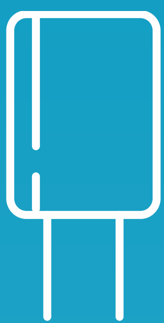
『The basic facts about capacitors』

Introduction to Capacitors



- What is a capacitor?
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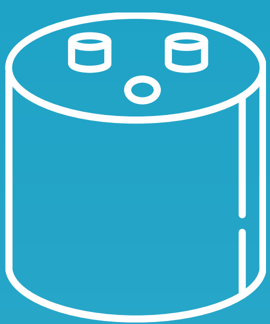

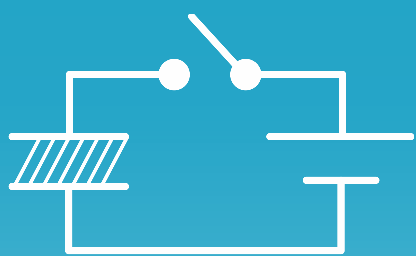

AIC tech Inc.

The basic facts about capacitors

Introduction to Capacitors

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Introduction

Capacitors are one of the most basic and important components in electronic circuits. For engineers who design circuits, accurate acquisition of knowledge about the characteristics and properties of capacitors is essential for product development.
However, if you think about the basic operation and mechanism of a capacitor again, you may notice that there are some things that are overlooked or misunderstood. For young circuit design engineers, we present the "You Cannot Ask About Now. Introduction to Capacitors" covering everything from the basics of capacitors to today's hot topic of large-capacitance capacitors.

Chapter 1 What is a capacitor?

What role do capacitors play in electronic circuits? This chapter explains the basic structure of capacitors, how they work, and the units used to express the size of capacitors in design and development.

1-1. Is there a difference between a condenser and a capacitor?

There is no clearly defined difference between condensers and capacitors; both are electronic components that can physically store electric charges.
In English-speaking countries, it is called a capacitor because of its "capacity", but in Japan, it is said that it came to be called a "condenser" because it was translated as a "condenser (*chikudenki*)" because of its ability to condense electricity and store it.

1-2. Mechanism and function of capacitors

[Structure]

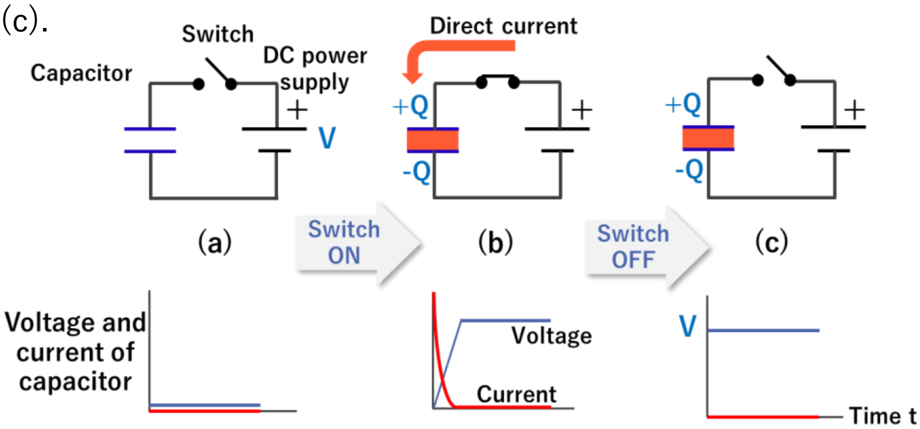
The circuit symbol used to represent a capacitor has two parallel lines drawn on it. This indicates that the capacitor consists of two parallel conductor plate electrodes. For electrolytic capacitors with positive and negative polarities, the positive side may be marked with a + symbol. There are differences in notation methods among countries such as Japan (JIS), the United States (EIA), and Europe (EU, IEC).

Common capacitor symbol
JISC0617-4
(IEC60617)

The larger the area of the capacitor's electrode plates and the closer the distance between the two electrode plates, the higher is its ability to store electricity. In addition, the electrode plates are electrically separated by an insulating material. This insulating material gives the capacitor the ability (capacity) to interrupt the DC current and store electricity. These materials are commonly referred to as dielectrics.

[Ability and unit to store capacitance]

As shown in the figure below, when the switch is turned on and a DC voltage is applied to the capacitor, electricity (electric charge) instantly accumulates on the electrode plate (b). If the voltage is removed, the electric charge accumulated on the electrode remains intact. (c).



State of voltage, current, and electric charge when DC voltage is applied to the capacitor

The ratio of the electric charge (Q) accumulated on the electrode to the applied voltage (V) is called the capacitance (C) of the capacitor. Capacitance is an index of the ability of an electrode to store an electric charge, and the unit called farad (abbreviated as F) is used in honor of the British physicist Michael Faraday. When a charge of one coulomb is stored on an electrode at a voltage of one volt, the capacitor is defined to have a capacitance of one farad.

