Technical Note

How to use Electric Double Layer Capacitors

INDEX

※The specifications do not guarantee performance.

Nippon Chemi-Con Corporation

How to Use Electric Double Layer Capacitors

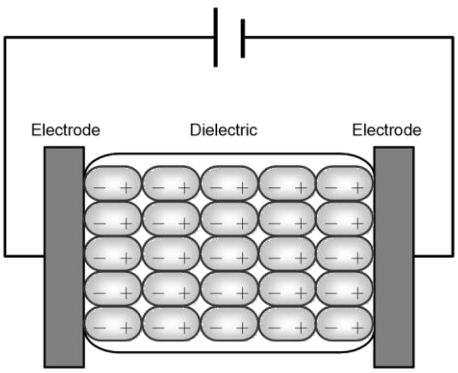
1. Overview of Electric Double Layer Capacitors

1-1 Basic Mechanism

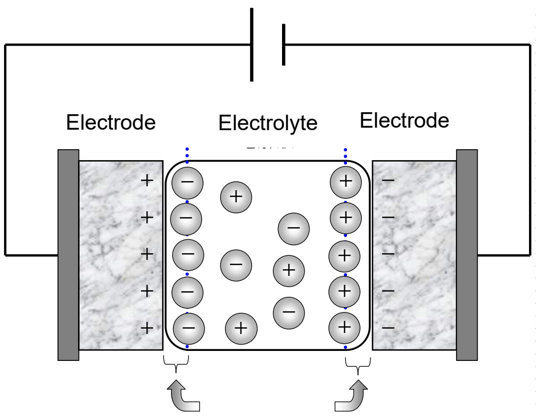
Conventional capacitors have a dielectric sandwiched between two electrodes. When a voltage is applied, dipoles are oriented, and thus electric charge is stored. Electric double layer capacitors have electric charges oriented at the boundary of electrolyte and electrodes in what is called the “electric double layer” (see Fig-1).

1-2 Structure

Electric double layer capacitors are constructed of ① the electrode assembly (separator between electrode, which consist of aluminum foil and activated carbon, in a rolled configuration then impregnated with electrolyte), ② aluminum tabs (connected to each electrode), ③sealing plate and aluminum case (to contain them) (see Fig-2). Nippon Chemi-Con produces cylindrical capacitors. The rolled structure of the cylindrical type is the same as that of our aluminum electrolytic capacitors. This structure has high mass productivity because construction material or production technology of aluminum capacitors can be applied.

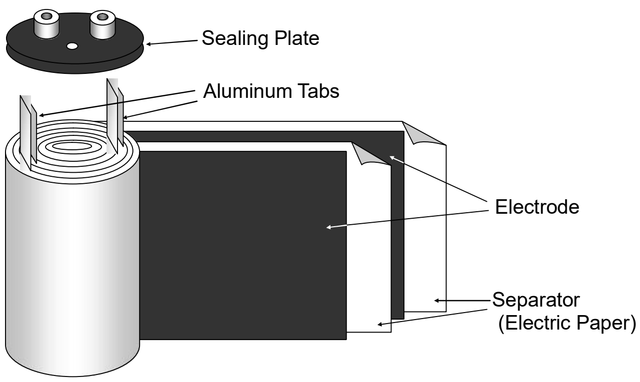


(Conventional capacitors)



Electric Double Layer
(Electric Double Layer Capacitors)

Fig-1 Mechanism



Basic Element Structure (cylindrical)

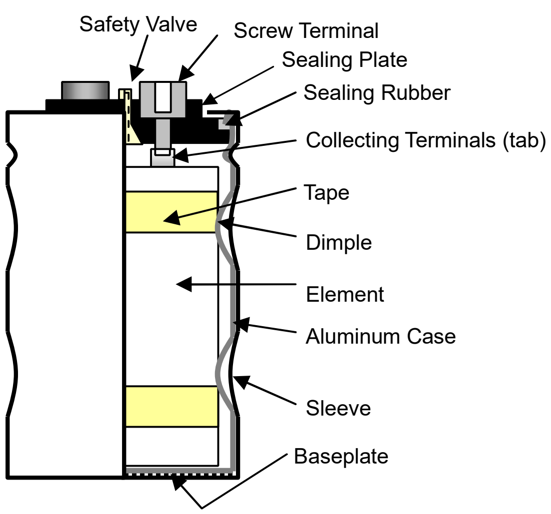


Fig-2 Structure

1-3 Characteristics of Constituent Material

① Electrode

[Activated Carbon]

Activated carbon, which has large specific surface area of about 2000m^2/g, is used for the electrode. Natural plant, pitch, and resin are some of the raw materials for the activated carbon. After they are carbonized, they are activated, a process which causes holes to be opened by steam or alkali to greatly increase the specific surface area. The shape of the holes and the specific surface area change depending on the raw material and the method of activation. This affects electrical performance including capacitance and internal resistance, as well as life performances and reliability.

[Current Collector]

This is the electrical path to conduct charge from the activated electrode to the capacitor terminals. Nippon Chemi-Con uses aluminum foil. Unlike aluminum electrolytic capacitors, this aluminum foil does not contribute to the capacitance.

