11.5.5: Capacitors

Capacitors on a circuit board

Figure 17.6.1

The circuit boards found in your computer, phone, calculator, and pretty much every other electronic device you own often look much like the one shown above. Many circuit boards have capacitors, including this one. Capacitors can be used to smooth out electrical impulses or to turn constant electric currents into a series of impulses. Use the simulation below to begin your exploration of capacitors and discover how capacitors are used in a camera's flash:

The Capacitor

Sharing Charge

We already know that insulators are materials that do not allow electrons to flow through them easily. When you place excess electrons on an insulator, the electrons remain where you put them and do not move around. Conversely, conductors are materials that allow electrons to flow thorugh them freely. Since electrons repel each other, excess electrons on a conductor move to positions as far apart as possible. The difference can be seen in the image below, where the electrons on the insulator remain clumped near each other, while the electrons on the conductor have spread out to cover the whole surface.

Illustration of the distribution of charge in insulators and conductors

Figure 17.6.2

Consider a charged conductor and an uncharged conductor. When the charged conductor is touched to the uncharged conductor, as far as the electrons are concerned, it has become one large piece of conducting material. The electrons on the charged object will run onto the uncharged object until the density of the charge is evenly distributed over the entire surface of both objects. If the objects are the same size, the charge will be shared equally throughout. This method is occasionally used to divide a charge by half.

The earth is also a conductor. Touching a charged object to the earth is called **grounding**. When you touch a conductor to the earth, you allow the earth to share the charge. Since the earth is billions of times bigger than the object, the earth takes nearly all of the charge. The charged object that was grounded now has zero charge.

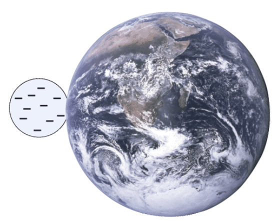

Figure 17.6.3

It is very easy to ground an object. All that is necessary is to touch a conducting wire to both the object and the earth. Electrical devices that run the risk of picking up a large static charge are grounded, meaning they are connected to the earth via such a conducting wire. Virtually all household appliances, especially washers and dryers, are grounded in this way to eliminate static charge. Similarly, large trucks, especially gasoline tankers, are grounded via a large chain hanging off the back to prevent sparks when fuel is being unloaded.

Spheres, whether hollow or filled, will always have the excess charge on the surface. In hollow spheres, the only place for an electron to exist is on the surface. Similarly, in a solid conducting sphere all the excess charge sits on the surface. This conclusion is a result of Gauss's Law, which tells us that the symmetry of the sphere and the fact that the electric field within the sphere is 0 forces the charge to the outside.

Capacitors Store Charge

Pieter Van Musschenbroek, a Dutch physician, invented a device in 1746 that could store electric charge. Though he named the device a Leyden jar, similar devices today are called **capacitors.** A typical capacitor consists of a pair of parallel plates of area Aseparated by a small distance d. The space between the two plates is most often filled with an insulator and frequently the plates are rolled into the form of a cylinder.

If voltage is applied to a capacitor, it quickly becomes charged. One of the parallel plates acquires a negative charge and the other an equal amount of positive charge. For a given capacitor, the amount of charge, Q, acquired by each plate is proportional to the potential difference, V.

$$Q=CV$$

Q is the charge in coulombs, V is the voltage in volts, and C is the particular capacitor's constant of proportionality. C is also called the **capacitance** of the capacitor. The capacitance is the voltage the capacitor can reach before it discharges, allowing the voltage across the capacitor to drop to zero and the current to cross the capacitor. The SI unit for capacitance, according to the equation above, will be coulombs/volt, and this unit has been given the name **farad** (F). Most capacitors have capacitances in the range of one picofarad (10^{-12} F) to one microfarad (10^{-6} F).

Example 17.6.1

A sphere has a potential difference between it and the earth of 60.0 V when charged with 3.0×10^{-6} C. What is the capacitance?

Solution

$C=Q/V=3.0\times10^{-6}$ coulombs/60.0 volts$=5.0\times10^{-8}$ farads

Have you ever used an electronic device that can be controlled by human touch? These types of touch screens are really amazing and utilize capacitance to work. When you place your finger on the screen, you disrupt the electric field patterns that exist in the device and cause changes to its capacitive system, which the computer understands. Launch the Touch Screen simulation below to play around and learn more:

Summary

- Since electrons repel each other, when excess electrons are placed on a conductor, they will move to positions as far away from each other as possible.
- When a charged conductor is touched to an uncharged conductor, the electrons will migrate until the density of the charge becomes evenly distributed over the entire surface.
- Touching a charged object to the earth is called grounding.
- A charged conducting sphere will always have all the excess charge on its surface.
- A typical capacitor consists of a pair of parallel plates, separated by a small distance.
- Q=CV, where Q is the charge in coulombs, V is the voltage in volts, and C is the constant of proportionality, or capacitance.

Review

1. The two plates of a capacitor hold $+2.5\times10^{-3}$ C and -2.5×10^{-3} C of charge when the potential difference is 950 V. What is the capacitance?
2. The potential difference between two parallel wires in air is 120. V. They hold equal and opposite charges of 9.5×10^{-11} C. What is the capacitance of the two wires?
3. How much charge flows from a 12.0 V battery when it is connected to a 9.00 microfarad capacitor?

Explore More

Use this resource to answer the questions that follow.

1. What do capacitors do?
2. What are the units of capacitance?
3. What is the formula for capacitance?

Additional Resources

Study Guide: Electrical Systems Study Guide

Videos: Capacitance - Overview

Real World Application: Storing Static Electricity

Interactive: Flashing Neon Light