[Properties at DC and AC]

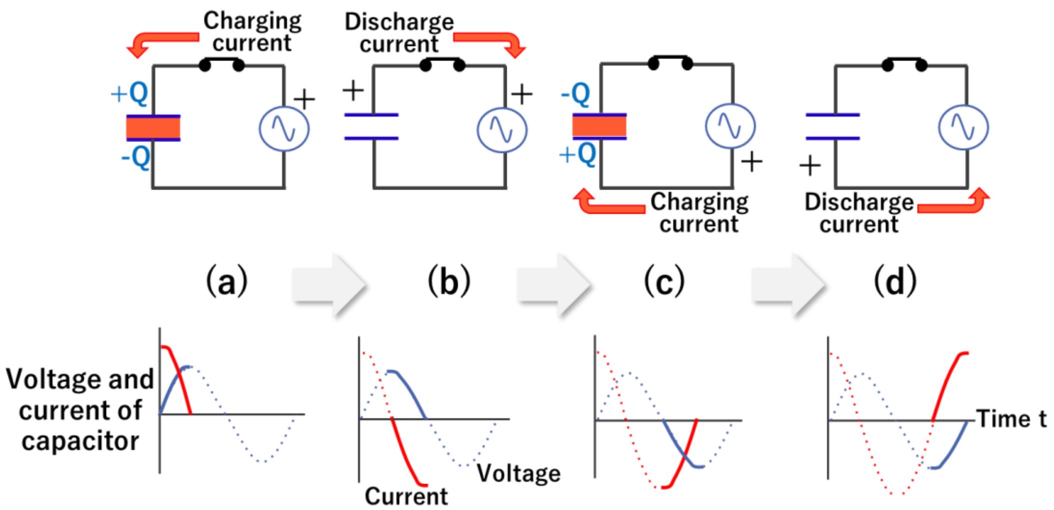
As shown in the previous section, when a DC voltage is applied to a capacitor, an instantaneous electric charge accumulates on the electrode plate, and no further electric charge movement is possible. In other words, the capacitor stops the DC current in an instant.

However, when an AC voltage is applied to the capacitor, the situation changes. This is because AC voltage is always switching between positive and negative voltage.

Initially, electric current flows like DC current, and an electric charge accumulates.
However, when the voltage changes in the next instant, the accumulated electric charge is discharged. Then, the current flows in the opposite direction to the previous one to charge it. In other words, charging and discharging are repeated in the capacitor according to the exchange of AC voltage, and it seems that electricity is flowing through it.

$$C = \frac{Q}{V}$$

C : Capacitance
Q : Electric charge
V : Voltage



In summary, the functions of the capacitor are the following two:
① Stores the electrical energy, and give this energy again to the circuit when necessary.
② Blocks the DC current flow, and permits the AC current flow.

Also, the faster the alternating current voltage is switched (called alternating current with higher frequency), the easier it is for the capacitor to pass the alternating current.

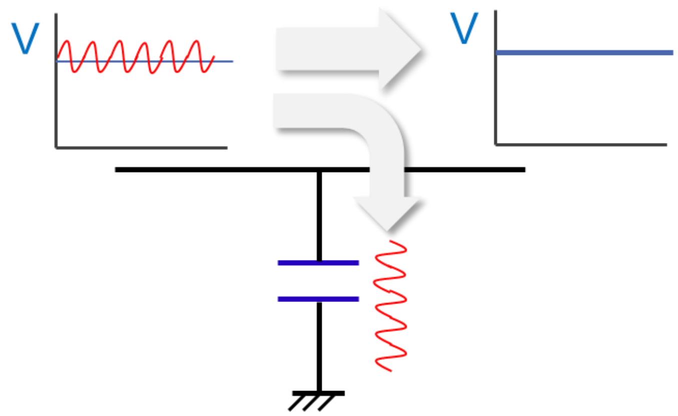
[How capacitors work]
Because of the above functions, capacitors perform two major functions in electronic circuits:

① In DC current, electricity is stored and discharged.

Capacitors not only store electric charge but also discharge it, so the capacitor itself becomes the power source. A simple example is the strobe light emission of a camera. The camera stores an electric charge in a capacitor built into the camera and discharges it all at once to create an intense flash.

② Create a clean direct current (remove AC components)

Using the function whereby the capacitor allows alternating current to pass through, it is possible to turn an unstable direct current with a wave-like component into a clean direct current.



As shown in the figure, if a capacitor is connected between the input and output sides and connected to the ground, the AC component will flow to the capacitor and only the direct current will flow to the output circuit. It is also possible to output a stable voltage even if there is a large voltage wave at the input.

