Announcements

- Program #3
  - is available – start before spring break!!
- Reading
  - Notes (Today)
  - Chapter 16, 13.3 (Tuesday (after Spring Break))
    - Skip 16.4-16.6 and 16.9

Representing Characters

- Need
  - Represent common characters
  - Have standards so computers can interoperate
- Common Formats
  - ASCII
    - 7 bits for characters (stored in 8 bits normally)
    - most commonly used
  - UNICODE
    - family of encodings 8, 16, and 32 bits/character
    - allow greater variety of characters
    - Able to represent virtually every character in use today
      - and some no longer in use

ASCII

- Represents normal characters on US keyboards
  - A-Z (101-132)
  - a-z (141-172)
  - 0-9 (60-71)
  - punctuation: !@#$%^&*()_+-=[]{}|\;:'"<>?,./
  - space
  - <control-A> - <control-Z>
    - Also have other names <control-M> is CR (\r)

UNICODE

- Unicode Representations
  - UTF-32 32 bit representation of all characters
    - all characters are the same size
    - wastes lots of space (2x UTF-16 for most things, 4x ascii for many things)
  - UTF-16 16 bit representation of characters
    - some characters are stored in two-character forms
    - popular since most things can be represented in 16 bits
  - UTF-8 8 bit representation of characters
    - provides backwards compatibility with ascii
      - low 7 bits are exactly ASCII
      - high bit on indicates part of UNICODE extensions
    - popular for web and other applications

Representing Integers

- All data stored in binary
  - all numbers are 0 or 1
- Unsigned numbers are stored using base 2

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

  - possible range 0 to 2^n-1 where n is the number of bits
- Signed numbers are stored using two's complement
  - left most bit indicates if a number is positive or negative
    - 0 is positive
    - 1 is a negative number

Adding Binary Numbers

- Add starting from right
- Carry if the number is too large to represent
  - if it is greater than 1

```
1001        1001        1011        1101
+  10       +  11       + 11        +111
-------     -------     ------      ------
 1011        1100       1110        10100
```

2's complement representation

- To compute a negative value:
  - flip all the bits of the positive value, add 1
- Allows addition of signed and unsigned numbers
- Valid range of numbers
  - -2^{n-1} to $2^{n-1}-1$ for n bits
  - Example: 16 bit 2's complement -32,768 to 32,767
  - Example: 4 bit 2's complement –8 to 7
- Example: adding 4-bit 2's complement numbers

0010	1101	1101	0101	1001
0011	0001	1110	0111	1010
0101	1110	1011	1100	0011

How do we represent real numbers?

- Each number has two parts
  - mantissa (represents a number between -1 and 1)
    - represented as a binary number i.e. 0.1 = 1/2
  - exponent (designates the position of the decimal point)
    - uses normal two's complement form
  - number = m r^e where r is the radix
    - 6132.789 = +0.6132789 x 10^4
- Normalization
  - convert to number between -1 and 1
  - the most significant digit of mantissa is non-zero

Floating Point Continued

- Computers normally use a radix of 2
- Examples of floating point numbers
  - 1001.11 = .1001110 x 2^4
  - 10.5 = 1010.1 or 10101 x 2^4
  - 7.4375 = 111.011100 = 1110111 x 2^3
- IEEE Floating point standard
  - 32 bit floating point (float)
    - 1 sign bit, 8 bits exponent, 23 bits mantissa
  - 64 bit floating point (double)
    - 1 sign bit, 11 bits exponent, 52 bits mantissa
    - most common for real applications
  - 128 bit floating point (quad)
    - 1 sign bit, 15 bits exponent, 112 bits of mantissa
  - normalization allows for an assumed 1 before the decimal point