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ИОНИСТОР КАК АЛЬТЕРНАТИВА АККУМУЛЯТОРУ

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Аннотация

В данной статье рассматриваются такие электротехнические устройства как ионисторы. Анализируются их полложительыне и отрицательные стороны, проводится сравнение с аккумуляторами.

Ключевые слова: ионистор, аккумулятор, ёмкость, напряжение, электролит.

IONISTOR AS AN ALTERNATIVE TO THE BATTERY

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ABSTRACT

Such electrical devices as ionistors are considered in the article. Their positive and negative sides are analyzed, the comparison with batteries is made.

Keywords: ionistor, battery, capacity, voltage, electrolyte.

Batteries are widely used in modern society. A battery is an energy storage device for the purpose of its further use. The principle of operation of the battery is based on the formation of a potential difference between two electrodes immersed in the electrolyte. When the load is connected to the battery terminals, the electrolyte and the active elements of the electrodes react. There is a process of moving electrons, which, in fact, is an electric current. And batteries have gained their wide distribution due to the ability to restore and reversibility of chemical reactions. So, in order to charge the battery, an electric current is passed through it in the direction opposite to the direction of the discharge current. To evaluate the use of a battery in a particular field of activity, each battery, as an electrical device, can be characterized by the following parameters: electrochemical system, voltage, electrical capacity, internal resistance, self-discharge current and service life. And its condition is assessed by the totality of the values of its three main characteristics: real capacity, internal resistance and self-discharge current.

At the moment, there is a large number of varieties of batteries. In particular, these are lead-acid, nickel-cadmium, lithium-ion batteries. At the same time, the latter are the most promising and modern. Compared to other types of batteries, lithium-ion batteries have relatively high capacity and low self-discharge current. But they also have a number of serious drawbacks: high sensitivity to low ambient temperatures, chemical degradation, instability during overcharging.

Temperature sensitivity. The optimal temperature range for the operation of a lithium-ion battery is from 5 to 45 °C [1]. When operating this type of battery at low temperatures, below the optimal range, there is an initial voltage drawdown (Fig. 1) [2].

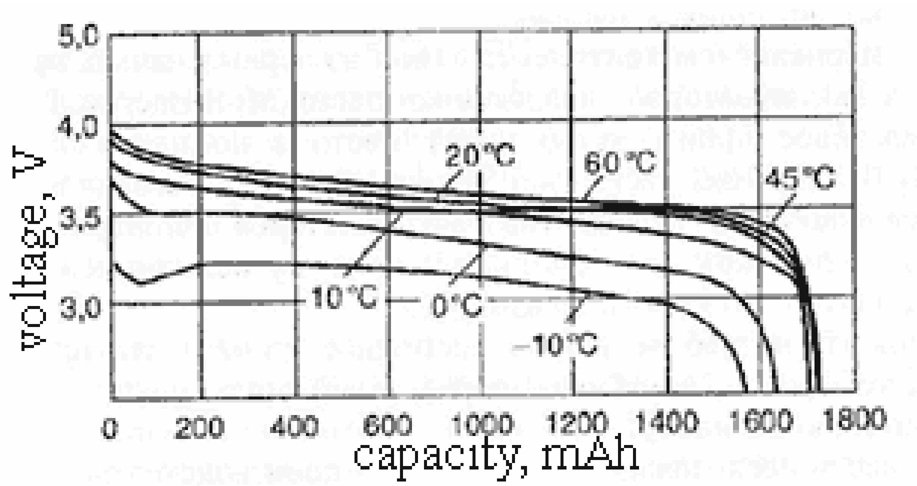

Figure 1. Discharge characteristics of a Li-ion battery at different temperatures. [Electronic resource]. https://i5.imageban.ru/thumbs/2019.03.21/25778368857a88bbb9f3ec1689ddfe92.gif

Chemical degradation. Chemical degradation of the battery is a natural process and consists in reducing the amount of charge that the battery is able to store and give out. The SOH (State Of Health, %) indicator is used to assess the degree of battery performance. This indicator is measured in % and indicates the remaining capacity of the battery from the original SOH 100%. It does not have a single calculation formula and a threshold value, after passing which the battery will be considered non-working – everything is individual and depends on the specific battery and the field of application. Chemical degradation of the battery is a nonlinear process. At first, there is a relatively sharp drop, which then gradually slows down. At the end of the battery life, there is another noticeable decrease in capacity (Fig. 2) [3].

