The Evolution of Battery Technology

An Online Continuing Education Course for Engineers

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The Evolution of Battery Technology

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1. Introduction

The ability to store electrical energy is a recent historical feat. Of course, our ability to control and use electrical energy also started a short time ago. Batteries provided the main source of electrical energy before the advent of electric generators around the end of the 19th century (the late 1800s). Up until Benjamin Franklin's experiments with lighting and static electricity, very little was known about storing electrical energy. And, it took some time before the storage of electrical energy became practical. This course will look at and study the evolution of electrical energy storage, from capturing static electrical energy to using various chemicals and materials to store and generate electrical energy. We will look at how the chemical revolution has affected this increasingly important part of our culture. We will consider both rechargeable and non-rechargeable technologies.

2. The Capture of Static Electrical Energy

In 1749, Benjamin Franklin used the term "Battery" to describe a set of linked capacitors that were charged with a static generator. The capacitors were called "Leyden Jars." He experimented with connecting Leyden Jars in series and parallel to either increase the voltage or current levels. Figure 2.1 is a picture of 4 water-filled Leyden Jars that could be used to store an electric charge. As a matter of interest, a capacitor is two metal plates separated by an insulator.

Figure 2.1 Picture of Four Water Filled Leyden Jars

Leyden Jars were the first reliable source of electrical energy that could be used in electrical experiments. They were charged with a D.C. voltage, and the individual jars could be connected in series to produce a higher voltage or in parallel to produce a bigger current. They could be discharged to run various experiments by early scientists. Once discharged, they had to be recharged by some sort of static electrical generator. This was a real disadvantage of using Leyden Jars as a source of electrical energy. They could not be used to actually generate an electrical charge, only hold the charge for experiments that were being done. The discharge could be relatively fast, and once they were discharged, they had to be recharged. With a proper load, the discharge time could be increased. Technically, we could call this device a battery. A Leyden Jar is actually a capacitor with two plates. If filled with water, the water becomes one of the plates. The water is not necessary; only two metal plates separated by an insulator are necessary. Although they had limited usefulness, they were used for many experiments on electrical energy. At the time, it seems that they were the best way to store electrical energy. The energy stored by any Leyden Jar was equal to ½ C V^2. The capacitance was typically very small. A typical one pint Leyden Jar had a Capacitance of about one Nano farad. That's a really small capacitor. It did really help in the development of the theory of electrical energy. Depending on the design, a Leyden Jar could hold a high voltage charge. It is estimated that some early Leyden Jars could hold a charge of 20,000 to 60,000 volts. That's high enough to deliver a pretty good shock. The energy stored in a Leyden Jar is equal to:

$$W = \frac{1}{2} * C * V^2$$

Where W is energy in Joules, C is Capacitance in Farads, and V is voltage in Volts. As an example, consider a 1-farad capacitor (a pretty big capacitor) charged to 100 VDC. Its energy would be 5000 joules or 4428 foot-pounds. If the capacitor were 1 microfarad (a much more typical value) and the voltage remained at 100 VDC, the energy would be 0.005 joules or 0.00369 foot-pounds. Since the value of the capacitor depends upon its physical size, it would take a pretty big Leyden Jar to store enough energy to do any useful work. Better ways of generating and storing electrical energy soon became available. Figure 2.2 shows symbols of various types of capacitors. Figure 2.3 is a picture of a 0.1 microfarad capacitor. It is about 1 inch long. Since a capacitor is made of 2 metal plates separated by an insulator, the symbols are very appropriate.

