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Technical guide

Aluminum Electrolytic Capacitor
Conductive Polymer Hybrid Aluminum Electrolytic Capacitor



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Design and specifications are each subject to change without notice. Ask factory for the current technical specifications before purchase and/or use. Should a safety concern arise regarding this product, please be sure to contact us immediately.

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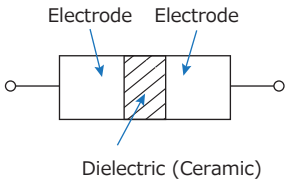
Capacitor is electronic component constructed electronic circuit. There are a variety of capacitors which have various materials and construction. Typical classification of capacitors shows in Fig.1-1. This technical guide summarizes the outline and use technique of aluminum electrolytic capacitor which is increasing in accordance with miniaturization of electronic components.

The type of capacitors can be selected from the circuit characteristics. Generally, you can select it by capacitance and voltage in Table1-1. About what each type have in common, reliability and price will be considered as well as performances such as frequency characteristics and temperature dependence, etc. (shown in Table1-2)

We have many types of capacitors trying to meet various customer's needs. Capacitors (especially aluminum electrolytic capacitors) are sensitive to operating condition.

We would be happy if this technical guide is helpful for better understanding, and if we could consult with you about the technical contents.

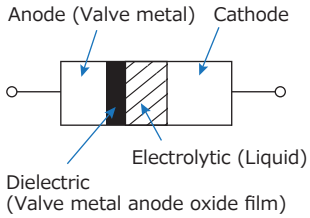
Ceramic capacitors



■ Classification by dielectric
titanium oxide, Titan ate,
Ba, Sr, Ca, Mg, etc.

■ Classification by construction
・Single plate ··· (150 μm to / layer)
・Layer built ··· (1 to 15 μm / layer)
・Semiconductor ··· (0.1 to 20 μm / layer)

Electrolyticc capacitors



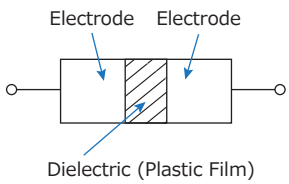
■ Classification by dielectric
Oxide film of aluminum,
Tantalum, Niobium, or Zirco

■ Classification by construction
・Electrolyte ··· Non solid
・Solid electrolyte ··· Solid
(MnO_2 ・ PbO_2 ・ Organic Semiconductor ・ Conductive Polymer)

■ Classification by construction
Discrete, Chip, Block

■ Classification by coating
・Metal case ··· Flexible tightening seal
Resin seal, Hermetic seal
・Resin coating···Dipped, Mold

Plastic film capacitors



Metallic plastic film capacitors are formed with metal deposition of electrode on the surface of plastic film

■ Classification by dielectric
polyethylene terephthalate
(Generally, Mylar, Polyester)
Polypropylene
Polyethylene
Polyphenylenenaphthalate

■ Classification by terminal
connection method
tab connection type,
Foil extrusion type

■ Classification by coating
・Case···Resin case, Metal case
・Resin coating···Dipped, Molded
・Tape wrapping end seal

■ Classification by use
for direct current, Alternating current,
Electric equipments or low voltage phase advance

Fig.1-1 Typical classification of fixed capacitors

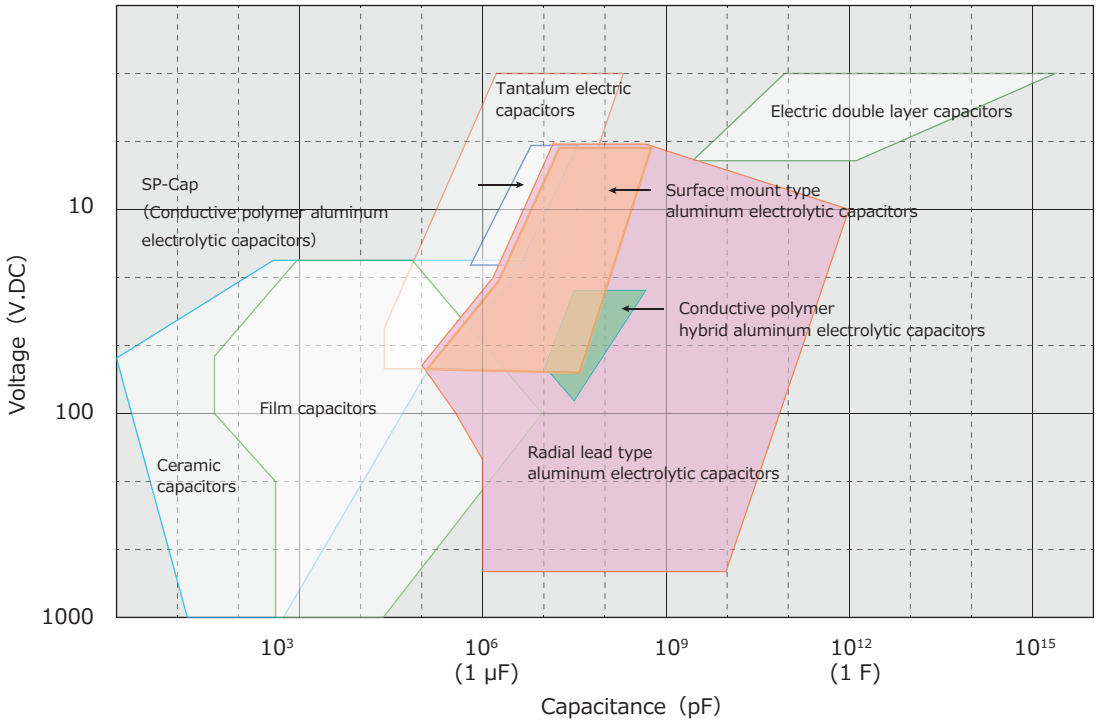


Table 1-1 Capacitance / voltage range of various capacitors

Note) It shows general, there are other products with capacitance and voltage.