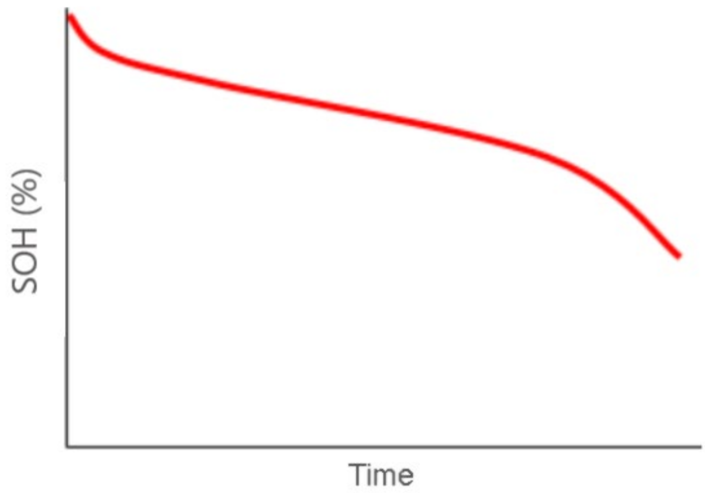

Figure 2. The usual degradation curve. [Electronic resource]. https://static.insales-cdn.com/files/1/3897/13176633/original/2_34bcb7fcd0581d170b70214d86a88902.png

For a lithium-ion battery, chemical degradation can be 1 – 20% per year, i.e., over the year of operation, the loss of battery capacity from the initial value can range from 1% to 20% [4].

Instability when the battery is overcharged. Incorrect charging of this type of battery can provoke a dangerous situation. With a significant recharge of the battery on the negative electrode, it becomes possible to precipitate lithium metal (in the form of finely fragmented mossy sediment), which has a high reactivity to the electrolyte, and active oxygen release begins at the cathode. There is a threat of thermal acceleration, pressure increase, depressurization and ignition [2].

An ionistor is devoid of all these disadvantages. An ionistor is an electrical device made of two electrodes and an electrolyte that is located between them. As a rule, porous materials are used for the manufacture of electrodes in order to increase the surface area of the so-called "plates" with the same occupied volume. Activated carbon or foamed metals are often used for this purpose. Metals are chosen according to the type of electrolyte. There is a separator between the electrodes, which, like the first ones, is in the electrolyte. The only purpose of the separator is to protect the electrodes from short circuit. The electrolyte in ionistors is solid and crystalline and is made on the basis of solutions of alkalis and acids. The main difference between an ionistor and a non-standard capacitor is the absence of a dielectric layer in the first one, because it implements a physical mechanism for the formation of a binary electric layer. Under these conditions, the behavior of this layer is absolutely similar to the behavior of a charged dielectric. On the surface of electrodes made of a porous material, as mentioned earlier, activated carbon or foamed metal, a charge-discharge process occurs. An ion layer forms on the surface of these electrodes. Since there is a potential difference between the electrodes, anions and cations move to the electrode of the corresponding charge and accumulate on its surface. This is the reason for the appearance of a double electric layer with an electrode charge.

It is because of the presence of this effect that the ionistor got its second name – "electric two-layer capacitor".

Currently, only two types of electrolytes are most commonly used – insoluble in water, organic and water-soluble aqueous electrolyte. With the help of an organic electrolyte, an ionistor element can be powered with a voltage of up to 3 V. For the input electrolyte, the possible voltage is approximately two times lower, that is, about 1.5 V. When using a water-soluble aqueous electrolyte, the double electron layer works in the same way as the insulating one, that is, it takes over its functions. This happens exactly until the electrolyte dissolves. When a certain voltage level is reached, current will flow in any case. This voltage is commonly referred to as the electrochemical decomposition voltage of the electrolyte, but the term decomposition voltage is also widely used to refer to this phenomenon. Thus, with an increase in voltage, there will be an acceleration in the process of decomposition of the electrolyte, and consequently, a greater current. When the current goes beyond certain limits, the ionistor may permanently fail. Thus, the applied voltage during charging of the ionistor must be limited by the decomposition voltage. That is why ionistors are usually connected in series.

