Chapter 2
How Electronic Devices are Made?

2.1 Use of Electronic Devices

The electronic devices are also a 'tool' to help ease for a variety of human activities like ax, spear, leverage, bowls, mirrors, boats, cars, etc. Then, what do the electronic devices help? The operation of all electronic devices needs the electrical energy that is made from the power plant. Only thing the plant performs is to separate '+' charge and '−' charge from a large neutral conductor and store each of them in prior to transfer the charges of different sign through the wires to the places wherever people need them. By reference, the direction of the induced force to a charge depends on the sign of the charge as described by the Fleming's law, and so the plant can separate charges of different signs through this law. Difference among hydropower, thermal power, nuclear power, wind power, tidal power, and geothermal power is just in where to get the energy required to separate charges, however, all of them commonly use the rotating turbine under the magnetic field to generate an electromagnetic force and so charges will move in a particular direction by its sign. Where, in most case, the charge that can move is limited to the 'electron' within the metal. If you look at the 'periodic table', elements of the metallic property exist separately, whereas very large energy is needed in order to remove electrons from a substance consisting of non-metallic elements that doesn't use in the power plant (See Fig. 2.1). Then, of course, a big piece of metal will be needed in order to remove and store a lot of charges enough to be able to be used by the millions of people who live in the city. These chunks of metal is called 'capacitor' that has the role of the source of charges to be used in the process of charge separation and the storing device of each separated charges at the same time. Figure 2.2 illustrates the process how charges are separated by a generator and the role of the metal is critical for the generation of electric power.

In fact, the power plant picks electrons from the moderate size of metal loaf and adjusts the volume of power generation to respond to the demand for electricity. Recently, 'smart grid' is very spotlighted as a concept that the power consumptions of individual households (where, the power consumption is proportional to the number of recombined electrons with protons at homes that separately

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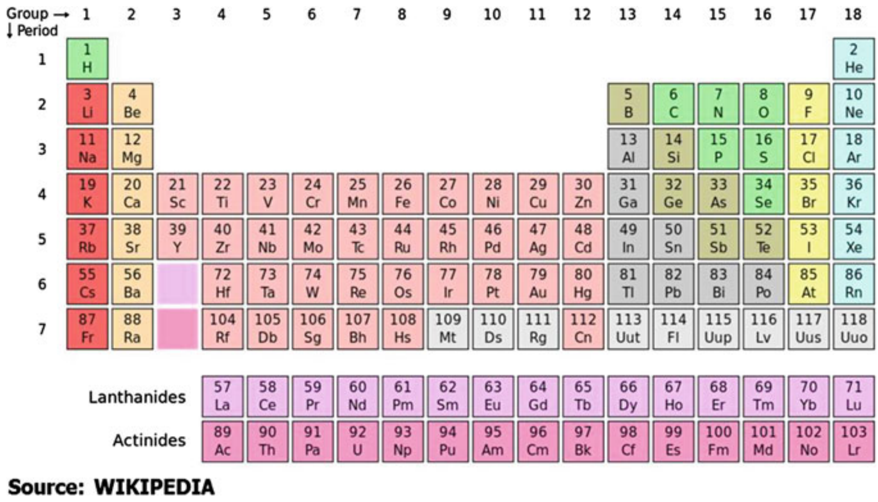
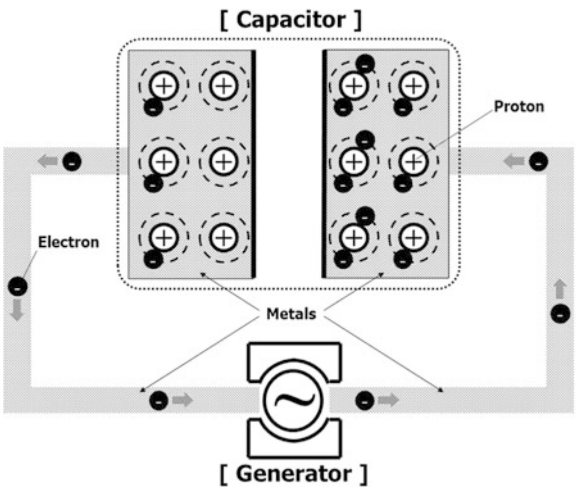