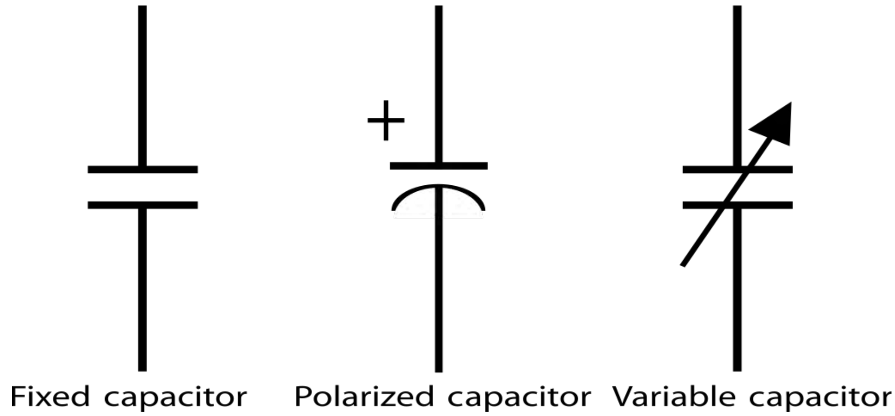

Figure 2.2 Symbols for Various Types of Capacitors

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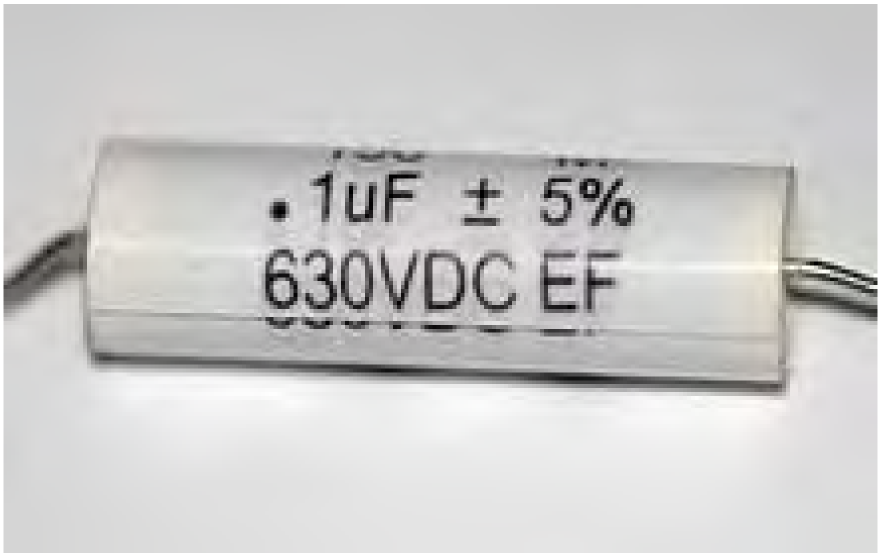
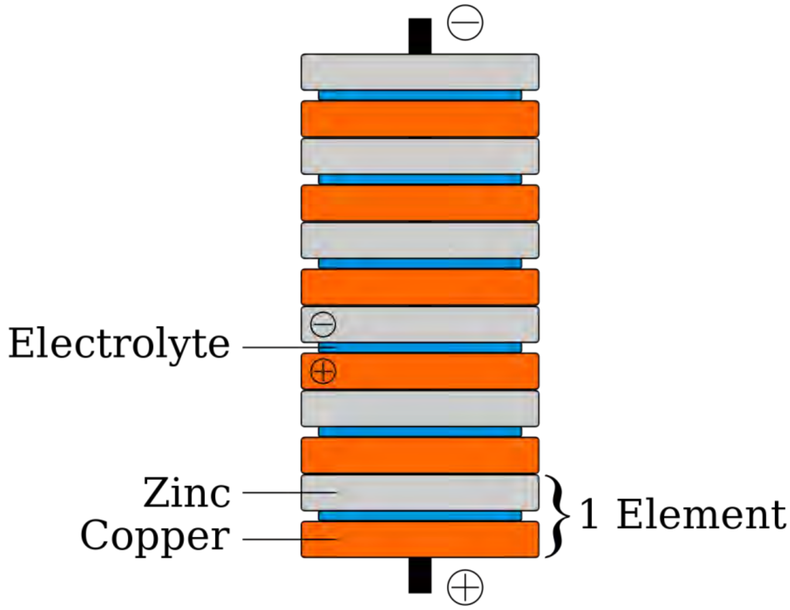