Representative fixed capacitors		Dielectric constant εs	Thickness of dielectric (μm)	Rated voltage (V.DC)	Product pressure capacitance stability			Characteristics
					Temperature dependency (%) (-40℃/+85℃)	Bias dependency	Frequency dependency	
Electrolytic capacitors	Aluminum electrolytic capacitors	8 to 10	0.03 to 0.7	to 450	-20 to -10 +8 to +15	Low	High	Compact and large capacitance, Inexpensive per capacitance. Temperature /frequency dependency is high.
	Conductive polymer hybrid aluminum electrolytic capacitors	8 to 10	0.03 to 0.7	to 80	-15 to -10 +5 to +10	Low	Low	Low ESR, High voltage, High reliability
	Tantalum electrolytic capacitors (Solid)	23 to 27	0.04 to 0.5	to 50	-4 to -2 +4 to +7	Medium	Medium	Compact and relatively large capacitance with high reliability. Temperature dependency is low. Relatively expensive.
Ceramic capacitors	Ceramic capacitors of high dielectric series	11000 to 18500 (40000)	Single plate 150 to Layer built 0.5 to 15 Semiconductor 0.1 to 20	Single plate 0.5K to 40K Layer built 2.5 to 3.15K Semiconductor 16 to 50	-60 to -40 -80 to -60	High	Low	Superior in frequency feature but bias/temperature dependency is high. Inexpensive with high reliability.
	Ceramic capacitors for temperature compensation	to 160			Temperature dependency at option	Low	Low	Both frequency feature and bias dependency are good. Capacitance is small.
Plastic film capacitors	Polyethylene terephthalate film capacitors	3.0 to 3.3	1.5 to 25	35 to 500	-5 to -3 +2.5 to -4	Low	Low	Best workability among films, despite of small size, large capacitance is obtainable, but inferior in characteristics. Most popular among film capacitors.
	Polypropylene film capacitors	2.1 to 2.2	4 to 22	50 to 600	+1.5 to +2.5 -1.5 to -2.5	Low	Low	Suitable for high frequency large current with-superior dielectric loss tangent and voltage resistance. Relatively inferior in film productivity and hear resistance.
	Polyphenylene sulfide film capacitors	2.8 to 3.4	2 to 30	25 to 500	Around+1 /Around-1	Low	Low	Superior in both heat resistance and feature. Coefficient of water absorption and temperature dependency are also low with gradual good Stability.

※A temperature dependence is expressed with the rate of change to 20℃

Table 1-2 Characteristics of various capacitors

2-1. Principle of capacitors

Capacitor consists of two metal plates with good transmittance in parallel, and dielectric (insulator) which does not transmit electricity between them. (Fig.2-1)
The name of capacitors is decided by the kinds of electrode material and dielectric.

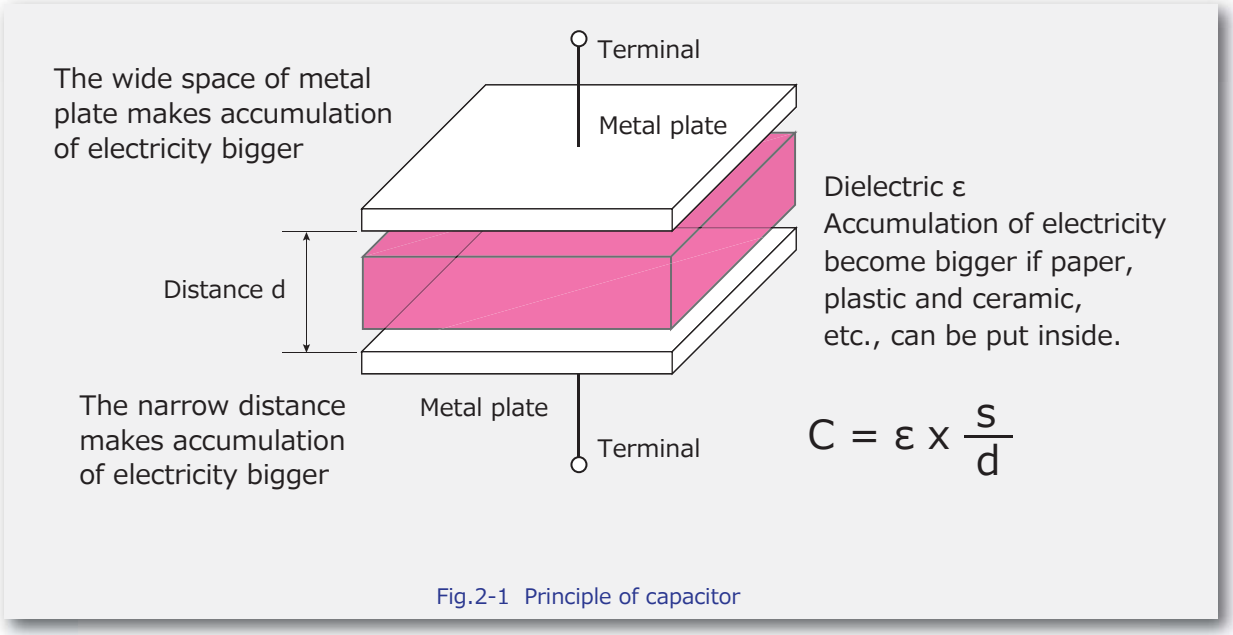


Fig.2-1 Principle of capacitor

Electrolytic capacitors are distinguished from other capacitors by the uniqueness of their electrode materials and dielectric. Fig.2-2 shows the principle diagram of electrolytic capacitor.

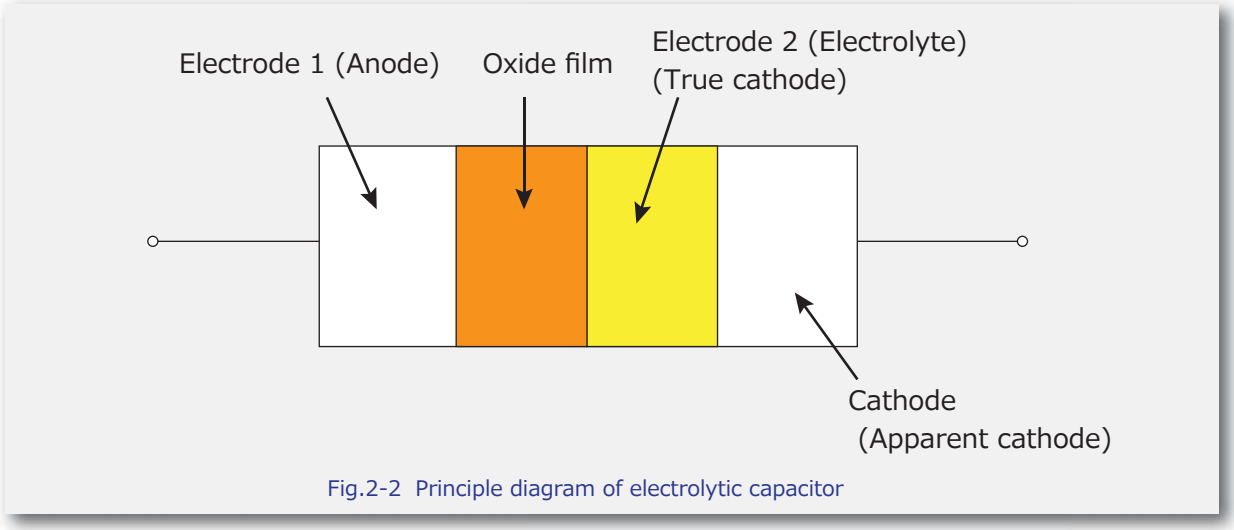


Fig.2-2 Principle diagram of electrolytic capacitor

Electrolytic capacitor names after using oxide film formed electrochemically on electrode surface as dielectric.
Aluminum (Al), tantalum (Ta), niobium (Nb), titanium (Ti), zirconium (Zr), hafnium (Hf) and other metals can form a fine, highly isolative oxide currently, the only three metals in practical application are aluminum, tantalum and niobium.
Oxide film formed on the surface of electrode 1 becomes an electrical insulator and functions as a dielectric only when the electrode on which formed becomes anode.
Therefore, electrolytic capacitors are, in principle, capacitors with polarity.