As mentioned above, a charge of the appropriate type is heated on the surface of each electrode, that is, positive and negative, as a result of which a double electron layer is formed, the charge of which corresponds to the charge of the electrode. With an increase in the potential difference between the electrodes, this area will increase, exactly as with an increase in the accumulated load. The double electron layer has an extremely small thickness, which is approximately 5 – 10 Nm. As an example, it is proposed to consider Panasonic ionistors, where activated carbon acts as the electrode material, which is presented in the form of a fine fraction. The electrodes are manufactured using a special powder technology. The electrolyte that firm uses for the manufacture of ionistors is organic. The electrolyte enters the cavities between the particles of porous activated carbon and thus "impregnates" the electrodes. As a result of this phenomenon, the total capacitance of the capacitor becomes equal to the sum of a huge number of small capacitors, which are particles of activated carbon, which acts as an electrode [5].

To simplify the calculations of circuits using ionistors, equivalent circuits with a conditional capacitor are used. This method is possible because a double electron layer forms on the surface of activated carbon, which is in direct contact with the electrolyte. The capacitance of each elementary capacitor, that is, the one formed by the coal particle and the electrolyte, will be equal to the capacitance of the double electron layer. Other parameters, such as the charging resistance and the resistance of uncompensated ions, will depend on the parameters of the direct ionistor, such as the distance between the "live" electrodes, the speed of movement of ions, contact resistances between the particles of the material from which the electrode is made, and other parameters.

One of the main advantages of an ionistor compared to a battery is its durability. It depends on the operating conditions. So, at an ambient temperature of about 70 °C and the voltage under which the ionistor operates is equal to the nominal, its service life will be about 500 hours, which at first glance does not seem so much. But when the operating voltage is reduced to 0.8 of the nominal, the ionistor's performance increases 10 times – that is, up to 5000 hours, which is already significant, especially in comparison with a lithium-ion battery. With a further decrease in temperature to 40 °C and a simultaneous decrease in the operating voltage to 0.6 of the nominal, the ionistor is able to correctly perform its functions for more than 40,000 hours. This suggests that the use of ionistors is most justified and their advantage is most clearly manifested at low temperatures. Unlike batteries, in particular lithium-ion, ionistors can operate in a much wider temperature range – from –20 to +70 °C. RL is the resistance load (kOhm, MOhm). (Fig. 3) [6].

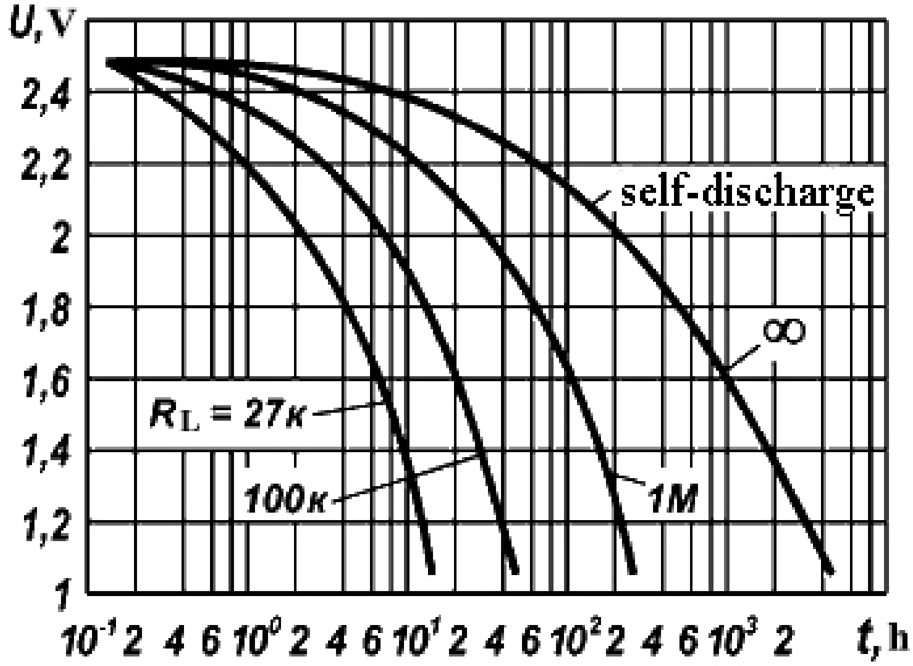

Figure 3. Typical discharge characteristics of ionistors. [Electronic resource]. http://vicgain.sdot.ru/ionistor/ionist.files/ionist2.gif