② Electrolyte

Electrolyte is usually a conductive liquid, which affects performance such as the internal resistance and operating voltage. There are aqueous-solvent type and organic solvent type electrolytes for electric double layer capacitors. Nippon Chemi-Con uses an organic solvent system electrolyte, which has an advantage of higher operating voltage. Acetonitrile and propylene carbonate are two of the most commonly used solvents; Nippon Chemi-Con uses propylene carbonate, which is safer in terms of flammability and toxicity.

Table-1 Electrolyte Solvent Comparison

Solvent	boiling point	flashing point
Propylene carbonate	242℃	130℃
Acetonitrile	81.6℃	5.6℃

③ Separator

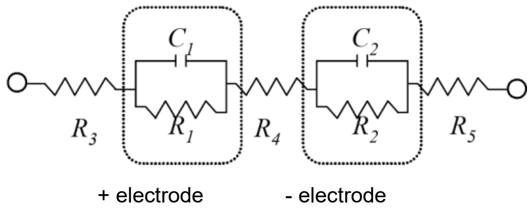
The separator is used to prevent short circuit caused by mechanical contact between the anode and cathode, and also to keep electrolyte evenly dispersed. Nippon Chemi-Con uses a type of paper separator.

④ Case/ Sealing Material

Nippon Chemi-Con uses an aluminum case with sealing rubber, which forms a high reliability seal against air and liquid.

1-4 Equivalent Circuit

Figure-3 is an equivalent circuit model that reasonably describes electric double layer capacitors. Total (cell) capacitance is a result of the capacitance of the two electrodes C1 and C2 connected in series.



C_1、C_2 : capacitance of carbon electrodes

R_1、R_2 : dielectric resistance of the carbon electrodes

R_3、R_5 : current collector resistance

R_4 : resistance of separator & electrolyte

Cell Capacitance: $C = \dfrac{C_1 \times C_2}{C_1 + C_2}$

Fig-3 Equivalent circuit (1)

The properties of this type of capacitor have a time or frequency dependence. The capacitance or resistance measured in 1 ms will have different values than capacitance and resistance measured over a period of seconds. The capacitor cannot be described by a single RC time constant. An equivalent circuit model that can describe this behavior is shown in Figure-4.

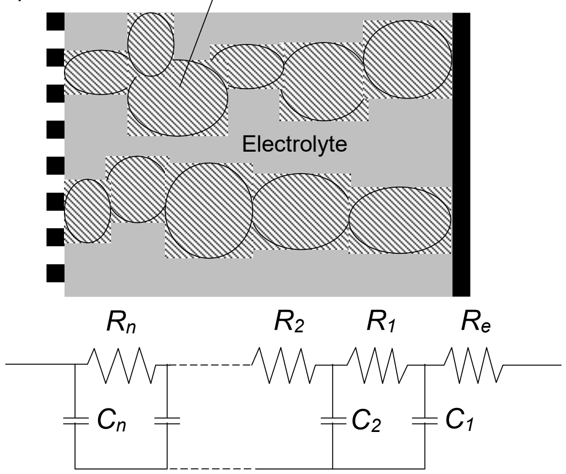


Fig-4 Equivalent circuit (2)

This behavior is due to the porous nature of the carbon electrodes and the distributed charge storage, each electrode consists of fine grains of activated carbon, and each grain acts as a capacitor with its own capacitance and internal resistance. Therefore, when electric double layer capacitors are charged, the capacitance with less resistance is charged first, and the one with high resistance will charge later. If charging is stopped immediately after reaching the charging voltage, the voltage at the terminals will decrease because of a phenomenon called self-charging, in which the capacitance with high resistance is charged from that with low resistance. To achieve a full voltage charge, continued lower current charging at constant voltage is needed after reaching the charging voltage.

2. Basic Performance

2-1 Capacitance

Capacitance is the ability of electric double layer capacitors to store electricity, and its unit of measurement is farad (F). The larger the area of the electrode, the greater the charge storage and capacitance. The electric permittivity of electrolyte also contributes significantly to the performance. The capacitance, C, is shown as the formula below.

$$C = \int \varepsilon / (4\pi \ \delta) \cdot dS \qquad \cdot \cdot (1)$$

or C = Q/V

ε : dielectric constant of electrolyte

δ : distance from electrode surface to ion center

S : surface area of electrode interfacial surface

2-2 Resistance

As described in Section 1.4 (Equivalent circuit) the resistance of electric double layer capacitors changes with frequency. Manufacturers often report values for Direct Current Resistance or Internal Resistance (DC Resistance or DCIR) as well as for the equivalent series resistance (ESR) at 1 kHz. In general, DCIR> ESR at 1 kHz and both have units of W. The DCIR consists of the resistance of material (electrode, electrolyte, etc.) and internal connecting resistance. The larger the area of the electrode, the lower the DCIR becomes. The internal resistance of electric double layer capacitors is normally measured through direct current. As previously described the cell resistance is due to resistances of the electrode, electrolyte, separator and internal connections in the cell.

