EN.540.635 "Software Carpentry"

Computers from the Ground Up

Introduction

Computers are ubiquitous in modern day life; however, far too few have anything more than a basic understanding of the "magic boxes". Simply put, if asked how a computer works many will respond with "ones and zeros", but when asked to elaborate few will be able to do so. Note, a concerted effort was put into finding statistics on computer hardware literacy (such as "percent of american's that know the difference between RAM and Hard Drives") to no avail; however, interestingly enough the following statistics on digital literacy were found (articles were written between 2015-2019):

- 60% of Millennials have "low" technology skills (employers consider them unable to stay on top of new technologies). link
- There is no inherent benefit to having been raised in the "digital age". link
- Many jobs now require some degree of coding background. link
- 52% of US Adults are "Relatively Hesitant" on using digital tools in learning. link
- 11% of Americans do not use the internet. link

So what is a computer? How does it work? Here we will go through the basics and develop a foundation for the course.

Transistors and Gates

So, back to those "ones and zeros", what exactly are they? Well, putting it simply they are binary. We use the decimal system (base 10) when we count from 1 to 10, or better put 0 to 9. This is because we have 10 digits to use (0, 1, 2, 3, 4, 5, 6, 7, 8, 9). What happens when we want to count above 9? Well, we simply add a number in front and continue. For those readers that speak Japanese or Chinese, this is how numbers are said. Instead of 11 being "eleven", it is "ten-one". Now, what if I stole every digit above 2 from you, leaving you only with "ones and zeros"? Well, just do the same:

Hexadecimal (Base 16)	Decimal (Base 10)	Binary (Base 2)
0	0	0
1	1	1
2	2	10
3	3	11
4	4	100
5	5	101
6	6	110
7	7	111
8	8	1000
9	9	1001
A	10	1010
B	11	1011
C	12	1100
D	13	1101
E	14	1110
F	15	1111
10	16	10000
11	17	10001
12	18	10010
13	19	10011

So, we can count in whatever system we want. But why use binary? Decimal is universally taught in schools, and it's what we're used to in our daily lives! Well, binary has a nice feature of being simple. Instead of 1 and 0, imagine it as "True" and "False". Now you can make logical statments! Think of the following situation:
Jerry is running from Tom and comes across a suspicious mouse hole. He thinks to himself **if** that hole leads to Tom's digestive system **and** I put live wires into the hole, **then** Tom will be punished. This is a logical statment, using **if-and-then**, and works in binary. The only situation in which Tom is punished for chasing Jerry is if both he has laid this trap and Jerry places live wires in his mouth.

Tom's Digestive System	0	0	1
Live Wires	0	1	1
Tom is Punished	0	0	1

Okay, so binary helps with logic at times. How does an abstract idea of numbers pertain to computers? Well, instead of a number, let's think of it as a flow of current! We define the term **gate** to be a device that performs a simple logical statement (AND, OR, ...). So, how do we actually make these gates? Well, the simplest method for the OR gate is to just connect two wires. If one or the other is "on", then the output is "on". But if we want anything more complex we need a special device: the **transistor**. The transistor takes advantage of material properties to allow a current through, if and only if both of the two inputs are "on". For more information on this device, it is recommended to take a class akin to EN.525.621 - Introduction to Electronics and the Solid State (link).

So now we know that "ones and zeros" mean binary, and binary is used to do the logic in a computer. The "ones and zeros" are simply indications of if current is flowing or not through wires, and transistors are devices that we can use to build up logic gates to build the foundation of how a computer works. To go any more low-level than that you will need to take another course. So for now let's just say all of this is what makes up the different components of our computer and ignore the details.

Hardware

So, what's in a basic computer? Well, let's logic our way through this. If we look at a computer we see a **case**. But that's just an object to house it, so let's look deeper. Well, in our computers we have a way to save files, which translates to our **hard drive**. But reading from this hard drive takes awhile, so we have something known as **Random Access Memory (RAM)** in which we store small amounts of data in faster memory to use when we actively edit/use our files. So, how do we get data from the hard drive to the RAM? That's where the **Motherboard** comes into play. This is the main part of your computer that holds and connects everything together. Unfortunately, the motherboard alone is stupid and it needs help, so we give it a brain, the **Central Processing Unit (CPU)**. That is the processor we always hear about (ex. Intel Core-i7). Now, we like to play video games and watch movies, so we want something that's capable of handling that. Some CPUs actually have built in graphics capabilities, but sometimes we need even more help. So, we add in a **Graphics Processing Unit (GPU)**. Now we have a really cool box that... doesn't turn on. A **Power Supply Unit (PSU)** is added to step down the voltage from your wall, convert it from Alternating Current (AC) to Direct Current (DC), and give you internal power ports for your various goodies. Okay, now we turn it on. It's really cool! Wait... it's hot now... hotter... GAH! We forgot the **cooling system**! Note, this isn't always necessary, and in modern day laptops some have even begun to remove fans. But, we decided to make a powerful computer with multiple GPU's so we need to cool this box. Let's reiterate what we have in the computer tower (or laptop):

1. Case - The external housing of the computer.
2. Motherboard - The central board that everything is connected to.
3. CPU - The "brain" of the computer. It is where most of the logic takes place.
4. GPU - The secondary "brain" of the computer, commonly used for only graphical processes.
5. Hard Drive - The "filing cabinet" of the computer. This is were everything is saved.
6. RAM - The "workspace" of the computer. This is where you actively use your files.
7. Cooling System - Fans on your case, and a CPU fan, to cool the computer.

8. PSU - The power supply to let us safely turn on our computer.

We also have a few other things that we need in order to get the most out of our computer and use it effectively:

1. Operating System - The software that manages all the processes done by the hardware.
2. Monitor - The display that allows us to visualize the processes happening in the computer.
3. Keyboard and Mouse - The tools that allow us to provide input to our computer.

There are plenty of other things one can put in a computer (a disk drive being one such example), but for now the above will work. Unfortunately, it is not as easy as going out and buying any old piece. Different manufacturers use different specifications, and thus we are left with different "socket types" for CPU's (that being, how they connect to motherboards), and different power ratings/internal ports for PSU's. Not only that, but the Motherboard itself can only handle so much, so there are limited ports and capabilities there as well. Typically, when building a computer, one needs to observe the following (though at times there are other personal preferences as well, such as how noisy the computer is):

- Does my Case support the Motherboard?
- Does the Motherboard + GPU + Fans fit in my Case?
- Does the Motherboard support the "socket type" of the CPU?
- Does the Motherboard support the type of RAM I want to use?
- Are the Motherboard and GPU compatible?
- Does my PSU provide enough power for everything?
- Are there enough ports (USB, Ethernet, etc...) on the Motherboard + GPU to support what I want?

Additional Resources:

- Reddit's Build A PC Subreddit (link).
- Newegg (link).
- Linus Tech Tips (link).
- PC Part Picker (link).