☆Point : Electrolytic capacitors have polarity.

2-2. Types of electrolytic capacitors

The types of capacitors in practical application are those shown in Fig.2-3.

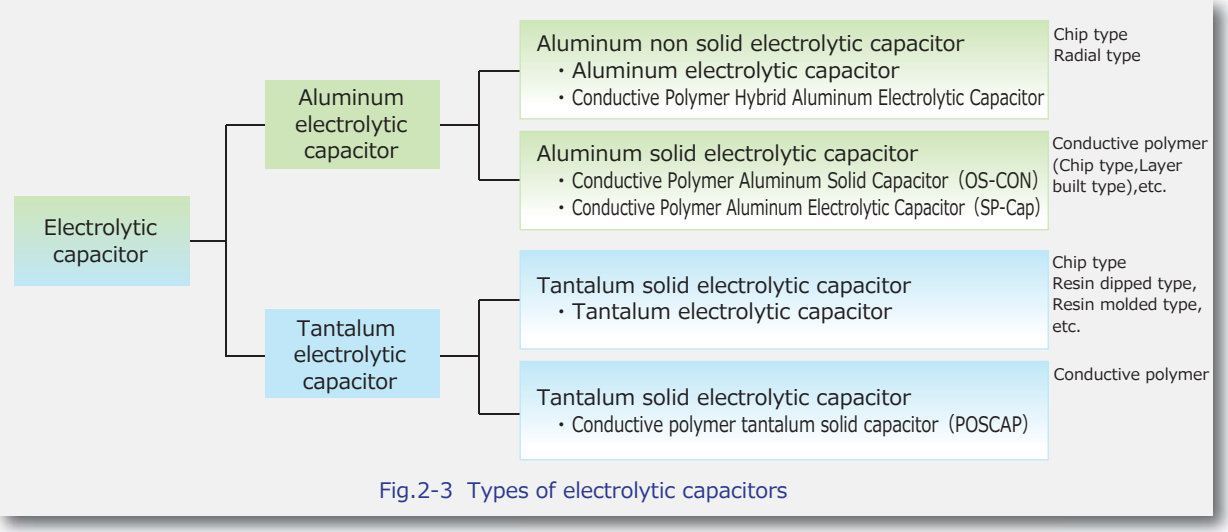


Fig.2-3 Types of electrolytic capacitors

Since the applications of tantalum non solid electrolytic capacitors are limited and extremely specialized and they are produced in only small numbers, aluminum electrolytic capacitors (non solid and solid) and tantalum solid electrolytic capacitors (tantalum electrolytic capacitors below) may be considered to be the only two main types of electrolytic capacitors.

Table 2-1 the features and differences between Aluminum Electrolytic Capacitors and Tantalum Electrolytic Capacitors

	Aluminum electrolytic capacitors	Conductive polymer hybrid aluminum electrolytic capacitors	Tantalum electrolytic capacitors
Voltage range (V.DC)	2 to 500	25 to 80	2 to 50
Cap.range (μF)	0.1 to 100000	10 to 330	0.047 to 2200
Miniaturization	Advantageous in high capacitance range	Advantageous in high frequency range	Advantageous in low capacitance range
tan δ	High	Low	Low
Leakage current	Relatively large	Relatively small	Relatively small
Temp. characteristics	Not very good	Good	Good
Freq.characteristics	Not very good	Good	Good
Failure mode	Wear failure (limited life), open	Wear failure (limited life), open	Random failure, increase in leakage current, short circuit
Solder heat resistance	Relatively weak	Relatively weak	Relatively strong
Voltage delating	No big influence on reliability (life)	No big influence on reliability (life)	Influence on failure rate (low voltage is good)
Ripple resistance	Relatively strong	Relatively strong	Can not take large ripple current
Reverse vol. resistance	Can not take it (*Correspondence possible in some series)	Can not take it	Can not take it
Surge	Relatively strong	Relatively strong	Strong
Price	Relatively inexpensive	Relatively expensive	Relatively expensive

Table 2-1 Features and differences

A liquid electrolyte, while tantalum electrolytic capacitors use a solid electrolyte.
These structural differences in aluminum electrolytic capacitors and tantalum electrolytic capacitors have a large influence on their performance and reliability.
The biggest difference of them is in their electrolytes (liquid･solid).
Such properties as temperature characteristic and frequency characteristic are not as good with the liquid electrolyte as with the solid electrolyte because the variation in conductivity is great.
In contrast, the recoverability of the oxide film is not as good with solid electrolytes as it is with liquid electrolytes, and so the development of a flaw in the oxide film could easily result in a failure mode such as an increase in leakage current or a short circuit.
Solid electrolyte capacitors do not have as good a ripple current resistance and charge-discharge resistance, and do not stand up as well to reverse current due to the difference in recoverability.
The life of aluminum non solid electrolyte capacitors is limited because the electrolyte gradually permeates through the seal and evaporation in recoverability.
Because the electrolyte gradually permeates through the seal and diffuses, causing the capacitor to dry up and lose capacitance and resulting in an open condition.
Solid capacitors, on the other hand, have an almost permanent life because their electrolyte does not evaporation.

☆Point : Aluminum electrolytic capacitor have a limited lifetime

The hybrid type which used the conductive polymer and the electrolysis solution for the electrolyte is also produced commercially, and the lineup also of the capacitor excellent in performance and reliability is carried out.