2-3 Leakage Current (LC)

When current is applied to electric double layer capacitors, the voltage increases until the capacitor is charged. When the capacitor is then held at this voltage, a small current keeps flowing. This is called leakage current (LC) and has units of ampere (A), milliampere (mA), or microampere (mA). As shown in Fig-5, this leakage current decreases as time passes, and eventually reaches a stable value. Initially the leakage current is due to continued charging of individual carbon grains and in the deeper pores as described in “1-4 Equivalent Circuit”. At longer times the leakage current may be due to reactions of trace impurities in the cell. This property depends on the storage conditions as well as the applied voltage and temperature and a fixed, leakage current value cannot be specified. As a standard, it is usually measured 1 to 24 hours after applying voltage.

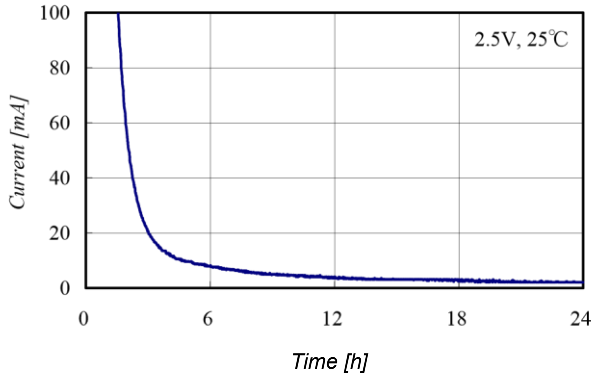


Fig-5 Leakage current as a function of time for an applied voltage

2-4 Voltage Loss at Open Circuit

Once electric double layer capacitors are charged to a specified voltage and then kept at open circuit, the voltage on the terminals gradually decreases. This is also termed the open circuit voltage decay or self-discharge rate. This performance is affected by charging time and charging voltage, and values are generally low at short charging time or high charging voltage

2-5 Discharge Characteristics

Since electric double layer capacitors store electricity physically, it is possible to discharge the capacitor all the way to 0V, unlike batteries. Discharging voltage changes linearly as shown in Fig-6, and it is easy to estimate remaining amount.

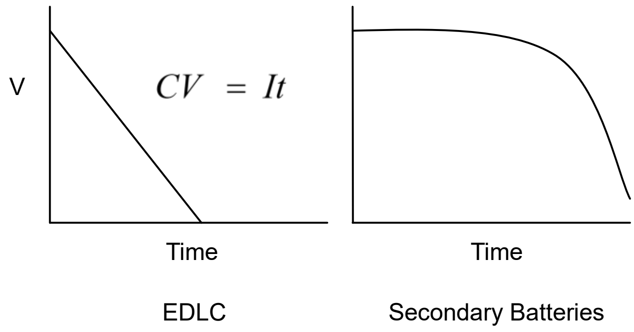


Fig-6 Discharging curve at constant current

At constant power, discharging voltage will not be linear as compared to constant current, but it is also possible to discharge to 0V (Fig-7).

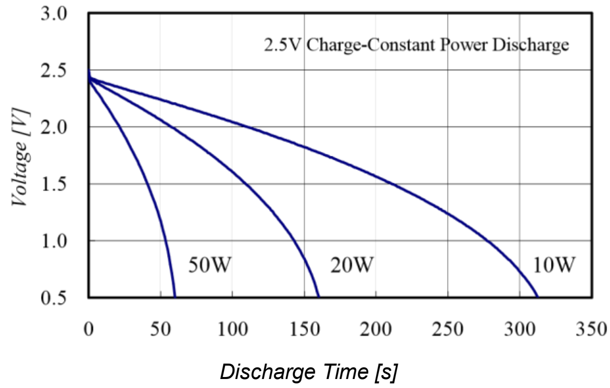


Fig-7 Discharging curve at constant power

There is a capacitance change as a function of discharging current as shown in Fig-8.

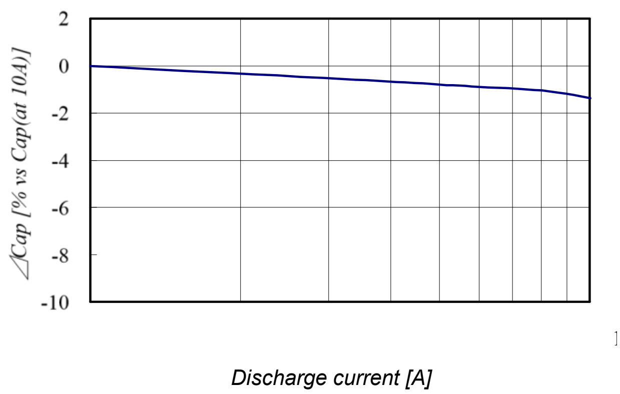


Fig-8 Capacitance change as a function of discharging current

2-6 Frequency Performance

Electric double layer capacitors are not suitable to be used for alternative current because its frequency response is poor at higher frequencies, different from electrolytic capacitors; they do not perform well at frequencies over 10Hz. They are more suitable for direct current applications.

2-7 Temperature Dependence Performance

Electric double layer capacitors experience performance changes as a function of temperature. This should be taken into account when using them.

① Capacitance

Generally, capacitance decreases under low temperature (see Fig-9).