Fig. 2.1 The periodic table

Fig. 2.2 Fundamentals to understand the electricity generation by the power plant



delivered from the charge stock of power plants) are being monitored to adjust the quantity of power generation dynamically. It is noticeable that the power transmission of piled charges from the plant to every doors through DC (direct current) method is so energy inefficient. This is because that all metals existing on the earth have a resistance at room temperature. In other words, moving charges (actually electrons) will lost the speed through the collisions with the metal atoms. It is same that rolling soccer ball on the grass will stop just in a moment. The ball can be sent to some place only by keeping dribble with physical efforts. Let’s consider a long

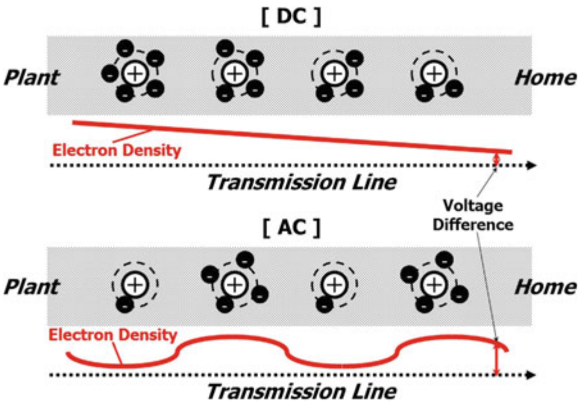


Fig. 2.3 The reason why the alternative current is so superior to the direct current in an aspect of the transmission power efficiency

metal, to pump the stacked electrons in the plant to the house tens of kilometers away through the metal, higher transmission voltage is required. Both of electron's direct long travel and high transfer voltage require large energy as an overhead. Surprisingly, the inventor Tesla found the method to create the 'charge imbalance' at the remote site without electron's travel that is the AC (Alternating Current) transmission widely used in modern power plants.

If the power plant shakes the voltage as a wave of 60 Hz (i.e., 60 times per a second) at one end of a long metal, then the wave can spread out away from the plant and can touch to the home. This method does not require large energy like a DC transmission as the surface of calm lake is easily filled with a wave by a small duck. Thus, AC changes the topical density of the electrons instead of direct moving of electrons inside of a transmission metal line. The wave of the electron density can effectively deliver the electrical energy from the power plant to the home as shown in Fig. 2.3. In other words, the moving distance of electrons is very shorter by which reducing the need to use the high energy and voltage to make a DC transmission in the power plant. However, the transmission voltage used by the plant is still very high in the sense of everyday life to be able to the level of hundreds or thousands KV.

