Hardware Fundamentals

Hardware is a general term used to describe the electronic machines that carry out the activities of computing, storage, and communications.

1. The basic model of computing

Most computer systems are based on the following model of computing:

- **Input**: Common examples of input devices include the keyboard, the mouse, the microphone (audio information) and the optical scanner (graphics).

- **Output**: Common examples of output devices include printers, video monitors and speakers (audio information)

*Try and think of three other input and output devices you have come across.*

2. Processing

If you opened up a computer today (I'm not recommending you try this in the CIT labs), you'll see a large variety of components inside. Each of these components is a specialized **chip**: a sealed package containing a number of electronic devices, called **transistors**, etched onto a silicon wafer. Transistors are like switches – they can represent the numbers 1 and 0 by being either on or off.

The two fundamental components of the computer, which together play the primary role in the processing of information, are the **CPU** (central processing unit) and the **primary memory**. The CPUs of today’s computers are built on a single chip, called a **microprocessor**.
Central processing unit (CPU): The CPU is the ‘brain’ of the computer system, and does the actual ‘computing’. Every task we ask our computer to do is eventually broken down into a set of simple operations, called machine-level instructions. Each of these instructions can involve retrieving and writing data, arithmetic operations (addition, multiplication and so on), or logical comparisons between numbers. The CPU reads these instructions, interprets them, and performs the required calculations, comparisons or data transfers.

Primary memory: Primary memory is composed of a set of cells, each of which is capable of temporarily storing a fixed amount of information. The CPU interacts closely with the primary memory, storing and retrieving data as it goes through its processing tasks. There are two types of memory – RAM (random access memory) and ROM (read only memory). When we choose the amount of memory in our computers, we are choosing the amount of RAM we want.

The RAM of a typical computer comprises a set of memory chips. Each chip has a large (typically a million or more) set of memory locations. Each memory location can store one or more bytes of data, and the CPU can access or write data in any memory location using the address of that location. A good way to think about memory locations/cells is as post office boxes. The actual box corresponds to the memory location, and the number of the box corresponds to the address of the location.

However, the RAM stores this data only so long as the computer is on; once the computer system is switched off, all the data in the computer’s RAM is erased. Evidently, we’d all like to store information a little more permanently; this is where secondary storage (discussed in section 4) comes in.

3. Families of microprocessors

There are a large number of different microprocessors available to today’s computer manufacturers and buyers. Loosely speaking, the microprocessors in the same family ‘speak the same language’ – we’ll talk about this more in class. The two most common families are:

Intel and Intel-compatible: This includes the microprocessors made by Intel, like the Pentium II and the Pentium III, and others that are compatible, like the AMD K6-3 and the Cyrix MII. Most PC’s use this family of microprocessors.
Power PC: This family of microprocessors was developed jointly by IBM, Apple and Motorola. They are used primarily in Apple computers. Examples include the PowerPC G3 and the PowerPC 630.

Other families of microprocessors are made primarily for high-end computers and servers (see section 6), and include the DEC Alpha and the Sun UltraSparc microprocessors.

4. Secondary Storage

Sometimes called auxiliary storage, this is the part of the computer system that lets us store information permanently (in class, we’ll discuss how permanent this storage actually is). All secondary storage units have two basic parts:

Storage medium: This is the actual physical medium on which the information is stored, as 1’s and 0’s. Examples include floppy disks and CDs.

Storage device: This is the electronic device that reads and writes information onto the storage medium, and communicates with the CPU. Examples include floppy disk drives and CD-ROM drives.

There are two popular types of storage media: magnetic media and optical media. The difference between them is in how the 0’s and 1’s are stored and read. Common secondary storage includes hard drives, floppy diskettes, CD-ROMs, and magnetic tape.

5. The speed of a computer system

When choosing a computer system, most people want to choose the system that will perform their computing tasks as fast as possible. There are a number of factors\(^1\) that influence how fast a computer is, and we discuss some of them below.