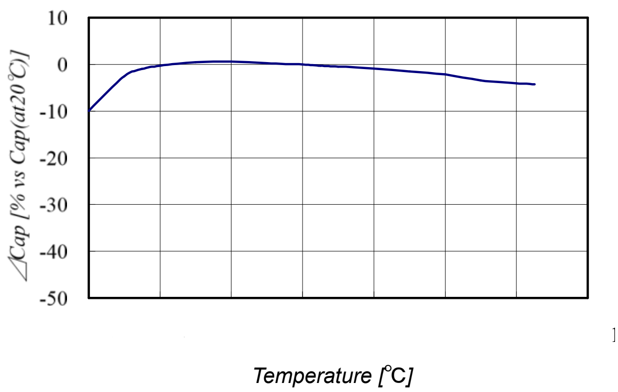


Fig-9 Temperature Performance (Capacitance)

② Internal Resistance

Generally, internal resistance increases under low temperature (see Fig-10).

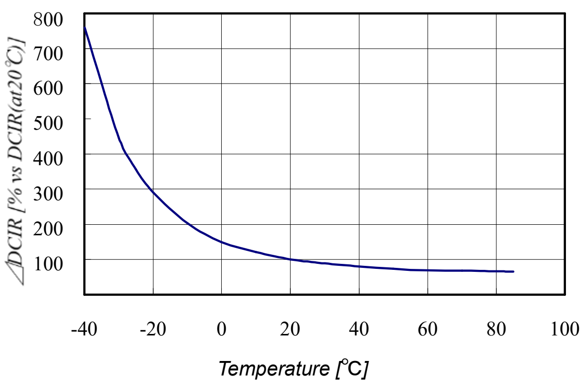


Fig-10 Temperature Performance (DCIR)

③ Voltage Decay Rate

Generally, voltage decay rate increases at higher temperatures (see Fig-11),

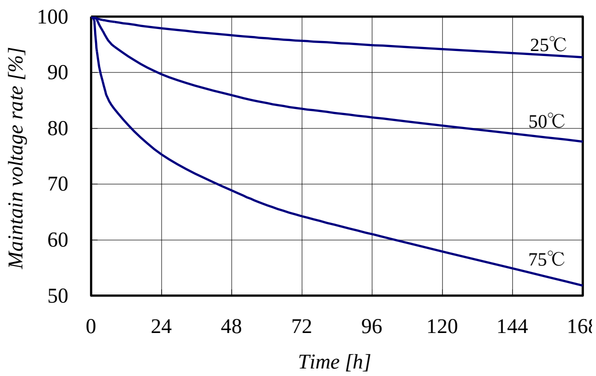


Fig-11 Voltage Decay Performance

3. Life Performance

Electric double layer capacitors are finite life devices. The lifetime is affected by environmental conditions such as temperature, humidity, pressure, or vibration, and the use conditions such as electrical conditions, applied voltage or charge-discharge conditions.

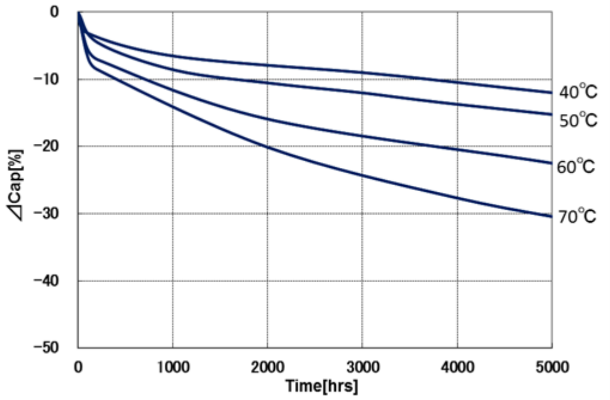
Life assurance of electric double layer capacitors is clearly written on the catalog or on the technical specification sheet (c.f. table-2).

Table-2 Example of DLCAP Life Performance

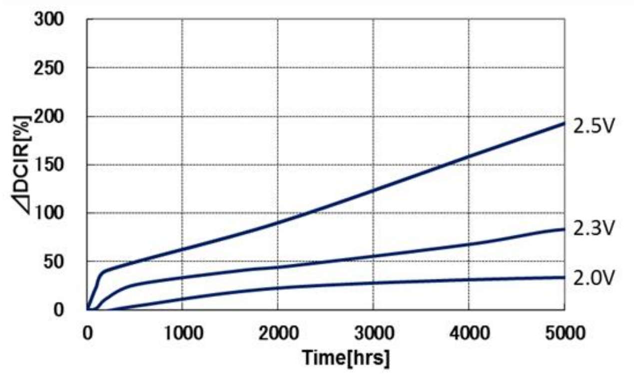
Results after applying constant voltage for 2,000 hours at 70℃, and measured at 20℃.	
Capacitance change	Within ±30% from initial value
Internal Resistance	Under +200% from initial standard value

3-1 Life Performance by Ambient Temperature

The lifetime of electric double layer capacitors is strongly affected by ambient temperature (see Fig-12). Longer lifetime will be expected by decreasing the ambient temperature.