Capacitors in a circuit have a simple but very important function. Our capacitors are characterized by their small size, large capacitance, high withstand voltage, and long life. We will explain in detail how to use these characteristics in the next issue.

Chapter 2 Types of capacitors

Although the basic role is the same, there are various types of capacitors depending on their application and size. This chapter explains the different types of capacitors and their respective characteristics.

2-1. Aluminum electrolytic capacitors

A capacitor that forms a dielectric oxide film on the surface of an aluminum foil that serves as the anode and uses an electrolyte or a conductive polymer, etc. as the cathode is called an aluminum electrolytic capacitor.

[Our product information link]

- Lead type aluminum electrolytic capacitors
- Screw terminal type aluminum electrolytic capacitors
- Snap mount type aluminum electrolytic capacitors

Many of them have a cylindrical shape and are so common that many people think of this shape when they think of capacitors. Compared to other types of capacitors, electrolytic capacitors have the major characteristic of being able to store a large amount of electricity even though they are the same size as other capacitors. While most capacitors are made for digital circuits with a diameter of 10 mm or less, we sell products for power electronics circuits with a volume of 0.5 to 1 liter.
Aluminum electrolytic capacitors use an electrolytic solution filled in paper (separator), which has the disadvantage that the electrolytic solution evaporates with age and the performance deteriorates. They are consumable parts that need to be replaced periodically.

2-2. Film capacitors

A film capacitor is a capacitor that uses plastic film as the dielectric. Compared to aluminum electrolytic capacitors, the amount of electricity stored in these capacitors is more stable at both high and low temperatures, and they can withstand higher voltages and have a longer service life.

[Our product information link]

- Film capacitors for power electronics

Since the film is wound into a cylindrical shape to make the element, most of the products with large capacitance are cylindrical in shape, but square products are also made for small and medium capacity products. We have both types available.

For the film that becomes the dielectric, materials such as polypropylene used for food containers, syringes, DVD cases, etc., clothing fibers such as fleece, and PET (polyethylene terephthalate) used for beverage bottles are used. Since these materials have the ability to store electricity (permittivity), which is only about 1/4 that of aluminum electrolytic capacitors, in order to store more electricity, a large amount of film is required, resulting in a larger capacitor size.

2-3. Ceramic capacitors

A capacitor that uses ceramic (pottery) as its dielectric is a ceramic capacitor. By changing the composition of raw materials, it is possible to create dielectrics with various performances.

The electrodes are not rolled up like aluminum electrolytic capacitors or film capacitors but are fabricated by layering multiple layers of a compounded slurry-like ceramic material and paste-like electrode material. For this reason, small capacitors with a size of a few millimeters or less are generally used, and they play an active role in digital circuits. A single smartphone uses 800 to 1,000 ceramic capacitors, and the production quantity is the largest production volume among the capacitors.

2-4. Electric double-layer capacitors (EDLC)

An electric double-layer capacitor has an extremely large capacitance compared to other capacitors. There is no dielectric in this capacitor, and a lot of electric charge can be stored in the area called the electric double layer, which is created between the activated carbon of the electrode and the electrolyte solution.

Since there is no dielectric to serve as the insulator as in other capacitors, the withstand voltage is low, and it is used as a power source like a battery rather than an electric circuit. Compared to rechargeable batteries, such as lithium-ion batteries, its characteristic is that the charging time is short.

Chapter 3 Capacitance of a capacitor

Capacitance is an index of the ability to store an electric charge. Capacitors have a rated capacitance for each product, which is measured using an LCR meter according to the method specified in JIS C 5101-1.

Even if the capacitor is rated at 100 μF, there is a certain range of variation in the actual capacitance (called tolerance), which also varies depending on the temperature and frequency. In other words, even if the capacitor is 100 μF, the actual capacitance may be 90 μF or 110 μF.

The capacitance indicated on the product is only a guide, so it is important to consider tolerances and changes due to conditions when selecting a capacitor. We have a variety of technical data available. Please contact us for more information.

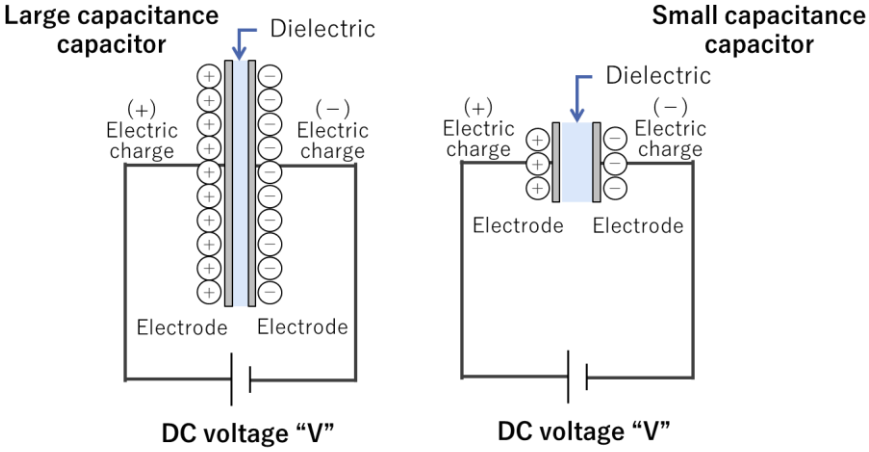
3-1. What is a large capacitance capacitor?