2-3. Structure of aluminum electrolytic capacitors

The structure of aluminum electrolytic capacitors is shown in Fig.2-4

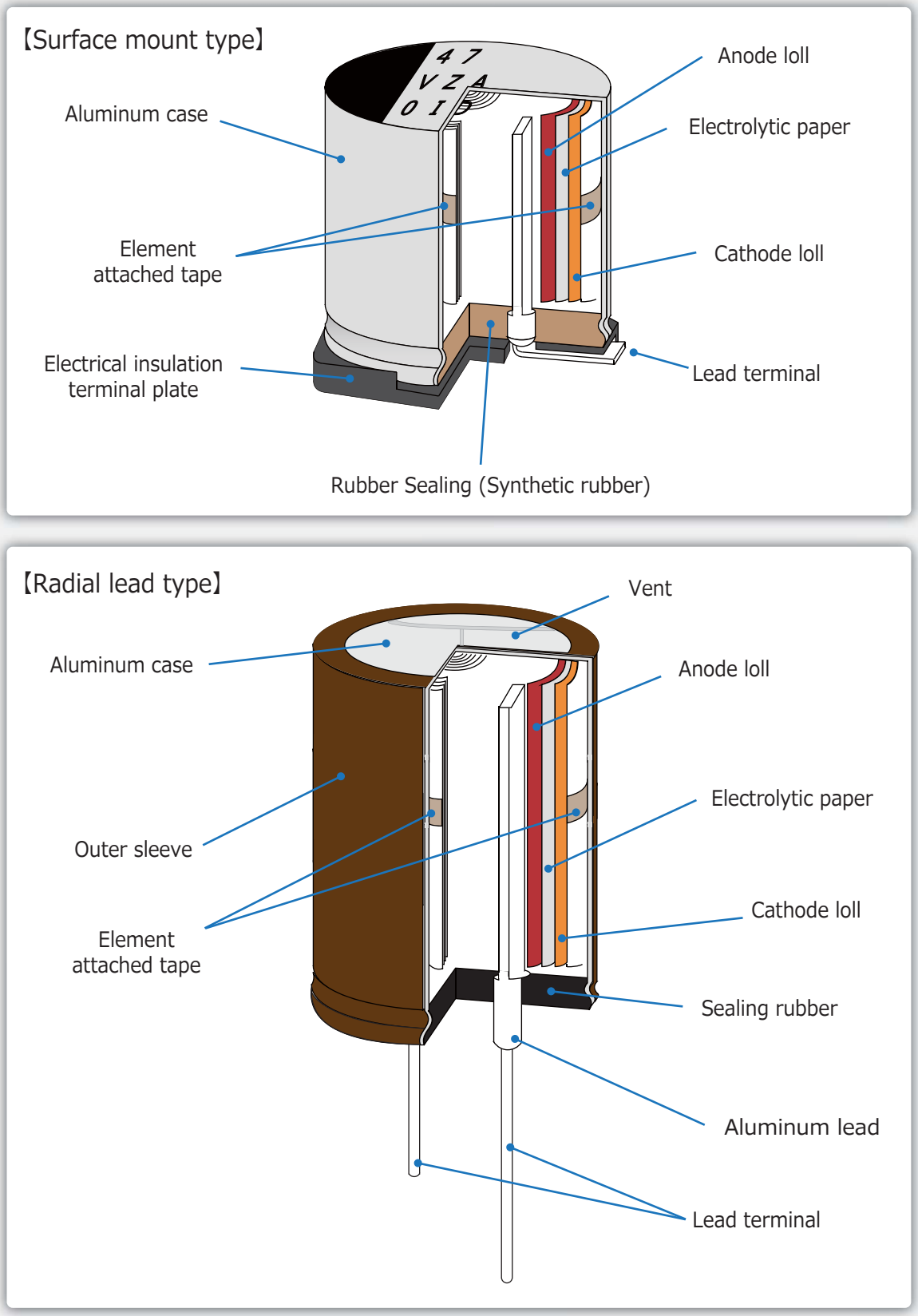


Fig. 2-4 Structure of aluminum electrolytic capacitor

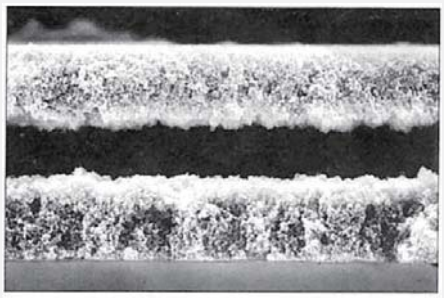
3-1. Electrodes and dielectric foil of aluminum electrolytic capacitors

Aluminum electrode foils

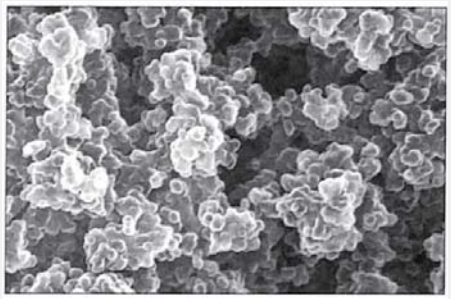
To increase the surface area, the surface of aluminum electrode foils is electrochemically roughened (etched).

〔 Etched foil for low voltage 〕

For low voltage, a sponge-like pitted surface is obtained by AC etching.



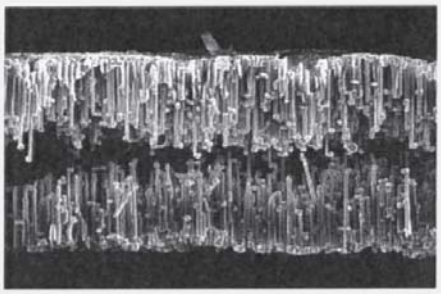
(Cross section) (x 500)



(Replica) (x 10000)

〔 Etched foil for high voltage 〕

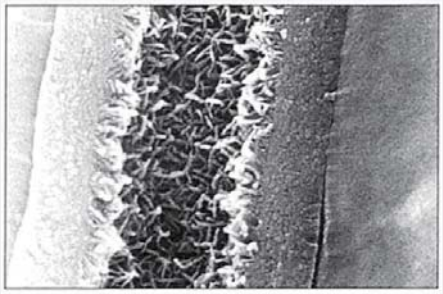
For high voltage, a tunnel-like pitted surface is obtained by DC etching.



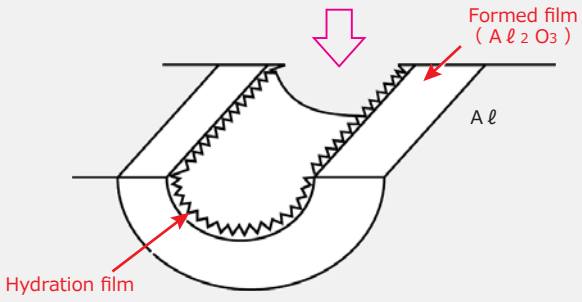
(Cross section) (x 500)

〔 Dielectric foil 〕

An aluminum oxide film is electrochemically on the etched aluminum foil to serve as the dielectric



(x 50000)



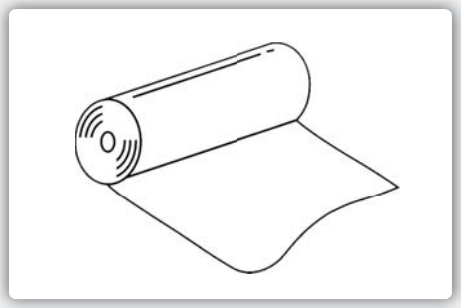
The oxide film in the figure is a cross section of formed film in the pits of etched foil in the pits of etched foil for medium to high voltage.

