Chapter 2

Data Storage … continued

Hexadecimal Number System

Binary may be what computers read, but it certainly is a pain to write, or type even. Numbers in binary are almost always long and unwieldy, hard to really understand. Just converting to decimal isn't a great system though, since the number of decimal digits needed for a number of bits is a less-than-pretty number (around 3.3219). Fractions of a digit don't really work, so we need another system.

A nice power of 2 we can use is 2^4, 16 (NOTE: we can also use 2^2 and 2^3, but it is far less efficient, as will be covered later). This system is called *hexadecimal*, or hex for short. Since hexadecimal is radix 16, we represent numbers through 16 unique digits. Isn't that a problem though? We only have 10 digits, 0-9. We could represent binary because it has less digits than decimal, but this has more. Six more, to be exact. There's a simple solution to this though: we use 0-9, then 10-15 are written as A-F. Resulting from this, hexadecimal numbers look like this: 4DB8.

Like decimal and binary, hexadecimal is also positional, so we can use our equation from last chapter. Let's convert A3 from hexadecimal to decimal:

Step 1: Find the value of each position. Since this is radix 16, we will use: $16^{position} *$ digit = value.

$$16^0 * 3 = 3$$

$$16^1 * A\ (A = 10\ in\ decimal) = 160$$

Step 2: Add the results together.

$$3+160=163$$

A3 in Hexadecimal is equivalent to 163 in decimal.

Great, now we can convert from hexadecimal to decimal, but how is that even helpful? Now we're just another layer away from binary, aren't we? Not really. Consider what we learned earlier, that decimal doesn't convert to binary very well because the number of digits does not match up right in each, and that hexadecimal has a radix of 2^4. This radix is important because it means we can represent four bits, one nibble, by just one single hexadecimal digit- a full byte can be shown in hexadecimal using only two digits.

A very useful part of binary and its relationship to hexadecimal is how easy it is to convert between the two. Let's use the bit pattern 1011000111010110:

Step 1: Break the pattern into groups of eight, then groups of four.

1011 0001 | 1101 0110

↓

1011 | 0001 | 1101 | 0110

Step 2: Convert each sub-pattern into hexadecimal

B | 1 | D | 6

Step 3: Simply put all of the digits together in the original order, and it's finished.

$$B1D6$$

In just three (really only two) quick steps, we've converted the long bit pattern into a much more understandable, or at least simpler hex pattern. It becomes far quicker to convert to decimal after this as well, as only 4 digits need to be converted, instead of 16.

Mass Storage

Up until now we've looked exclusively at small chunks of data- only really getting up to two bytes at most. Modern computers store quite a bit more than just these byte-sized pieces of data, however. For the last several years, computers have generally been able to store anywhere from 500 billion to upwards of 1 trillion bytes, and even more in many cases.

Many different forms of mass storage exist, each with different capacities, speeds, costs, sizes, and methods to store the data. Most commonly, the methods of data storage are magnetic, optical, and solid-state.

Magnetic Storage

Though slowly being replaced by solid-state storage, magnetic storage remains a prevalent way to keep data today. These devices include cassette tapes, floppy disks, and, most commonly now, hard disk drives. All of these contain a magnetic surface. On this surface, a write head applies a small magnetic charge, setting that area's polarity, which can be read as "1" or "0." Once it has been written to, a read head can move across it, interpreting the magnetic charge as data.

Without any organization, this whole process would be useless, as the computer wouldn't be able to tell what data fits where, or when to access specified data. Thus, the data is organized into sectors on the disk or tape. This way, if we know which sector the data is stored in, we can find it much more easily.

Magnetic storage has a couple of main advantages over its competitors. Namely, the price of hard disk drives is generally very cheap, only costing around 2-5 cents per gigabyte. Due to this small price, hard disk drives often come with far more storage capacity than their competing media.

These media are not without their issues, however. Since magnetic media must move past a read head to be interpreted, a significant amount of power must be used. This motion also generates heat and noise. They also are limited in their speed by how fast their data can be moved along the read head, meaning faster drives must take more power and will then be louder and warmer. Magnetic media also has a fairly short lifespan and can fail very easily. One of the reasons hard drives can have such high storage density is that the read/write heads hover very close to the disks themselves. This means if anything gets between the head and the disk, it will easily jam and fail. While this can happen very easily, hard drives are contained in sturdy cases which prevent anything that shouldn't be there from entering. On average hard drives only last for around 4-6 years, meaning they shouldn't be used alone for storing important, long-term data.

Optical Storage

Optical storage is another form that is becoming increasingly obsolete, mainly thanks to the internet and streaming. This form of storage is comprised mainly of CD's, DVD's, and Blu-Ray discs. These utilize the reflection of a laser to read data. When the laser is reflected, a "1" can be read, and when nothing is reflected, a "0" can be read.

Like with magnetic storage, optical discs also utilize sectors for easier access.

The biggest advantages of optical discs are their portability as well as their cost. Discs can easily be ejected and carried from place-to-place, and they can be used in most computers. Many modern computers are doing away with disc drives, however, as downloadable content becomes more and more prevalent. Another often overlooked advantage to optical media is their lifespan. As the data is stored in a more physical format, the data can last for a very long time- effectively forever as far as we're concerned. This means data stored on optical discs is more reliable, as long as the disc is kept safe.

However, optical storage is not without its downsides. One issue is that discs can be damaged easily. Scratches are common to find on all kinds of discs, and they can be bent and snapped with little effort. Similarly, again to magnetic disks, optical discs can only be read as quickly as they spin, which leads to taking more power, generating heat, and being loud.

Solid State

Solid-state storage has been gaining in popularity, due to its decreasing price and major benefits over magnetic storage. In a solid-state drive there are no moving parts, leading to faster read/write times as a result. This difference in speed can be as little as 10x, or as great as 10,000x. Solid-state drives work similarly to Random Access Memory, although their data is intended to be held for much longer periods of time. These drives essentially store electrons in gates to then be read from later, making more intuitive sense for 1's and 0's.

Speed is the largest benefit of solid-state over other forms of mass storage, however the lack of moving parts also removes much of the heat and noise from hard drives. This leads to significantly less energy usage and less chance of overheating.

Currently, solid-state's biggest detriment is its cost. While magnetic storage sits at around 2-5 cents per gigabyte, solid-state drives can cost around 20-70 cents per gigabyte. This large expense also means these drives generally have smaller capacities. Solid-state drives also suffer when written to over and over again. This wears out the components and can lead to the data leaking and no longer being reliable.

Another type of solid-state storage that has been popular for several years now is USB flash drives. These are small solid-state drives designed to be portably plugged into any USB port to access and write data. These have comparable prices to other forms of solid-state drives per gigabyte but are generally far smaller and store far less. For many uses, such as distributing operating systems, flash drives have been replacing more traditional optical media.