Week 2 - Monday

CS222

Last time

- What did we talk about last time?
- C basics
- Data types
- Output with **`printf()`**
- Lab 1

Questions?

Project 1

Quotes

ANSI C retains the basic philosophy that programmers know what they are doing; it only requires that they state their intentions explicitly.

Kernighan and Ritchie

from *The C Programming Language*, 2nd Edition

C standards

- Most programming languages have multiple versions
  - C is no exception
- The original, unstandardized version of the language used at Bell Labs from 1969 onward is sometimes called K&R C
  - It's similar to what we use now, but allowed weird function definition syntax and didn't have function prototypes
- The version we'll be talking about is ANSI C89 which is virtually identical to ISO C90
- A newer standard C99 is available, but it is not fully supported by all major C compilers
  - You have to use a special flag when compiling with **`gcc`** to get it to use C99 mode

Makefiles

- The order of compilation matters
- You have to compile all necessary files yourself to make your program work
- To make these issues easier to deal with, the `make` utility is used
- This utility uses makefiles
  - Each makefile has a list of targets
  - Each target is followed by a colon and a list of dependencies
  - After the list of dependencies, on a new line, preceded by a **tab**, is the command needed to create the target from the dependencies

Sample makefile

- Makefiles are called **`makefile`** or **`Makefile`**

```
all:    hello

hello: hello.c
    gcc -o hello hello.c

clean:
    rm -f *.o hello
```

Control flow

- You're already a better C programmer than you think you are
- For selection, C supports:
  - `if` statements
  - `switch` statements
- For repetition, C supports:
  - `for` loops
  - `while` loops
  - `do while` loops
- Try to implement code the way you would in Java and see what happens…

Conditionals

- One significant gotcha is that C doesn't have a **`boolean`** type
  - Instead, it uses **`int`** for **`boolean`** purposes
  - **`0`** (zero) is false
  - Anything non-zero is true

```
if( 6 )             if( 0 )             if( 3 < 4 )
{                   {                   {
    //yep!              //nope!             //yep!
}                   }                   }
```

Type safety

- Java is what is called a **strongly-typed** language
  - Types really mean something
- C is much looser

```
double a = 3.4;
int b = 27;
a = b; //legal in Java and C
b = a; //illegal in Java, might
       //give a warning in C
```

Declaration syntax

- Another gotcha!
- Can't declare a variable in the header of a **`for`** loop
- Doesn't work:

```
for( int i = 0; i < 100; i++ )
{
    printf("%d ", i);
}
```

- You have to declare **`int i`** **before** the loop

Precision

- The C standard makes floating-point precision compiler dependent
- Even so, it will usually work just like in Java
- Just a reminder about the odd floating-point problems you can have:

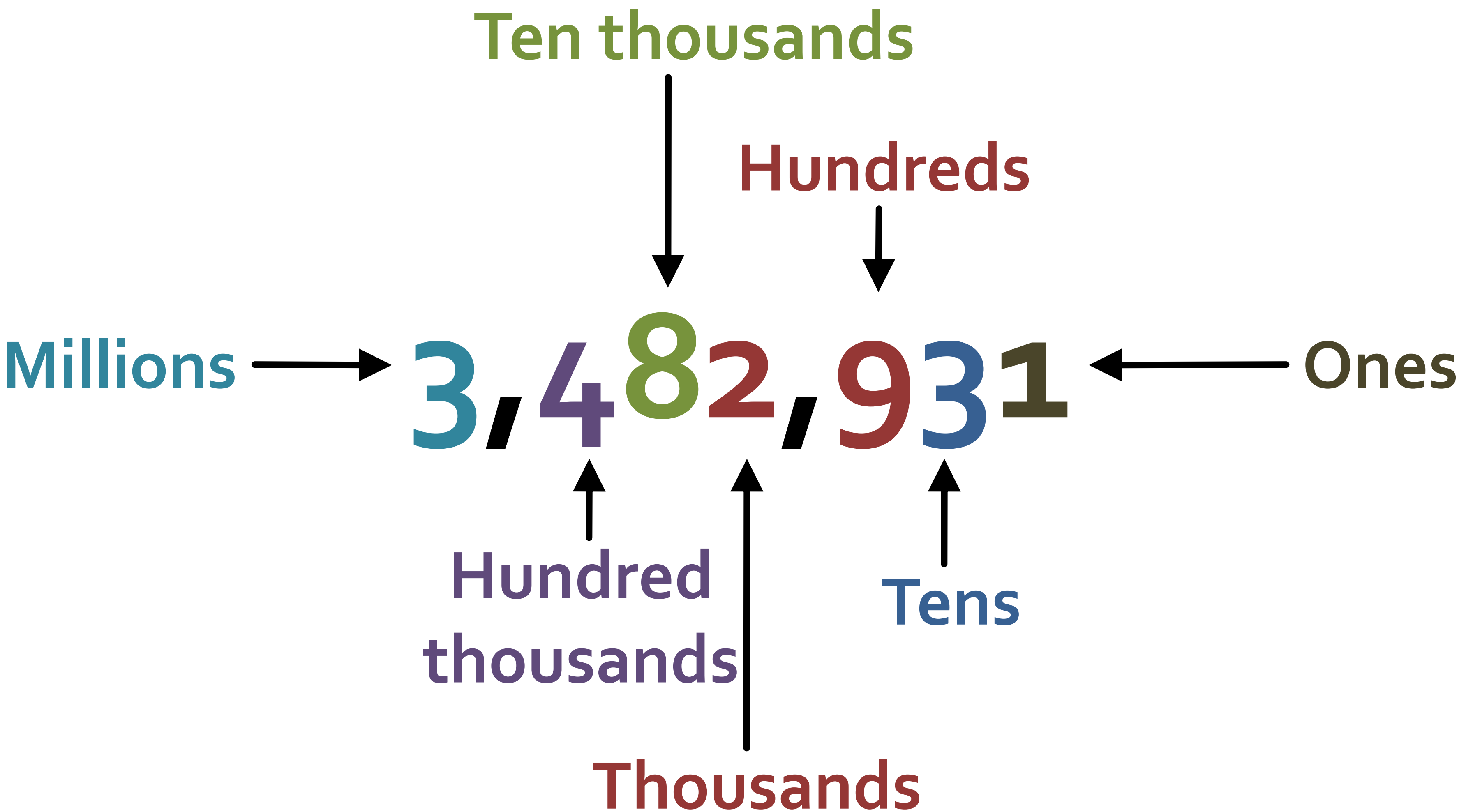
```c
#include <stdio.h>

int main()
{
	float a = 4.0 / 3.0;
	float b = a - 1;
	float c = b + b + b;
	float d = c - 1;
	printf("%e\n", d);
}
```

Base 10 (decimal) numbers

- Our normal number system is base 10
- This means that our digits are: 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9
- Base 10 means that you need 2 digits to represent ten, namely 1 and 0
- Each place in the number as you move left corresponds to an increase by a factor of 10