Figure 2.3 Picture of a 0.1 Micro Farad, 630 VDC Capacitor

3. The First Real Battery

There are several claimants for the making of the first real battery. This device had to be able to convert chemical energy into electrical energy and do it reliably. Figure 3.1 is a schematic and picture of a Voltaic Pile, one of the first real batteries. It consisted of alternate layers of materials immersed in a liquid or electrolyte. These devices had a relatively short lifetime and could not be recharged. Hydrogen was released in normal operation and inactivated the electrodes. When they ran out of energy, the elements, usually copper and zinc, and the electrolyte had to be replaced. Alexander Volta first made a similar device in 1800. In spite of its shortcomings, it helped make the evolution of the electrical industry possible. The Voltaic cell would gather hydrogen bubbles on the copper electrodes, and short circuits would appear on the zinc electrode. Both of these phenomena decreased the lifetime of the Voltaic Piles. Fortunately, the ingenuity of the engineers and scientists of the time solved many of the problems of Voltaic Piles. In 1836, John Frederic Daniell found a way to absorb the hydrogen produced in normal operation. He added a third electrode that absorbed the excess hydrogen. It became the first successful battery and was used by the telegraph industry. The Daniell cell was also used as the first working standard for the definition of the volt, which is the unit of electromotive force. Its actual voltage was about 1.1 volts. The Daniell cell was safer to use and had a longer lifetime than Voltaic Piles and was less corrosive. Figure 3.2 is a schematic picture of a Danielle Cell. It still had copper and zinc electrodes that would need to be replaced and an acid electrolyte (H_2SO_4). The sulfuric acid (H_2SO_4) would also be used up or consumed in normal operation. Charging these early batteries consisted of replacing the electrodes and electrolyte. Fortunately, the state of the art technology improved and better, and sometimes rechargeable batteries were made. Various cells were developed and included Bird's Cell, Porous Pot Cell, Gravity Cell, Poggendorff Cell, Grove Cell, and Dun Cell. This evolution led to the development of dry cells, which were not rechargeable, and rechargeable cells, which usually had a liquid electrolyte.



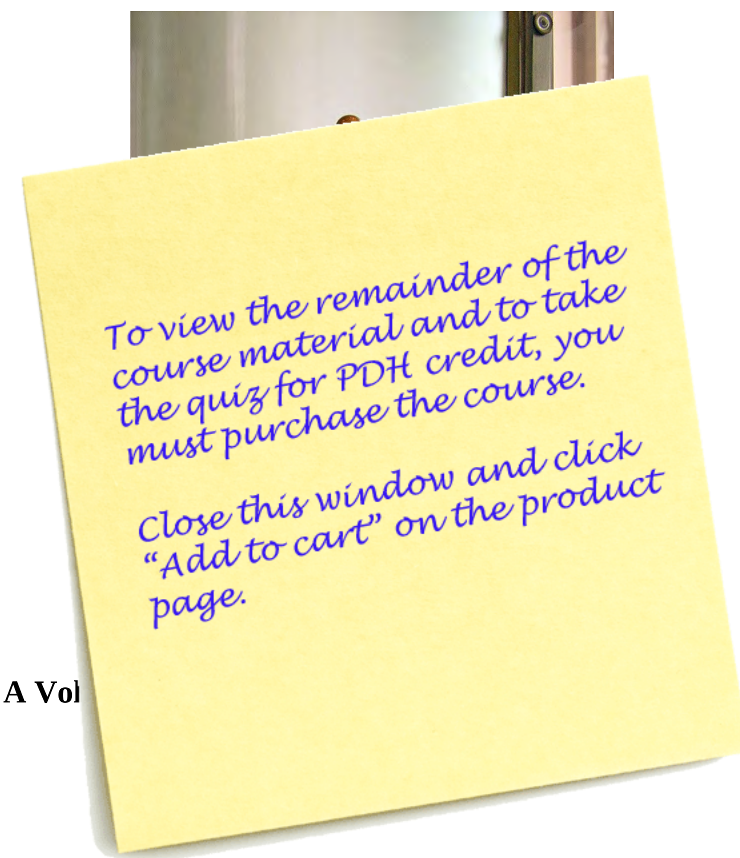


Figure 3.1 A Vol ... cal Battery

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