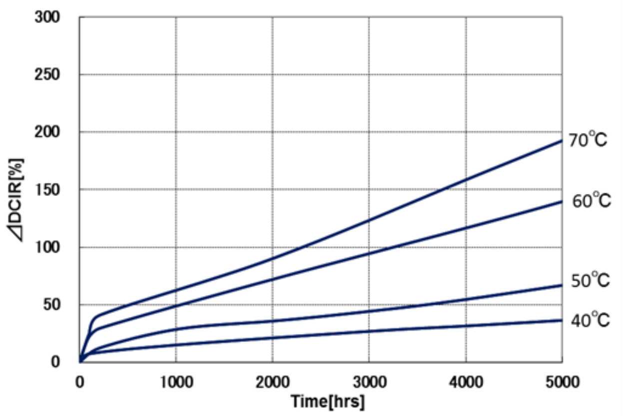


Life performance test (Capacitance)



Life performance test (DCIR)

Fig-13 Life Performance (Voltage Parameter)

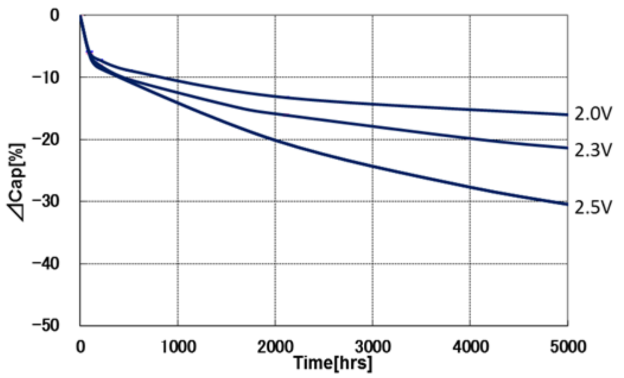


Life performance test (DCIR)

Fig-12 Life Performance test (Temperature Parameter)

3-2 Life Performance by Applied Voltage

The lifetime of electric double layer capacitors is strongly affected by the applied voltage (see Fig-13). Longer lifetime will be expected by decreasing the applied voltage.



Life performance test (Capacitance)

3-3 Self-Heating by Charging and Discharging

As a result of electric double layer capacitors having internal resistance, internal heating occurs due to charging and discharging current. This affects the lifetime of the capacitor. Degradation is accelerated when the capacitor is charged or discharged continuously at large currents because it involves a rise in internal temperature. As self-heating changes greatly depending on the charge-discharge pattern, rise in internal temperature due to this heating needs to be considered. We recommend low-resistance devices for the applications which have frequent charge-discharge patterns. When frequent charge-discharge is needed, design considering voltage lowering because of voltage drop, or IR drop, occurs at the beginning of charging and discharging due to internal resistance.

3-4 Life Estimation

General factors which affect the life of electric double layer capacitors are temperature and continuous applied voltage. There is linear relationship between the change of electrical performance and the root of experiment time root t (see Fig-14), and the formula (2) is introduced.

$$\Delta C = k\sqrt{t} + a \qquad \cdots\cdots\cdots (2)$$

k is life acceleration factor, and it changes depending on the condition of temperature and voltage. It is possible to estimate the life by calculating *k* under the actual condition. As k and a differ depending on temperature, voltage and series, contact our company for details. The upper limit of life estimation is about 10 to 15 years in consideration of aging degradation of sealing rubber. If you use electric double layer capacitors exceeding the upper limit time, it may occur rapid deterioration of the characteristics and leak the electrolyte.

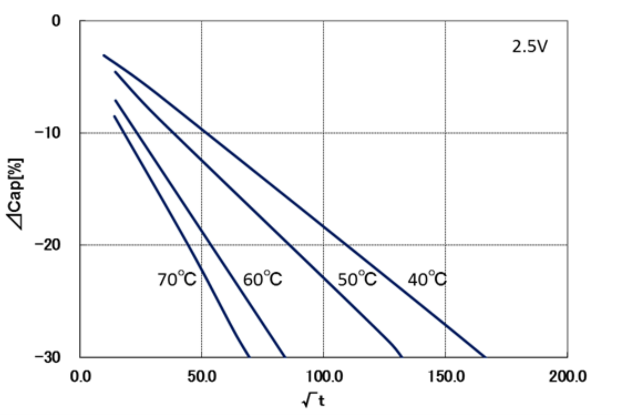


Fig-14 √t plot on life performance test

Please use our products based on the information contained in the catalog and product specifications.

[Supplement]

1. Measuring Method of Electrical Characteristics

1-1 Calculating Formula of Capacitance and Internal Resistance

Capacitance is calculated from voltage change and time at constant current discharge. The unit is farad (F).

Capacitance $$C = \frac{I_d \times T_m}{V_1 - V_2} \quad \cdots\cdots\cdots (1)$$

Internal resistance is calculated from the voltage change, 1 second after the voltage is open circuited after achieving the rated voltage, and the charging current. The unit is Ω.

DCIR $$R = \frac{V_c - V_{n1}}{I_c} \quad \cdots\cdots\cdots (2)$$

(*T=1sec*)

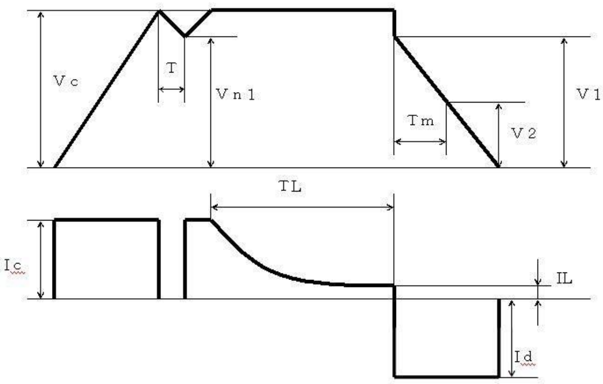


Fig-1 Discharging curve and measurement range

I_c	:	Charging current [A]
I_d	:	Discharging current [A] (*I_c=I_d)
T_m	:	Measuring time [sec]
V_c	:	Charging voltage [V]
V_1	:	First measuring voltage [V] (=V_{n1})
V_2	:	Final measuring voltage [V] ($V_c/_2$)

1-2 Power Density

This is a max power per mass or volume which can be taken from charged capacitors. The unit is W/kg or W/L. Generally, it is calculated from internal resistance and rated voltage.