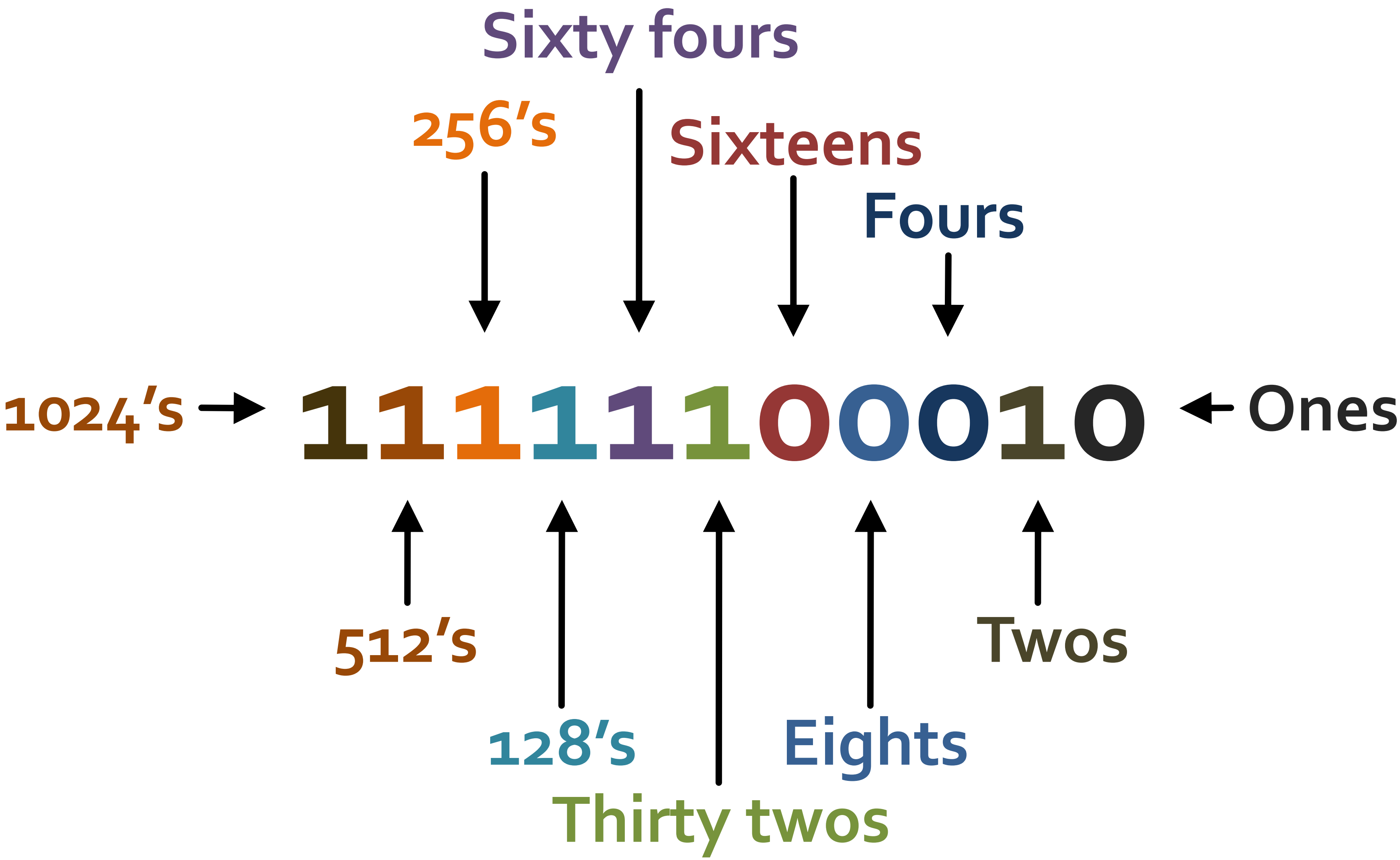
Base 10 Example



Base 2 (binary) numbers

- The binary number system is base 2
- This means that its digits are: **0** and **1**
- Base 2 means that you need 2 digits to represent two, namely 1 and 0
- Each place in the number as you move left corresponds to an increase by a factor of **2** instead of **10**

Base 2 Example



C Literals

Literals

- By default, every integer is assumed to be a signed **`int`**
- If you want to mark a literal as **`long`**, put an **`L`** or an **`l`** at the end
  - **`long value = 2L;`**
  - Don't use **`l`**, it looks too much like **`1`**
  - There's no way to mark a literal as a **`short`**
- If you want to mark it unsigned, you can use a **`U`** or a **`u`**
  - **`unsigned int x = 500u;`**
- Every value with a decimal point is assumed to be double
- If you want to mark it as a **`float`**, put an **`f`** or an **`F`** at the end
  - **`float z = 1.0f;`**

Integers in other bases

- You can also write a literal in hexadecimal or octal
- A hexadecimal literal begins with **`0x`**
  - **`int a = 0xDEADBEEF;`**
  - Hexadecimal digits are **`0`** – **`9`** and **`A`** – **`F`** (upper or lower case)
- An octal literal begins with **`0`**
  - **`int b = 0765;`**
  - Octal digits are **`0`** – **`7`**
  - Be careful not to prepend other numbers with **`0`**, because they will be in octal!
- Remember, this changes only how you write the literal, not how it is stored in the computer
- Can't write binary literals

Printing in other bases

- The **`printf()`** function provides flags for printing out integers in:
  - **`%d`** Decimal
  - **`%x`** Hexadecimal (**`%X`** will print **`A`**-**`F`** in uppercase)
  - **`%o`** Octal

```
printf("%d", 1050); //prints 1050
printf("%x", 1050); //prints 41a
printf("%o", 1050); //prints 2032
```

Binary representation

- This system works fine for unsigned integer values
  - However many bits you've got, take the pattern of 1's and 0's and convert to decimal
- What about signed integers that are negative?
  - Most modern hardware (and consequently C and Java) use **two's complement** representation