3-2. Production method aluminum electrolytic capacitors

[Etching]

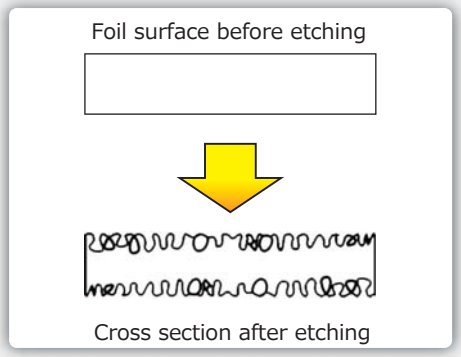
① Anode aluminum foil

Aluminum foil normally 40 to 110 μm thick and more than 99.9% pure is used for the anode foil.



② Etching

This process electrochemically roughens the smooth surface of the rolled aluminum foil to increase its effective surface area.
The ratio of the capacitance of the smooth foil to that of the etched foil at a certain forming voltage is referred to as multiplying factor, and it normally reaches tens times to hundreds tiems fold.
Most companies are placing emphatic.

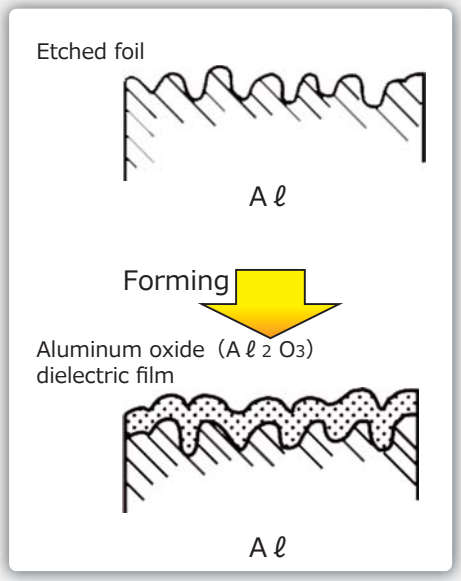


[Forming]

③ Forming

In this process, which greatly determines the performance of the capacitor, electrolysis is performed in an electrolyte (differs from the electrolyte impregnated in element with respect to purpose and composition and is normally referred to as formation liquid) with the etched foil as the anode (Anodic oxidation), thereby electrochemically forming an aluminum oxide film on the aluminum foil surface to serve as the dielectric.

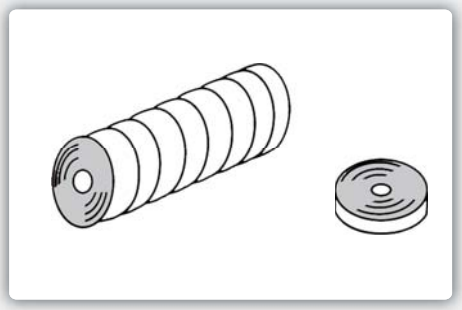
One aspect of this capacitor that distinguishes it from others is the ability to change the withstand voltage (i. e. , thickness of the aluminum oxide film) and the capacitance as required by the intended use by adjusting the forming.



[Slitting]

④ Slitting
⑤ Attaching lead
⑥ Winding-1

The formed electrode foils are cut to prescribed dimensions depending. On the required capacitance of the product, and then after attaching the leads, the anode foil is wound up with the cathode foil an the electrolytic caper (Separator) in between to form a cylinder.



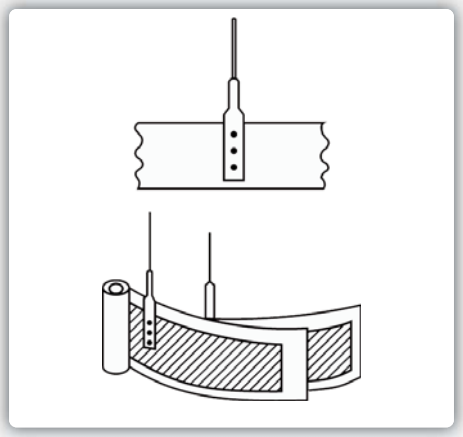
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[Winding]

⑦ Winding-2

☆The electrolytic paper is specially made for electrolytic capacitors and serves two functions.

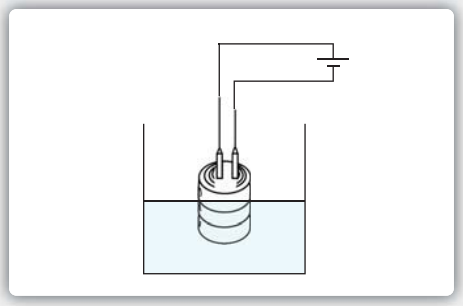
1) It separates the anode foil and the cathode foil so they will not short - circuit.
2) It is saturated with the electrolyte and retains it. For this season, a superior paper of uniform thickness, density, water absorption, tensile strength, etc, is required.
The principal materials used



[Forming of section]

⑧ Forming of section (Only hybrid capacitors)

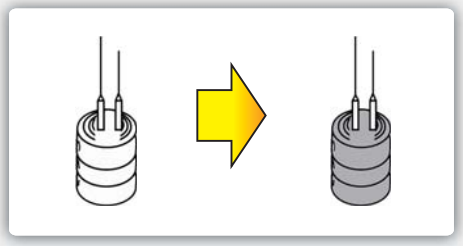
It is the process of restoring the part in which transformation is not formed, and the part where transformation is insufficient.
The leakage current is stabilized.



[Polymer formation]

⑨ Polymer Formation (Only hybrid capacitors)

It is the process of forming polymer in an element.
The characteristic of ESR and capacitance is pulled out.



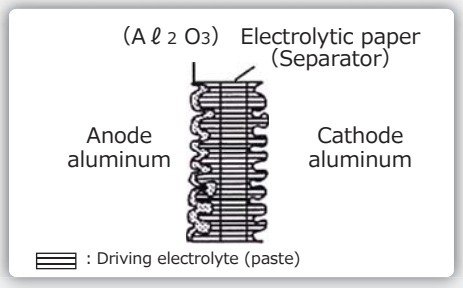
[Impregnation]

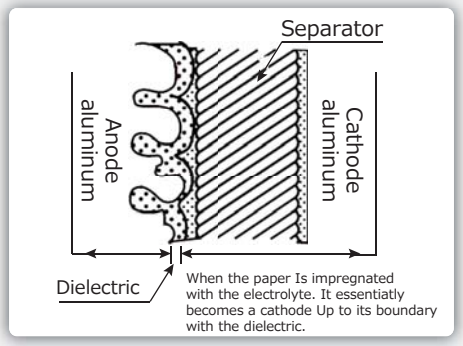
⑩ Impregnation

Impregnation is the process of saturating the wound element with electrolyte.
The type of electrolyte used varies with the characteristic application of the product.