Although there is no clear definition of a large capacitance capacitor, we specialize in large capacitance capacitors for power electronics. So, what kind of capacitor is a large capacitance capacitor?

A capacitor stores an electric charge on an electrode. The larger the area of the electrode, the more electric charge can be stored. The two electrodes accumulate positive and negative electric charges, respectively, and the electric charges attract each other. The closer the electrodes are to each other, the stronger the force of attraction, so much electric charge is accumulated.

Also, as explained in section 1.2, an insulating material called dielectric is sandwiched between the electrode plates. Depending on the type of dielectric, the ability to store electric charge varies, and the index of that ability is called the permittivity. The above can be expressed in the following equation and diagram:

$$\text{Capacitance (C)} = \frac{\text{Permittivity } (\varepsilon) \times \text{Electrode area (S)}}{\text{Distance between electrodes (d)}}$$



Also, as explained in section 1.2, the capacitance is the electric charge (Q) accumulated on the electrode divided by the applied voltage (V). If rewriting this equation, we can understand that as the voltage applied to the capacitor increases, the amount of electric charge increases.

$$\text{Capacitance (C)} = \frac{\text{Electric charge (Q)}}{\text{Voltage (V)}}$$

$$\Downarrow$$

$$\text{Electric charge (Q)} = \text{Capacitance (C)} \times \text{Voltage (V)}$$

3-2. What are large capacitance capacitors?

The capacitance and voltage rating ranges of the four types of capacitors explained in Chapter 2 are shown in the figure. Capacitors cover an extensive range of capacitance, from a minuscule one nano farad (1 nF: one billionth of a farad) to a battery-like 1000 farads (F).

There is no precise definition for a large capacitance capacitor, but if we consider a large capacitance capacitor to be a capacitor with a capacitance of 47 to 100 microfarads (μF) or more, which is often used in the power supply circuits of electronic equipment, then electric double-layer capacitors, most aluminum electrolytic capacitors, and film capacitors of 1500 V or less can be considered large capacitance capacitors.

3-3. The future of large capacitance capacitors

[Miniaturization]

A large capacitance capacitor can be made by increasing the area of the electrodes and increasing the size of the capacitor. However, the use of large capacitors makes electronic devices larger and heavier, which leads to higher costs. For this reason, the miniaturization of large capacitance capacitors has always been a concern for customers and the most important task for capacitor manufacturers. We have achieved the miniaturization of capacitors by improving electrode materials and processing technology. We are developing and improving materials and processing technologies, such as increasing the surface area of the anode aluminum electrode foil in aluminum electrolytic capacitors and using thinner films as dielectrics in film capacitors.

[Responding to the evolution to power semiconductors]

In recent years, power semiconductors have evolved greatly in power electronics, where large capacitance capacitors are used, and devices have become more efficient and smaller. Capacitors for these applications are required not only to have a small size and large capacitance but also to have improved heat resistance and longer life. In addition to the technologies we have cultivated in miniaturization, we are pursuing breakthroughs in large capacitance capacitors by developing electrolyte solution and film materials and improving the capacitors' structure.

Conclusion

Capacitors (C), along with resistors (R) and coils (L), are the three most essential passive components in electronic circuits. In electronic circuits, attention is focused on semiconductors, but without passive components, semiconductors would not work. In particular, capacitors are indispensable partners for semiconductors that operate on direct current.

This time, we have explained the basics of capacitors and their capacitance. We hope you have become familiar with capacitors.
As mentioned earlier, large capacitance capacitors include electric double-layer capacitors, aluminum electrolytic capacitors, and film capacitors, and we have a full lineup of all of these. However, the performance, size, and price of each large capacitance capacitor have advantages and disadvantages. For this reason, we offer solutions for your applications. Next time, we will explain the applications and reliability of capacitors. We hope you find this column useful.

[Our product information link]
▶ Aluminum electrolytic capacitors
▶ Film capacitors

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Issuer：AIC Tech Inc. Administration Department
1065, Kugeta, Moka-shi, Tochigi 321-4521, Japan
TEL：+81-285-74-1231
Contact Us：https://aictech-inc.com/en/contact/