Two's complement

- Two's complement only makes sense for a representation with a fixed number of bits
  - But we can use it for **any** fixed number
- If the **most significant bit** (**MSB**) is a 1, the number is negative
  - Otherwise, it's positive
- Unfortunately, it's not as simple as flipping the MSB to change signs

Negative integer in two's complement

- Let's say you have a positive number ***n*** and want the representation of **–*n*** in two's complement with ***k*** bits

1. Figure out the pattern of ***k*** 0's and 1's for ***n***
2. Flip every single bit in that pattern (changing all 0's to 1's and all 1's to 0's)
   - This is called one's complement
3. Then, add 1 to the final representation as if it were positive, carrying the value if needed

Example

- For simplicity, let's use 4-bit, two's complement
- Find -6

1. 6 is **0110**
2. Flipped is **1001**
3. Adding 1 gives **1010**

Two's complement to negative integer

- Let's say you have a ***k*** bits representation of a negative number and want to know what it is

1. Subtract 1 from the representation, borrowing if needed
2. Flip every single bit that pattern (changing all 0's to 1's and all 1's to 0's)
3. Determine the final integer value

Example

- For simplicity, let's use 4-bit, two's complement
- Given **`1110`**

1. Subtracting 1 **`1101`**
2. Flipped is **`0010`**
3. Which is 2, meaning that the value is -2

All four bit numbers

Binary	Decimal	Binary	Decimal
0000	0	1000	-8
0001	1	1001	-7
0010	2	1010	-6
0011	3	1011	-5
0100	4	1100	-4
0101	5	1101	-3
0110	6	1110	-2
0111	7	1111	-1

But why?!

- Using the flipping system makes it so that adding negative and positive numbers can be done without any conversion
  - Example 5 + -3 = **`0101`** + **`1101`** = **`0010`** = 2
  - Overflow doesn't matter
- Two's complement (adding the 1 to the representation) is needed for this to work
  - It preserves parity for negative numbers
  - It keeps us with a single representation for zero
  - We end up with one extra negative number than positive number

Floating point representation

- Okay, how do we represent floating point numbers?
- A completely different system!
  - IEEE-754 standard
  - One bit is the sign bit
  - Then some bits are for the exponent (8 bits for float, 11 bits for double)
  - Then some bits are for the mantissa (23 bits for float, 52 bits for double)

More complexity

- They want floating point values to be unique
- So, the mantissa leaves off the first 1
- To allow for positive and negative exponents, you subtract 127 (for **`float`**, or 1023 for **`double`**) from the written exponent
- The final number is:
  - $(-1)^{\textit{sign bit}} \times 2^{(\textit{exponent} - 127)} \times 1.\textit{mantissa}$

Except even that isn't enough!

- How would you represent zero?
  - If all the bits are zero, the number is 0.0
- There are other special cases
  - If every bit of the exponent is set (but all of the mantissa is zeroes), the value is positive or negative infinity
  - If every bit of the exponent is set (and some of the mantissa bits are set), the value is positive or negative NaN (not a number)

Number	Representation
`0.0`	`0x00000000`
`1.0`	`0x3F800000`
`0.5`	`0x3F000000`
`3.0`	`0x40400000`
+Infinity	`0x7F800000`
-Infinity	`0xFF800000`
+NaN	`0x7FC00000` and others

One little endian

- For both integers and floating-point values, the **most significant bit** determines the sign
  - But is that bit on the rightmost side or the leftmost side?
  - What does left or right even mean inside a computer?
- The property is the **endianness** of a computer
- Some computers store the most significant bit first in the representation of a number
  - These are called **big-endian** machines
- Others store the least significant bit first
  - These are called **little-endian** machines

Why does it matter?

- Usually, it doesn't!
- It's all internally consistent
  - C uses the appropriate endianness of the machine
- With pointers, you can look at each byte inside of an **`int`** (or other type) in order
  - When doing that, endianness affects the byte ordering
- The term is also applied to things outside of memory addresses
- Mixed-endian is rare for memory, but possible in other cases:

`http://users.etown.edu/`	**`w/wittmanb/cs222/`**
← More specific	More specific →

Upcoming

Next time…

- Math library
- More on types

Reminders

- Read K&R Chapter 2
- Attend Dr. Teli's talk today!
  - 3:30pm in E270
  - Introduction to Machine Intelligence
  - Please come so that you can give feedback about our faculty candidate