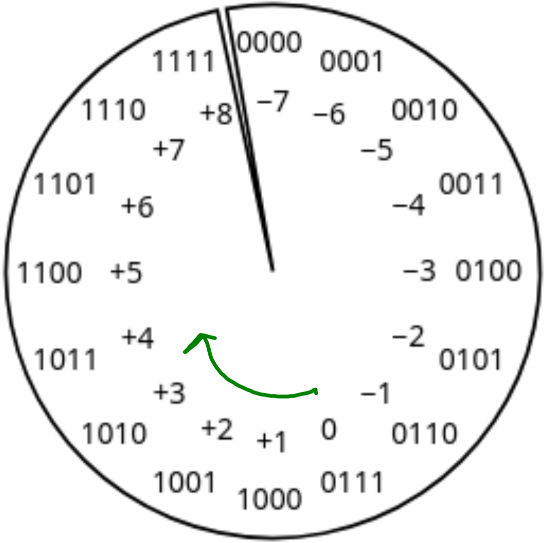
- **sign** (1-bit): 1 if negative, 0 if positive
- **fraction** or **mantissa**: (?-bits): bits after binary point
- **exponent** (?-bits): how far to move binary point



Biased Integers

Similar to Two's Complement, but add **bias**

- **Two's Complement**: Define 0 as 00...0
- **Biased**: Define 0 as 0111...1
- Biased wraps from 000...0 to 111...1



Floating Point Example

$3.\boxed{141} = \frac{141}{1000}$

$.011$

$2^{-1}\ 2^{-2}\ 2^{-3}$

$\frac{1}{2}\ \frac{1}{4}\ \frac{1}{8}$

$\frac{1}{4} + \frac{1}{8} = \frac{3}{8}$

$5\ \ 3/8$

$4\ 2\ 1$

101.011_2

1.01011×2^2

$$\begin{array}{r} 1 \\ 1\ \ 10 \\ +\ 0111 \\ \hline 1001 \end{array}$$

sign: 1

exp: 4

frac: 3

biased

$$\begin{array}{r} 1001 \\ -\ 0111 \\ \hline 0010 \end{array} = 2$$

0	1001	011
sign	exp	frac.

Floating Point Example

$$101.011_2$$

Floating Point Example

What does the following encode?

$$\overset{}{\boxed{1}}\ \overset{6}{\boxed{001110}}\ \overset{7}{\boxed{1010101}}$$

$$-\ 1.1010101 \times 2^{-17}$$

$$\begin{array}{r} 1\ 10\ 1\ 1\ 10\ 1\ 10 \\ 1\ 1\ 1\ 1\ 1\ \ \\ 0\ 0\ 1\ 1\ 1\ 0 \\ -\ 0\ 1\ 1\ 1\ 1\ 1 \\ \hline 1\ 0\ 1\ 1\ 1\ 1 \end{array} \quad \text{bias} \quad = -17$$

$$\begin{array}{r} 0\ 1\ 0\ 0\ 0\ 0 \\ 1 \\ \hline 0\ 1\ 0\ 0\ 0\ 1 \end{array} = 17$$

$$-0.000000000000000011010101$$

Floating Point Example

What does the following encode?

$$\boxed{1}\ \boxed{001110}\ \boxed{1010101}$$

What about 0?

Floating Point Numbers

Four cases:

- **Normalized**: What we have seen today

$$s\ eeee\ ffff = \pm 1.ffff \times 2^{eeee - \mathrm{bias}}$$

- **Denormalized**: Exponent bits all 0

$$s\ eeee\ ffff = \pm 0.ffff \times 2^{1 - \mathrm{bias}}$$

- **Infinity**: Exponent bits all 1, fraction bits all 0 (i.e., $\pm\infty$)
- **Not a Number (NaN)**: Exponent bits all 1, fraction bits not all 0

Operations So Far

So far, we have discussed:

- Addition: $x + y$
    - Can get multiplication
- Subtraction: $x - y$
    - Can get division, but more difficult
- Unary minus (negative): $-x$
    - Flip the bits and add 1

Operations (on Integers)

1010 01001

Bit vector: fixed-length sequence of bits (ex: bits in an integer) 0101 10110

- Manipulated by bitwise operations

Bitwise operations: operate over the bits in a bit vector

0 → 1
1 → 0

tilde

- Bitwise not: $\sim x$ - flips all bits (unary)
- Bitwise and: $x \& y$ - set bit to 1 if x, y have 1 in same bit
- Bitwise or: $x|y$ - set bit to 1 if either x or y have 1
- Bitwise xor: $x\hat{}y$ - set bit to 1 if x, y bit differs

0110
1011

Example: Bitwise AND

```
  11001010
& 01111100
----------
  01001000

  01001000   -
```

Example: Bitwise OR

```
  11001010
| 01111100
----------
  11111110
```

Example: Bitwise XOR

```
  11001010
^ 01111100
----------
  10110110
```

Your Turn!

What is: `0x1a ^ 0x72`

Operations (on Integers)

- Logical not: $!x$
  - $!0 = 1$ and $!x = 0, \forall x \neq 0$
  - Useful in C, no booleans
  - Some languages name this one differently
- Left shift: $x << y$ - move bits to the left
  - Effectively multiply by powers of 2
- Right shift: $x >> y$ - move bits to the right
  - Effectively divide by powers of 2
  - Signed (extend sign bit) vs unsigned (extend 0)

Right Bit-shift Example

```
01011010 >> 3
```

Left Bit-shift Example

```
01011010 << 2
```

Bit-shift

Computing bit-shift effectively multiplies/divides by powers of 2

Consider decimal:

$$\texttt{2130} \ll_{10} \texttt{2} = \texttt{213000} = \texttt{2130} \times \texttt{100}$$

$$\texttt{2130} \gg_{10} \texttt{1} = \texttt{213} = \texttt{2130 / 10}$$

Right Bit-shift Example

For signed integers, extend the sign bit

- Keeps negative value (if applicable)
- Approximates divide by powers of 2

```
11001010 >> 1
```

git