Processor clock speed: This is typically measured in MHz (megahertz, or millions of cycles per second). The clock speed of a microprocessor is related to (but not exactly equal to) how many instructions the CPU can process per second. The higher the clock speed of the microprocessor, the faster is the computer. Typical speeds these days range from 300MHz to 600MHz.

Size of primary memory: The more memory your computer has, the faster it can process instructions. We’ll discuss why in class. The typical size of memory ranges from 32MB (megabytes) to 256 MB.

Size of cache memory: Cache memory is a special kind of primary memory that resides on the microprocessor chip, and stores frequently accessed intermediate processing results, thus making the processing faster. Typical cache memory sizes range from 256KB to 1MB.

Speed of hard drive: Most computer systems today need to access data from their hard drive very frequently; therefore, the faster your hard drive can serve up data, the faster you’ll see your applications

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\(^1\) There are a couple of other factors that also make a difference in the speed of a computer: bus width, word size and whether the processor uses RISC. However, it's not common for these factors to be under our control (i.e. its not something we can commonly choose when selecting a computer system). If you are interested, see SENN, chapter 4, for more details.
The speed of a hard drive is determined by a number of factors; all we need to know for this course that SCSI is faster than ATA, and that the higher the RPM measure of the hard drive, the faster it is.

Video memory: If one is planning to use a computer system for graphics-intensive stuff, then more video memory (a special kind of primary memory that is dedicated to rendering graphics) makes the system much faster. Typical sizes of video memory range from 4MB to 16MB.

6. Other concepts of interest

Stored program computing: Most computers today are stored-program computers. The idea of stored programs was conceived in the 1940's and is widely attributed to John von Neumann. A stored program computer has the following features:

1. A memory containing both data and instructions. It should allow both data and instructions to be stored in the same collection of memory locations. These locations must be such that they can be read from, and written to, in any desired order.

2. A calculating unit capable of performing both arithmetic and logical operations on the data.

3. A control unit, which can interpret an instruction retrieved from the memory and select alternative courses of action based on the results of previous operations.

This model of computing (also called the stored program concept) has been used ever since the first computer was built more than 50 years ago. The ‘calculating unit’ (now called the ALU) and the ‘control unit’ are both part of the microprocessor.

Moore’s Law: In the 1960’s, Gordon Moore, who was one of the founders of the microprocessor giant Intel, made a bold prediction – that the speed of microprocessors would double every 18 months, in the foreseeable future. This prediction has held so well that it has come to be known as Moore’s Law. In the computer industry, where the pace of technological change makes predicting even a few years into the future difficult, it is the most widely known and acclaimed technological prediction.

Mainframe computers and servers: Most computers we come in immediate contact with are personal computers (often called client machines or workstations), which are used by a single person. There are other, typically more powerful computers, such as those which do airline reservations processing, or process financial transactions, that are designed to be used by multiple people concurrently, and to handle much heavier processing loads. Such computers are called mainframe computers (or

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2 In general, the performance of your computer system depends a lot on what kinds of things you are using it for. For example, a computer that runs Excel really fast may be very slow when it comes to creating graphics. It’s always a good idea to look at online reviews (such as those found at www.cnet.com) to check out how different computer systems performed for different applications.

3 If you’re interested in finding out more about hard drive performance, let me know – there’s a bunch of resources on the web that I can point you to.
mainframes). These computers were popular many years ago, when computers were large and expensive; many are still in use today. Modern, shared computers today are called servers. Loosely, one can think of mainframes as ‘older servers made by IBM’. There are some conceptual differences between mainframes and servers, but that discussion is beyond the current scope of this course. Remember, however, that the term server itself can mean many different things, depending on whether the context is hardware or software.

Parallel processing: Most computers have exactly one CPU (or microprocessor), and process instructions sequentially, one by one. Computer engineers have tried to get around this bottleneck by building parallel processors – computers with multiple CPUs that run faster by processing many instructions simultaneously. Until recently, parallel processing was restricted to computers in scientific and research environments – currently, however, it is common for corporate servers to have four or more microprocessors.