The operating time of the monitor on a single charge is determined primarily by the operating conditions of the element, the main of which are the voltage under which it operates and the ambient temperature. This parameter characterizes the time during which the ionistor can act as a backup power source, between charge-discharge cycles and is designated tback-up. Let's take for a more precise consideration a Panasonic ionistor of type F, EECF5R5H105 with a rated voltage of 5.5 V and a capacity of 1 farad. Full charge at a constant voltage is of 5.0 V, discharge current is of 10 µA. The ambient temperature at discharge is assumed to be equal to 40 °C. The voltage to which the element will be discharged will be 2 V.

The tback-up parameter can be calculated as follows:

$$t_{back-up} = \frac{CV}{i} = C \times \frac{V_0 - ixR - V_1}{I + i_L},$$

where C is the capacitance of the ionistor (F), i is the current during the tback-up (A), iL is the leakage current (A), R is the internal resistance of the ionistor (Ohms at 1 kHz), V1 is the voltage to which the ionistor will discharge (V), V0 is the applied voltage (V).

Then C = 0.8 F (1.0 F – 20%), R = 50 Ohms, V0 = 5 V, V1 = 2 V, i = 10 µA. Therefore: tback-up = 0,8×(5-0,0005-2)/(10+2×10-6) = 55 hours. This calculation shows that the time that the ionistor will work under these conditions as a backup power source is about 55 hours, which is seriously less in comparison with a lithium-ion battery.

The range of ionistor capacities occupies an intermediate position between the capacities of an aluminum electrolytic capacitor and batteries and accumulators. (Fig. 4) [7].

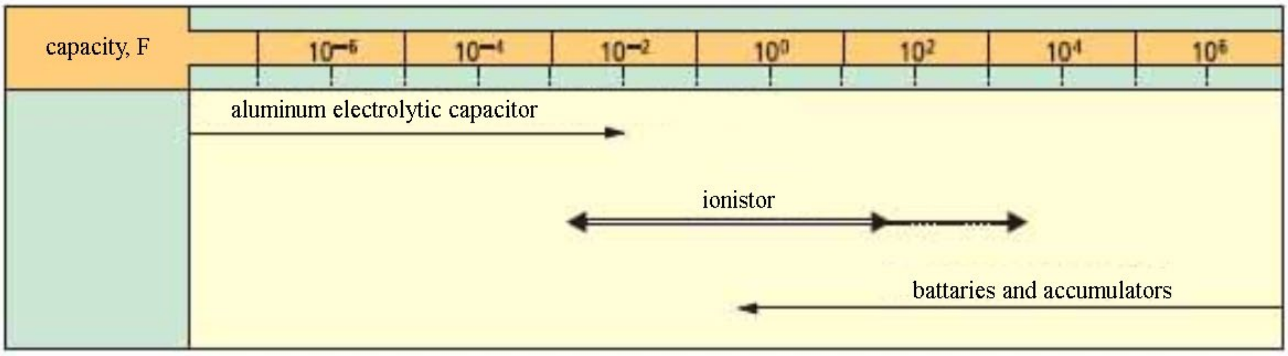

Figure 4. Capacity range of ionistor, aluminum electrolytic capacitor, batteries and accumulators. [Electronic resource]. https://imgur.com/a/4wcExi5

Despite all the advantages of ionistors, they have several serious drawbacks. One of them is relatively low operating voltages: for standard models from 2.3 V to 7 V. To obtain higher voltages, a series connection of ionistors is required, which entails serious economic costs.

Thus, at this stage of the development of ionistors, they cannot fully replace batteries. Their use is economically justified only as a short-term power source, due to the high degree of self-discharge and low specific capacity, compared with lithium-ion batteries. Now the specific capacity of supercapacitors is increasing, and the charge time, on the contrary, is decreasing. When a certain limit is reached, it will be possible to talk about the complete replacement of batteries with supercapacitors in some areas, which, in general, is already happening. At the moment, the ionistor is mainly used as a backup or autonomous power supply.

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