☆ About the electrolyte
The electrolyte impregnated in the element is referred to as driving-electrolyte and performs the following two functions.

1) It impregnates and adheres to the surfaces of the anode and cathode foils to extract 100% of their capacitance. (essentially a cathode action,)
2) Repairs defects in the anode oxide film.
The characteristics of electrolyte greatly influence the temperature characteristic, frequency characteristic, high temperature load life, etc. Of the capacitor, and so an electrolyte with a composition different from that of the formation liquid and one that also satisfies economic, other requirements is, of course, required.



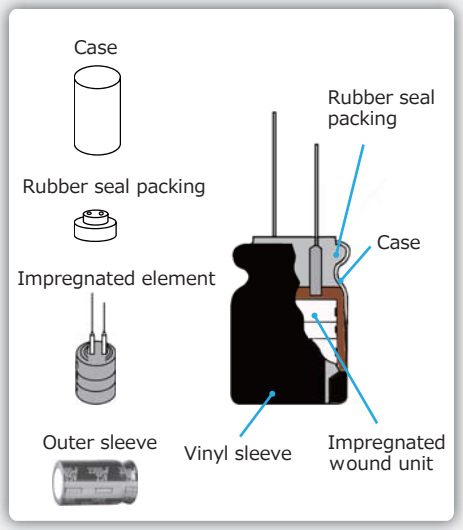


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[Assembly]

⑪ Assembly

Wound unit impregnated with electrolyte already have the function of a capacitor, to avoid deterioration of the characteristics of the capacitor due to evaporation or moisture absorption of the electrolyte, they must be inserted in a metal case and sealed with rubber packing or other sealing material.
The capacitor also receives a vinyl sleeve noting such necessary information as polarity, rated voltage, capacitance and use temperature.



[Reforming]

⑫ Reforming (Aging)

This process impresses a prescribed voltage on the assembled product to stabilize its characteristics.
Upon assembly, the slit surface of the electrodes, lead connections and other unformed places and places where the film has been damaged must be reformed. This process also permits confirmation of the withstand voltage and screening of defective products. It is important in raising the reliability of capacitors in the initial stages so that they will yield stable operation from the beginning when assembled in devices.

[Seal processing]

⑬ Seal processing (Only SMD Type)

After sealing the heavens side of an aluminum case in a display (Rated voltage code, Cap. Lot No., negative pole display.) about a field mounting article, lead processing is carried out, after carrying out seat board insertion.

[Completion inspection]

⑭ Completion inspection

Products that have undergone reforming are inspected for capacitance, tan δ leakage current, external appearance, etc., to ensure they will perform as required, and then they are packaged.



4-1. Aluminum electrolytic capacitor failure

Failure modes are roughly classified as follows.

- Failure mode
  - Aluminum electrolytic capacitor body failure
    - Catastrophic failure ・・・Air tightness failure of the vent (gas generation)
    - Degradation failure (Wear) ・・・Capacitance reduction, tan δ increase, Leakage current increase
  - Capacitor peripheral failure
    - Disconnected pattern ・・・Corrosion
    - Short pattern ・・・Ion migration

Degradation failure can not be found for most other capacitors.
Aluminum electrolytic capacitors increase the failure rate by passing time shown in Fig.6, all the capacitors eventually become open.
In catastrophic failure, the function of the capacitor is completely lost, it is easily to judge failures, but since the characteristics gradually deteriorate in degradation failure, the failure stage vary greatly with the performance required by each individual electronic device. In case of degradation failure, failures come from values going out of range from those in the Product Standards and catalog based on JIS-C5101.

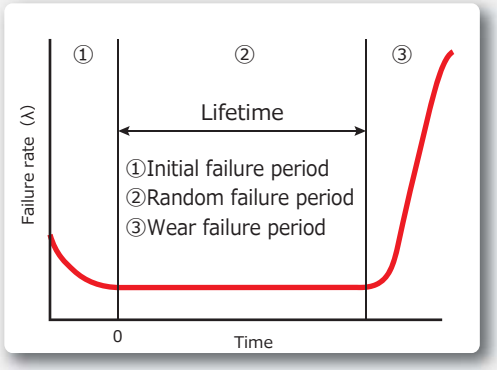


Fig.4-1 Degradation failure of aluminum electrolytic capacitor

Table 4-1 shows the relationship between each failure mode and cause and failure mechanism.

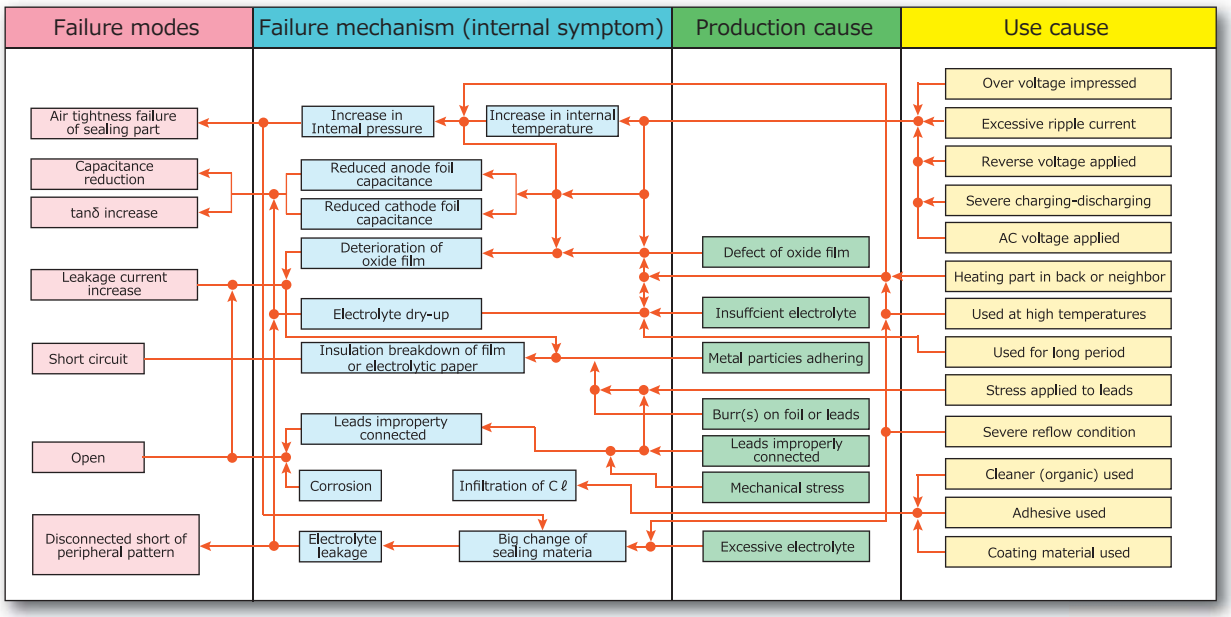
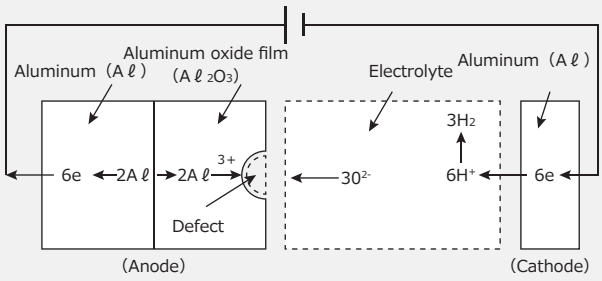


Table 4-1 Failure mode・mechanism of aluminum

☆Point : Mounting condition greatly influences on the reliability of capacitors.