Now the electric energy was ready for operating electronic devices and so let's look at about the electronic equipment itself from now. It should be emphasized that the target user of electronic devices is a human in the end. As the bulbs are to provide light to be seen by people and the electric motors are to generate dynamic power on behalf of the human, the electronic devices have a role of accepting and sending information for people. Even though the ultra fast semiconductor chips can perform a tremendous amount of calculations per a second, the electronic device should consider that people can send and receive to/from electronic devices only a very small amount of information through human's particular way to accept information (namely, most of people don't want to accept information via the monitor of heavy sombre low-resolution black-and-white display and to paint a picture via the typing instrument). Thus, many electronic devices have been devoting a lot of effort for convenient human–machine interface together with the effort for high performance semiconductor chips. Of course, nobody can discuss about the electronic device without computing capabilities. The computer was born for the high-speed calculation and it has evolved to the calculator that can convert the calculation method freely, so we could call it to 'programmable calculator', and, in recent years, it becomes the highly 'general purpose' information processing equipment. We can perform various applications, i.e., game, word processing, watching movie, photo editing, product development, and scientific calculation, on a single computer using different 'software'. In addition, electronic devices have widely utilized a variety of sensor devices which can detect the small signals (light, sound, vibration, magnetic field, pressure, temperature, smell, etc.) that is not detectable by humans. Surprisingly, the semiconductors play a key role in all of that mentioned in above human–machine interface, computer, and sensors. Why should this be? Because this makes it easier that building smaller size electronic devices and electrical circuits inside the semiconductor. The only way to create the sub-micrometer size electronic devices and circuitry is using a semiconductor. Creating a smaller electronic device and electric circuit gives several advantages, so both of device and circuit can be faster, more sensitive to the small signal, less power consumption, much cheap, etc. So, once the electronic equipment is connected to the power line, a variety of benefits could be expected while electronic circuits are operating in a manner of the human friendly interfacing, high speed information processing, and small signal sensing. Then, somebody may have one question in here. So, specifically what benefits will be achievable using electronic devices actually? If someone wants to gratify the desire by owning the latest electronic equipment, that will be no difference with the case of owing the jewelry. Can we find the unique benefits of electronic devices? If most of people should recognize that they spend a lifetime in production activities as a true nature, will the electronic device be just a 'tool' as the evolutional form of ancient 'papyrus' or 'beacon mound' to help our production activities? As Adam Smith's 'Wealth of Nations' became an important theoretical background to pursue the 'productivity' in order to maximize the power of a nation, and so the birth of modern electronic devices could have the meaning of a sort of 'weapon' in competition with other countries. Anyway, in conclusion, the improvement of the 'productivity' could able to relieve many concerns of people that was continued from primitive times only if they belong to the middle class of the wealthy country. Automate machines have enabled that more 'foods', cold and heat avoidance with durable and comfortable 'homes', many necessities of life such as 'clothes' to protect themselves, and liberation from a lot of pains with high quality 'medicine'. It will be an undeniable fact that a lot of people could have been relieved from many pains through the improvement of the absolute level of life quality. Surely there was ancient people who could enjoy their life based on the production of grain surplus like of 4 ancient civilizations, but they had little turns under the change of the natural environments and were quickly connected to disasters that have impacted on the rise and fall of civilizations. As a consequence, the time has come that a lot of people are starting to talk about how to live for the ‘happiness’. Unfortunately, the ‘relative’ quality of life through the comparison with others will be improved much more slowly, and people will not be able to avoid the ‘unhappy’ from that. It seems clear that electronic devices play a key role for people to protect a variety of threats by making all human tools more efficient. However, from the point of view that human is an existence having the strong desire to explore the surroundings endlessly, electronic devices have the value as the ‘intellectual tools’ to acquire the crucial ‘interesting’. Very large physics experiments with huge instrument such as ‘Large-Hadron-Collider (LHC)’, ‘rocket’ and ‘satellite’ to explore the universe, a variety of ‘simulation’ (for example, weather forecasting, chemical reaction, mechanical devices, hydrogen bombs, etc.), and virtual experiences like ‘game’ and ‘movies’ could have been practicable with the help of electronic devices. Furthermore, electronic devices are used to design more advanced electronic devices as a key tool, which continues the development of electronic devices by forming a virtuous circle. In conclusion, the electronic devices seem to be worth at least in two things for human. One is helping to comfortable and affluent life for human by direct or indirect ways and another is providing to stimulate ‘imagination’ and ‘fun’ for human as an innate explorer.

2.2 Inside of Electronic Devices

What components are used in the electronic devices? As earlier told, the power supply must be equipped in that. Electronic devices use DC power instead of AC power delivered from the power plant, so the rectifier is required to convert AC to DC. Or the charged battery will be the role of DC power supply if the devices are using the battery in mobile environment. It was already mentioned that many semiconductors are used in the electronic devices. Where, each of the semiconductors operates at different power supply voltages. For example, CPU, memory, storage, and network devices operate at different power voltages, and sensors and display devices need another power supply voltages, respectively.

Power-Management-Integrated-Circuit (PMIC) is a semiconductor chip that has the role of the generation of stable voltages with aforementioned external power or battery power to be used by various components within the electronic devices. Figure 2.4 shows an exemplary power delivery for each semiconductor components, where different voltages are used for the operation of various semiconductor chips.