As the power density increases, it will be more capable of providing higher currents

$$P_{dm} = \frac{1}{4} \times \frac{U_R^{\ 2}}{RM} \quad \cdots\cdots\cdots (3)$$

P_{dm}	:	Max output density [W/kg or W/L]
U_R	:	Rated voltage [V]
R	:	Actual internal resistance [Ω]
M	:	Mass or volume [kg or L]

1-3 Energy Density

This is a max energy per mass or volume which can be taken from charged capacitors. The unit is Wh/kg or Wh/L. As the energy density increases, it will be possible to provide the same power for longer times under the same mass or volume.

$$E_{dm} = \frac{1}{2} \times \frac{C \times U_R^{\ 2}}{M} \times \frac{1}{3600} \quad \cdots\cdots\cdots (4)$$

E_{dm}	:	Energy density [Wh/kg or Wh/L]
U_R	:	Rated voltage [V]
C	:	Actual capacitance [F]
M	:	Mass or volume [kg or L]

2. Modules

When operating voltage is higher than single cell rated voltage, electric double layer capacitors can be connected in series. When larger capacitance or lower resistance is required, they can be connected in parallel. These connected capacitor cells are called modules.

Example of DLCAP module

The specification formula and assembly notice for modules will be explained in this section.

2-1 Calculating Formula for Module Design

Module Capacitance C_{mod} [F]

$$C_{\text{mod}} = C_{\text{cell}} \times \frac{Parallel\ number}{\text{Series number}} \quad \cdots\cdots (5)$$

Module operating voltage V_{mod} [V]

$$V_{mod} = V_{cell} \times Series\ number \quad \cdots\cdots (6)$$

Module internal resistance R_{mod} [Ω]

$$R_{\text{mod}} = R_{\text{cell}} \times \frac{\text{Series number}}{Parallel\ number} \quad \cdots\cdots (7)$$

Module IR drop Δ*V* [V]

$$\Delta V = I_{\text{mod}} \times R_{\text{mod}} \quad \cdots\cdots (8)$$

Module discharging time *t* [sec]

$$t = C_{\text{mod}} \times \frac{(V_{\text{mod}} - \Delta V - V_e)}{I_{\text{mod}}} \quad \cdots\cdots (9)$$

V_{cell} : Cell voltage [V]

C_{cell} : Cell capacitance [F]

R_{cell} : Cell internal resistance [Ω]

I_{mod} : Module discharging current [A]

V_e : Module final discharging voltage [V]

Constant current is the premise for formula (9). The following formula is also used as a rough indication of voltage and time in charging and discharging at constant resistance.

Constant resistance discharging time *t* [sec]

$$t = -CR \ln\left(\frac{V_1}{V_0}\right) \quad \cdots\cdots (10)$$

Constant resistance charging voltage

$$V_1 = V_0 \left(1 - e^{\left(\frac{-t}{CR}\right)}\right) \quad \cdots\cdots (11)$$

Constant resistance discharging voltage

$$V_1 = V_0 \cdot e^{\left(\frac{-t}{CR}\right)} \quad \cdots\cdots (12)$$

t : Discharging, charging time [sec]

C : Capacitance [F]

V_0 : Initial voltage, charging voltage [V]

V_1 : Terminal voltage after t seconds [V]

R : Load at constant resistance[Ω]

Self-discharge or initial voltage drop due to internal resistance should be considered depending on load resistance and current.

The following formula is used to convert energy unit.

Energy of the capacitors *E* [*J*]

$$E = \frac{CV^2}{2}[J] = \frac{1}{3600} \cdot \frac{CV^2}{2}[Wh] \quad \cdots (13)$$

$$1Wh = 3600J = 3600Ws \quad \cdots\cdots (14)$$

$$1J = 0.239cal \quad \cdots\cdots (15)$$

2-2 Precautions in Assembling Modules

- When connecting electric double layer capacitors in series, please insert the voltage balancing circuit in parallel with the capacitors to prevent voltage spread among them. Certain spread can be expected even with the balancing circuit, so please set some margin considering it.

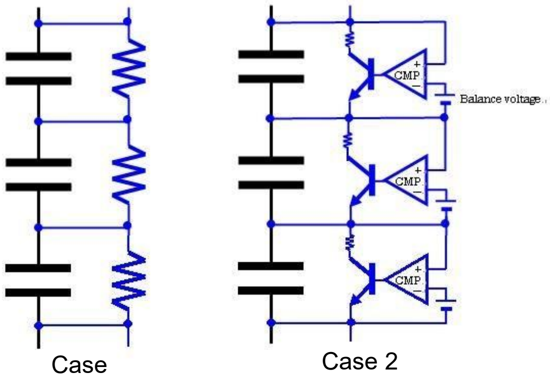


Fig-2 Example of balancing circuit

If no prevention for voltage spread is done, voltage balances break up due to the different specification among capacitors may cause an over voltage on some of the capacitors.

