Bits and Bytes

BIT

- Modern computers are binary:
  - Everything is represented as being in one of two possible states:
    - the state of being a 1
    - the state of being a 0
  - A bit is the name for this smallest unit of storage in a computer.
    - Bit is sort-of derived from "Binary digIT".

Digital

- Marketing and advertising folks have decided to characterize anything that is based on bits as being "digital".
  - Digital Cable TV
  - Digital Telephone
  - Digital Camera
  - Digital Audio
- A better name might be “discrete” - digital information is broken up into discrete pieces; it is not continuous. (Your fingers (digits) are used for discrete counting)

Byte

- An ordered sequence of 8 bits (an octet)
- Modern computers are based on memory systems organized as bytes of memory
- Memory sizes are typically given in numbers of bytes:

kilobyte	2^{10} bytes	1024 bytes	≒ a thousand bytes
megabyte	2^{10} kilobytes	2^{20} bytes	≒ a million bytes
gigabyte	2^{10} megabytes	2^{30} bytes	≒ a billion bytes
terabyte	2^{10} gigabytes	2^{40} bytes	≒ a trillion bytes
petabyte	2^{10} terabytes	2^{50} bytes	≒ a million billion bytes
exabyte	2^{10} petabytes	2^{60} bytes	≒ a million trillion bytes

  - e.g. 16G vs. 32G iPhone

Why an 8-Bit Byte?

- Some hardware systems used 4, 5, 6, 7, 9 and even 16 bit bytes.
- Why did we settle on an octet?
  - Powers of 2 are convenient when working in a binary system: 2, 4, 8, 16, …
  - We need a large enough byte to handle character sets
    - $2^4 = 16$ values… not big enough
    - $2^8 = 256$ values… big enough (generally – DBCS?)
  - 0/1 or On/Off or yes/no is helpful
    - Electricity can be on or off

64 bit machine

- A machine that processes information in 64 bit chunks.
- The processor simply transports the information 64 bits at a time
- The data-path, or bus, that runs to and from the processor is 64 bits wide.
- 8 bits still = 1 byte
  a 64 bit machine transports 8 bytes at a time

How many possible values can one byte hold?

- A byte is a sequence of 8 bits, and each bit can hold only two values (0 or 1).
- How many sequences (permutations) of ones and zeros are possible?
- Here are a few:
  00000000 00010000 10000000 10101010

of byte values: derivation

- 2 x 2 x 2 x 2 x 2 x 2 x 2 x 2
- # of permutations = $2^8 = 256$
- There are 256 possible byte values.
- Q: what is the largest actual *value* held in a byte?

Understanding Bases

- We are familiar with base ten and its “places”
- In base ten, the value 10,423.9 can be imagined as

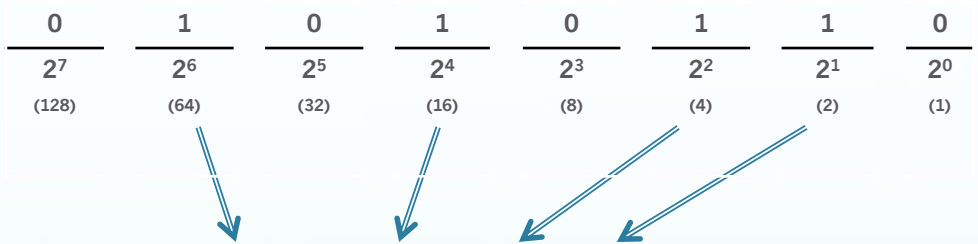
1	0	,	4	2	3	.	9
10^4	10^3		10^2	10^1	10^0		10^{-1}
(10,000)	(1,000)		(100)	(10)	(1)		(1/10)

- This is a way to visualize the numbers in their places (it is not division). The value could be more accurately expressed as

$$(1*10^4) + (0*10^3) + (4*10^2) + (2*10^1) + (3*10^0) + (9*10^{-1})$$

Binary Numbers

- We can talk about byte values by treating a byte as a base 2 number and converting to base 10 (decimal):



$$64 + 16 + 4 + 2 = 86$$

$$(0*2^7) + (1*2^6) + (1*2^5) + (0*2^4) + (0*2^3) + (1*3^2) + (1*2^1) + (0*2^0)$$

$$01010110_2 = 86_{10}$$

Binary Numbers

- Converting decimal to any base can be done by dividing by the base and setting aside the remainder.
- So to convert base 10 to base 2:

Divide	Remainder
2 86	0
2 43	1
2 21	1
2 10	0
2 5	1
2 2	0
1 → carry it over	1

Then, gather up the remainders from the bottom up:

$$86_{10} = 1010110_2$$

Hexadecimal

- Base 16 is also convenient for representing byte values. Each group of 4 bits corresponds to a single hex digit.

Decimal	Binary	Hex	Decimal	Binary	Hex
0	0000	0	8	1000	8
1	0001	1	9	1001	9
2	0010	2	10	1010	A
3	0011	3	11	1011	B
4	0100	4	12	1100	C
5	0101	5	13	1101	D
6	0110	6	14	1110	E
7	0111	7	15	1111	F

Hex Example: RGB Values

- Red, Green, Blue values used in additive color are commonly represented by hex values, one byte of information per color (e.g. in CSS):

000000 (black) to FFFFFF (white)

$16^6 = 16$ million colors (16.8 million, really)

For example, solid red is:

Red	Green	Blue
FF	00	00

Q: How many values of Red are possible?

Decimal-Binary Fill-In

Base 10	Binary
247	
	10001001
	00010000
255	

Decimal-Binary Fill-In

Base 10	Binary
247	11110111
137	10001001
16	00010000
255	11111111