Now one basic requirement to run all parts of the electronic devices was satisfied by being prepared the power supply voltages using the PMIC. Then, what methods were being used to control each of the semiconductor components by a single chain of commands instead of individual actions per a frame of those components. Each semiconductor components should be able to be manipulated by human in any way, eventually the decision making devices (i.e., keyboard, mouse, touch pad, speech recognition, motion detector, etc.) must be connected to the

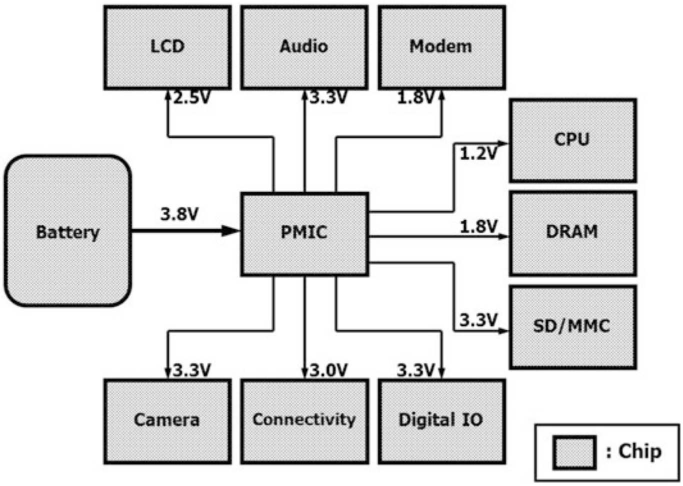
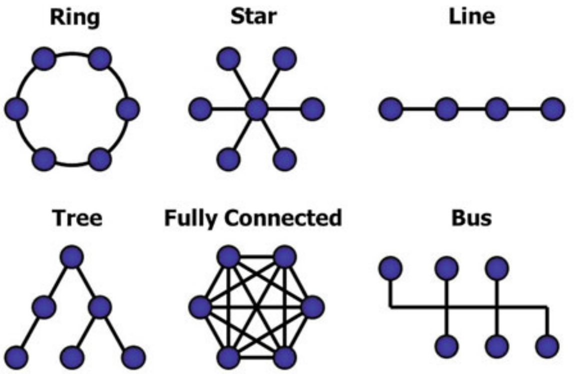


Fig. 2.4 Voltages for a mobile system

Fig. 2.5 Network topologies



components with direct or indirect way. Anyway, each of parts should be connected to each other to send and receive signals, which will require the communication network among semiconductor components as a result. So, one remaining problem is how to build the network among the parts efficiently. This could be considered a major problem to be manipulated in the 'network' discipline in a major of the electrical engineering. A variety of networks (different networks are distinct with a term of 'topology') are existing, where the network to connect the internal components in a electronic device is usually using the 'star' topology. Diagrams of different network topologies are illustrated in Fig. 2.5. The 'star' topology has a central component from which the connections to all the other parts are spread out with a star-shaped structure. Such a central one is the Central-Processing-Unit (CPU). In other words, all the components in electronic devices