- When connecting the capacitors using a conductive bar or distributing cable, please discharge them in advance for safety. Please consider the conductive resistance of the connecting conductors or tightening torque for the screws in addition to the internal resistance of the capacitors. Please be sure the torque is within the range which is regulated in the technical specification sheet.
- When using several capacitors connected in the device case, please take following measures to prevent overheating as needed.
  ① Bore a hole in the case, or place radiating fins or a fan to provide proper aeration.
  ② Do not place heat generating devices such as power semiconductors or transistors right under or near the capacitors.
  ③ Design to make sure temperature spread among capacitors is eliminated.
- As electric double layer capacitors are capacitors, their discharging voltage decreases. When constant output voltage is required, a circuit system such as converter is needed.
- Please note that when the capacitors are open circuited after discharging to 0V, the voltage gradually increases*. It is also noted that although the voltage of the single capacitor is low (2.5V), when connected in modules their voltage becomes higher. When assembling or disassembling the module, please discharge using a controlled current or a resistive load. It is very dangerous to directly short circuit the terminals of the charged capacitors because of large current flows.

*Because each grain of activated carbon of the capacitor has capacitance and resistance, capacitance with larger resistance will appear later even after voltage becomes 0V apparently.

2-3 Module Calculation Examples

Calculation example of the number of capacitors in series/parallel under the following condition

[Operating Condition]

- Operating voltage range: 48 – 28V
- Charging current: 120A (constant)
- Discharging current: 120A (constant)
- Charging time: 30sec.
- DLCAP: rated voltage2.5V, capacitance1400F, DCIR (typical)2.5mΩ

[Calculation Example]

① Calculate the number of the capacitors in series. Max operating voltage 48V, single capacitor voltage: 2.5V
48/2.5=19.2
=> 20 capacitors in series

② Calculate the voltage change (⊿V) after 30 second discharge at 120A from 48V. two capacitors in parallel:
(total capacitance of the module) = 1400×2/20 =140F
V=120×30/140=25.7V
In this case, the remaining voltage after discharge will be 48V-25.7V=22.3V, and it falls below the minimum operation voltage of 28V.

③ three capacitors in parallel:
(total capacitance of the module) = 1400×3/20=210F
ΔV=120×30/210=17.1V
The remaining voltage after discharge will be 48V-17.1V=30.9V, and it satisfies 28V after discharging.

④ Considering the voltage drop, IR drop, after discharging due to DCIR,
(total DCIR of the module) = 0.0025 ×20/3=0.0167Ω
The discharging current is 120A,
(IR drop right after discharge) = 0.0167× 120=2V.
The remaining voltage considering IR drop will be 30.9V-2V=28.9V, and it satisfies the minimum operating voltage of 28V.
⇒ RESULT: 20 in series, 3 in parallel

(※)one example of the calculation is shown here. Please consider the following for the actual application:

- The degradation degree of electric double layer capacitors differs depending on environmental and electrical conditions. Please design considering the lifetime under the operating condition.
- Please design considering the resistance of the connecting area.
- Please design considering the effect on self-discharge performance by voltage balancing circuit or balance resistance.
- Please design considering the rise in temperature when frequent charge-discharging is expected.

[Precaution Statement]

1. Precautions in use

① Please do not use electric double layer capacitors under the environment, which exceeds the rated performance range.

a) High temperature (over operating temperature)

b) Over voltage (over rated voltage)

c) Application of reverse or alternate voltage

② The outer sleeve and resin plate of the EDLC does not assure electrical insulation.

③ Electric double layer capacitors have finite and regulated life

④ Please do not use or store electric double layer capacitors under the following environment;

a) Environment where the capacitors could be exposed to water, saltwater or oil, or the environment which is filled with gaseous oil or salt.

b) Environment which is filled with toxic gases such as hydrogen sulfide, sulfurous acid, chlorine, ammonia, bromine, or methyl bromide.

c) Environment where the capacitors could be exposed to acidic or alkaline solvent.

d) Environment where the capacitors could be exposed to direct sunlight, ozone, ultraviolet rays or radiation.

⑤ Please note the followings when designing;

a) Please assemble the module with cell terminals upward. Do not mount electric double layer capacitors with terminals facing downward or sideways as the electrolyte inside the capacitors may block pressure release vent and cause it to open, electrolyte to leak, and shorten lifetime.

b) Please keep the sealing plate facing upward whenever handling the capacitors. Facing it downward even for a brief time may shorten lifetime.

c) Please provide enough clearance space over the pressure relief vent.

d) Please do not locate any wire or circuit pattern over the pressure relief vent or between the anode and cathode terminal of the capacitors.

e) Please avoid locating any heat source components near the capacitors.

f) To assure insulation voltage, please provide adequate space among the capacitors' case, cathode terminal, anode terminal, circuit pattern and chassis.

g) Please note that electrical properties of the capacitors may change according to the changes in temperature and frequency of the capacitors.