(1) Airtightness failure of the vent (gas generation)

Aluminum electrolytic capacitors have characteristics which quickly repair film defects by the mechanism.(Show in Fig.4-2) However, as in a battery, oxidation at the anode will cause reduction at the cathode, resulting the generation of hydrogen gas (H2).
When used under conditions within the guaranteed ranges noted in the catalog or delivery specifications, the hydrogen gas generated is extremely small, and any that generated is dissipated by the depolarization action of the electrolyte or through the sealing element, so there is no problem, but if used under conditions, such as temperature, over voltage, reverse voltage and excess ripple current, exceeding the guaranteed ranges, damage to the film will increase, causing a sudden increase in the amount of hydrogen gas generated by the self-repairing action. This will cause the internal pressure to rapidly increase and may cause the aluminum case to swell, the vent to operate, or some other external change.



$$2A\ell \rightarrow 2A\ell^{3+} + 6e^-$$
$$3H_2O \rightarrow 6H^+ + 3O^{2-}$$
$$2A\ell^{3} + 3O^{2-} \rightarrow A\ell_2O_3$$
$$6H^+ + 6e^- \rightarrow 3H_2$$

Fig.4-2 Self-repairing mechanism

(2) Open Failure

Open failure can occur due to any of the following conditions

① Mechanical damage to the lead conditions.
Due to improper connection at the time of production or the lead being subjected to excessive stress, vibration, or impact.

② Corrosion due to the infiltration of a corrosive material.
When chlorine ions ($C\ell^-$) enter during production, or the capacitor is cleaned with a chlorine cleaner or is reinforced with a resin containing chlorine compounds and chlorine substances enter the capacitor.
These corrode the leads or electrode foils until an open condition results.

③ Evaporation of electrolyte due to operation of the vent.
When internal electrolyte evaporates causing the capacitor to dry up. This reduces the capacitance and increases tan δ.

④ Final stage of gradual deterioration.
At the end of life of the capacitor through the process of deterioration ; i.e., the final stages of degradation failure in which the electrolyte gradually penetrates through the seal causing the capacitance to drop and tan δ to increases.

(3) Short circuit

We use electrolytes with excellent film repairing characteristics in our aluminum electrolytic capacitors, so any film defects that do occur are quickly repaired and local concentrations of current avoided.
Therefore, catastrophic failures such as short circuits or breakdown are normally very rare.
However if defects such as metal or other conductive particles or burrs on electrode foils or leads are allowed to pass in production, or if, during use of the capacitor, stress is applied to the leads or it is subjected to undue vibration or shock, the capacitor' s separator paper may be damaged allowing the anode and cathode foils to come in contact and result in a short circuit.

(4) Degradation failure (End of life)

Fig.4-3 shows the relation of electrolyte amount and capacitance tan δ. It has changed (Capacitance reduction and tan δ increase) according to aluminum case, contact part of sealing material and lead wire, and penetration evaporation of electrolyte from sealing interface.
Judgment of degradation depends on the product type, so that catalog or delivery specifications should be referred.
For capacitance and tan δ in Fig.4-3, the characteristics are drastically changed when the electrolyte amount reduces to a certain point.

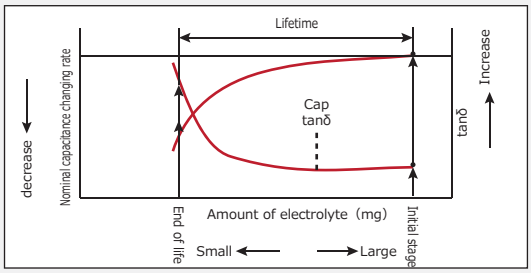


Fig.4-3 Characteristics degradation & Electrolyte amount

(5) Failure of a capacitor periphery

Aluminum electrolytic capacitors may influence on its periphery of PCB (especially, wiring pattern), not only capacitor itself.
Electrolytic used is gradually penetrated and evaporated below the capacitor through one of the two routes, and the following phenomena may happen.

① Pattern disconnection (a)

Disconnected pattern the pictures of Fig.4-5 show the capacitor which was forced to drop electrolyte, applied 32V/mm voltage and left for 20 hours at 40℃ 90 to 95%R.H.

② Pattern short (b)

Short pattern where the electrolyte adheres the patterns which have potential difference over two, copper or silver of pattern materials may make ion migration.

This phenomenon varies a lot depending on environment condition (especially, humidity and dew condensation should be careful) and intensity of electric field.

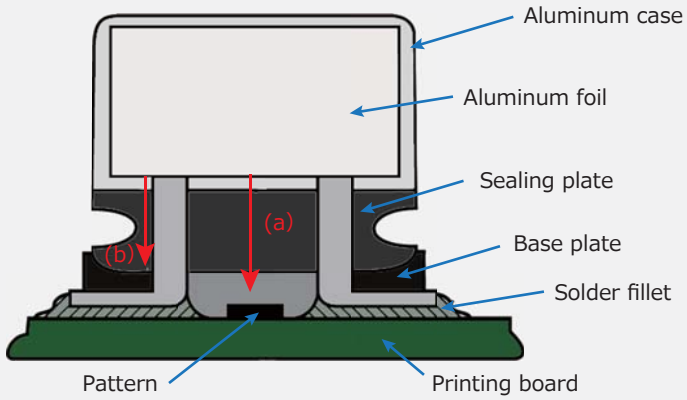
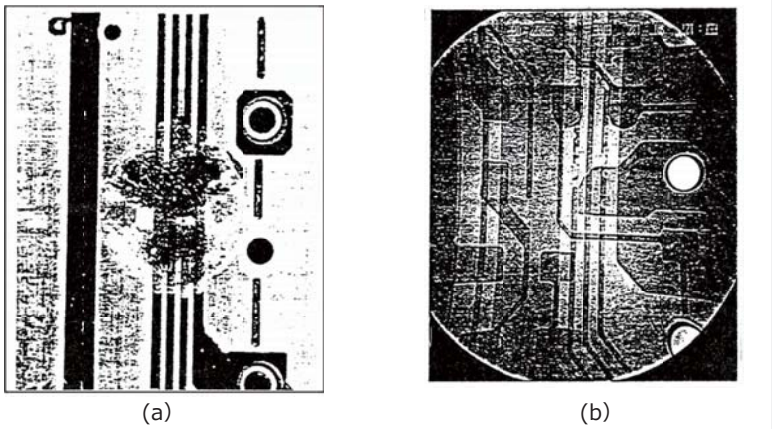


Fig.4-4 Electrolyte penetration of aluminum electrolytic capacitor



(a) (b)

Fig.4-5 Corrosion at electrolyte dropping test

Please read the following & use it properly in order to show full performance and keep the stable quality of surface mount type aluminum electrolytic capacitor.