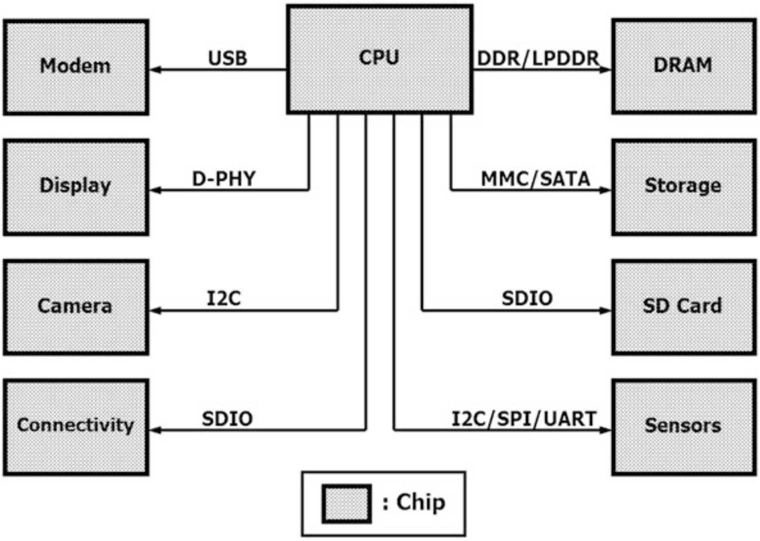


Fig. 2.6 Example of the data interfaces in a mobile device

are equipped with the communication network to connect to the CPU. Now we will need to determine the technology used to build the networks. First, we need to decide whether wired network or wireless network will be used in there, and then the type of protocol should be determined to be used for communication. Someone who opened the PC by oneself would discovered that there was the green board and several semiconductor components were attached on the board by soldering. The same thing will be found in the most of current electronic devices, i.e., laptop PC, tablet, mobile phone, TV, computer server, consumer electronics, etc. Actually, each of parts are connected with the wired network to send and receive signals through the metal wires on top of the green (or other colors are available for it) board. But different protocols are used between the CPU and rest parts, respectively. This is such that the memory interface between CPU and memory, the SATA, SAS, USB, SDIO, and NAND interfaces between CPU and storage, the PCIe, SDIO, and USB interfaces between CPU and network devices (for instance, ethernet, 3G/LTE, WiFi), the TTL, LVDS, and D-PHY between CPU and display, and the I2C, SPI, and UART interfaces between CPU and sensors have been used. Figure 2.6 shows an example how the interfaces were adopted in a real system. Why so many different interfaces are required, even though one unified interface will be easier to implement? One answer is that the optimization of both of the cost and power consumption will be possible with the adequate interfaces to meet the communication needs bit to avoid the excess performances. If you use a high-speed interface for parts that require only a slow communication speed, power consumption and cost will increase. Now the reason why the metal wires are so much on the green board while looking at the inside of electronic devices will be understood. In other words, those wires are for the communication among various parts including CPU and for the distribution of the power supply voltages. Then one question will come to mind why all the things on the board are not being replaced by a single semiconductor component? Although it would be clear that the one component of many parts allows the fastest and highest energy efficiency, but the component will be too expensive to become a commercial product. Therefore, the reason why the current internal form of electronic devices has been widely accepted can only be described as aforementioned the 'principle of economics'. The price of semiconductor components is determined by summing that the cost of equipment for manufacturing semiconductor chip, the number of semiconductor chips can be created within a wafer, the number of process steps required to make the chip, and the ratio of the number of normal operation chips without defects and that of total fabricated chip (this is called 'yield'). Complex and more circuitry within the semiconductor chip increases the size of the chip, which results in the bad yield and higher manufacturing cost. Also two different processes should be used together to implement a single chip by integrating two components of different power supply voltages, so that raises the manufacturing cost of a chip due to the increased number of process steps. In the front of the story, these components could be divided into two kinds of things in accordance with the purposes of purely information processing and human–machine interfacing. Parts for information processing will be dealt with in more detail later, let's look at the parts for human–machine interfaces a little more. Characteristics of these electronic components is that it is exposed to the outside instead of hidden to the inside of electronic devices to be able to interact with people. The most visible one, for example, is the display as which people can accept information through the eyes. In addition, speakers are a component for human to accept information through the sound, and such as cameras, microphones, and GPS sensors are the parts for machines to accept images, sounds, and radio signals of outside, respectively. Moreover, sensor devices for touch, motion, light intensity, and near-field detections and mechanical devices such as a vibration motor are a component that has a role to help the comfortable exchange of information between human and machine. The parts for nature-machine interfacing exist for machine to accept various external environmental information such as geomagnetic, angular velocity, acceleration, and temperature. As earlier told, all of these parts should be connected to the CPU through the wires as well. Now since sufficiently many electronic components have been introduced, any parts found in the disassembled electronic devices might not be excluded from the aforementioned components obviously.

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