h) When the temperature among the capacitors in a same system differs largely, it may amplify the slight characteristic difference of each cell and may cause the system to malfunction in the end. Please make sure to design the system with an adequate heat radiation to avoid variation in temperature among the cells.

i) When heat increase is expected due to charging and discharging of the capacitors, please conduct a load test to confirm there is no abnormal heat rise, and the temperature stays within the capacitors' specified temperature range.

j) Please assure appropriate current balance when connecting two or more capacitors in parallel.

k) Please assure appropriate voltage balance when connecting two or more capacitors in series.

l) In case of use outside of specification, such as overvoltage and/or above specified temperature range, the electrolyte fume from inside may expelled through releasing valve. Please take that in consideration at the time of system design.

m) Please establish safety design such as stopping charge /discharge in case of abnormal temperature and voltage. Applying voltage that exceeds rated voltage frequently may cause the devices to smoke or burn Please design the system with fail-safe functions.

n) As the capacitors have internal resistance, the internal heat generated by charge-discharge affects

its life. Please choose the products with low resistance and make sure to avoid overheat of the capacitor.

o) Due to the capacitors' internal resistance, there is a voltage drop (also referred to as "IR drop") at the beginning of charge-discharge. Please consider this voltage drop in your circuit design.

⑥ When a capacitor is fully charged, short-circuiting the output terminals could cause the electric current to flow as high as a few hundred amperes. Please do not install or uninstall a module when it is charged.

⑦ Please do not drop the capacitors. Do not use it once it is dropped.

⑧ Please make sure of the polarity when assembling the capacitors into a module.

⑨ Please follow the specification of the screw tightening torque.

⑩ Please do not deform the capacitors when assembling them into a module.

⑪ Voltage of the capacitor changes in proportion to the stored energy. If stable output voltage is required, circuit system such as converter needs to be added.

⑫ When using the capacitors for industrial application, following periodical check is recommended. Please disconnect power from the device and fully discharge the capacitors before conducting periodical check.

a) Appearance: Significant damage in appearance including deformation, liquid leakage, discolor, dust between the terminals and stain.

b) Electrical characteristics: Characteristics prescribed in the catalog or product specifications.

⑬ Please stop the whole system when the capacitors generate excessive heat or a foul smell.
In case of excessive heat, do not get close to the part in order to avoid injury.

⑭ Please stop the system immediately and ventilate the area sufficiently when the safety vent on the capacitors operates and releases a gas from inside. Never expose your face or your hand as hot gas may expel. If the gas is inhaled or hits eyes, please wash your eyes, gargle, and consult with a doctor immediately. Do not lick the electrolyte of the capacitors. Wash away the electrolyte from the skin with soap and water.

⑮ The capacitors may have been spontaneously recharged with time by a recovery voltage phenomenon. Discharge the capacitors as necessary especially before connecting multiple capacitors in series.

⑯ Please discharge the capacitors before assembling or removing. There is a risk of large current flow and electrical shock when short circuiting the terminal with residual voltage. Note that the capacitors may be self-charged while being left open circuit even after fully discharged.

⑰ Do not wash the capacitors.

⑱ Do not use any adhesive or coating materials containing halogenated solvents.

2. Precautions in transportation

① When exporting electric double layer capacitors, fumigation process may be required for export in some countries. Please note that some types of fumigation process which uses halogenated ions may cause corrosion on the capacitors' material.

② Due to the Export Trade Control Ordinance, the documents obtained to the exporter concerning that export trade, with information that the product is being used for developing mass destruction weapons, the exporter will have to apply and hand in the export permission from the Ministry of Industrial Trade and Industry.

③ During transportation of the capacitors, please make sure to place its terminal upward to avoid electrolyte leakage.

④ Transport operations of the capacitors has been changed in line with the revision of "The Recommendations on the Transport of Dangerous Goods" adopted by the United Nations in December 2010. Please confirm the latest information of the followings as well as laws of each country.
- United Nations (UN) Recommendations on the Transport of Dangerous Goods-Model Regulations.
- International Civil Aviation Organization (ICAO) Technical Instructions for the Safe Transport of Dangerous Goods by Air.
- International Air Transport Association (IATA) Dangerous Goods Regulations.
- International Maritime Organization (IMO) IMDG (International Maritime Dangerous Goods) -code.

3. Precautions in storage

① Please store electric double layer capacitors at temperature between 5℃～35℃ and humidity less than 75%. Please avoid an environment with drastic temperature change which could damage the product.

② If the capacitors have been stored for long periods of time, it may appear to have high leakage current. Voltage treatment is recommended when the capacitors are stored for more than one year.
For voltage treatment, please charge at 5mA/F up to the rated voltage, and then keep applying rated voltage for about 20 hours.

4. Precautions in disposal

Please discharge the electricity to safety voltage before disposal.
Please follow the laws or regulations at the place of disposal.
Please drill or crash the part before incineration.

Please refer to the following report before using electric double layer capacitors.

Japan Electronics and Information Technology Industries Association, JEITA RCR-2370C
"Safety Application Guide for electric double layer capacitors
(Guideline of notabilia for electric double layer capacitors)"
Japan Electronics and Information Technology Industries Association
“Guidelines of the transport of fixed electric double-layer capacitors for use in electric and electronic equipment”

How to Use Electric Double Layer Capacitors
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