5-1. Life calculation

As repeated, aluminum electrolytic capacitor is the limited life component. Temperature is only a key for life under the normal use condition. Other factors such as voltage and mounting conditions shown in 5-2.
Become the reason to shorten the life under the abnormal condition, but don’ t cause any problems under the normal condition.

【 How to calculate the life from temperature 】

The dissipating speed of electrolyte changes with the rate doubling with every 10℃ increase in temperature, this “double rule with 10℃” will be applied between 40℃ and about 140℃. Therefore, expected life at operating temperature can be described in equation (1). for quick calculation, see Fig.5-1

$$L = L_0 \times 2^{\frac{T_0 - T}{10}} \quad \text{(Equation 1)}$$

L : Expected life in actual use [hour]
T : Actual ambient temperature + temperature rise due to ripple current [℃]
L_0 : Guaranteed life of capacitor [hour]
T_0 : 1) Product that defines the endurance by superimposing the rated ripple current.
Upper category temperature of capacitor + temperature rise (5℃) due to rated ripple current [℃]
2) Product that defines the endurance by applying a rated voltage.
Upper category temperature of capacitor [℃]

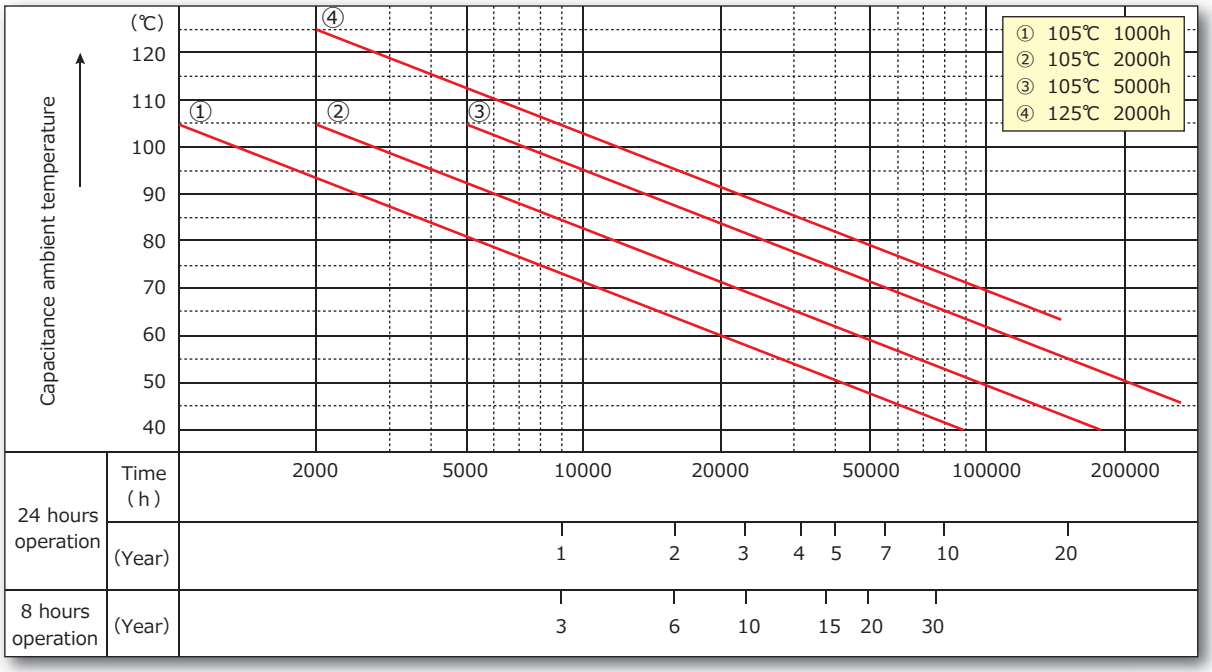


Fig.5-1 Deleting lifetime quick Reference Guide

・Example

1） Expected life of equipment (required conditions)

A : 10 years with 24h operation

B : 10 years with 8h operation a day

2） Ambient temperature of capacitor

65℃ (Check・no heat generated part on reverse or around)

・Life calculation

In case of a capacitor with 105℃ 2000h guarantee

$$L = 2000 \times 2^{\frac{105 - 65}{10}}$$

$$= 2000 \times 2^4 = 32000$$

⇒ Under the temperature 65℃, the expected life will be 32000 hours

・Capacitor selection

case 1) A : For 10 years with 24h operation

L = 24 (hour) × 365 (day) × 10 (year)

= 87600 (hour) ←——— Working hours for 10 years

Because the value is larger than 32000 hours, the 105℃ 2000h product does not satisfy the expected life, and the ambient temperature should be lowed.

Case 2) B : For 10 years with 8h operation a day

L = 8 (hour) × 365 (day) × 10 (year)

= 29200 (hour) ←——— Working hours for 10 years

Because the value is smaller than 32000 hours, the105℃ 2000h product can be used.

5-2. Circuit design

◎ Circuit design consideration

⚠ Safety precaution

[Applying to the equipment focused on the safety]

We do the best for our product quality, but short circuit (or open) may occur as failure mode such as life, etc.

1. Provide protection circuits and protection devices to allow safe failure modes.
2. Desing redundant or secondary circuits where is possible to assure continued operation in case of main circuit failure.
   Design should be considered well and safety to be assured.

The following seven points should be considered for circuit design when using surface mount type aluminum electrolytic capacitor.

	Precaution on design	Phenomenon (Influence)
(1) Excessive voltage	Over the rated voltage is not applied ?	Capacitance reduction, tan δ increase capacitor breakdown
(2) Reverse voltage	Reverse voltage is not applied at ON/OFF etc.? Polarity is not reversed ?	Capacitance reduction, tan δ Increase, leakage current increase capacitor breakdown
(3) Ripple current	Ripple current is not over flown ? Heat generation by ripple current is O.K. ?	Shorter life, capacitor breakdown
(4) Charge/ Discharge	The circuit is not often repeated charge discharge ?	Shorter life, leakage current increase, capacitor breakdown
(5) Temperature characteristic	Especially, checked circuit operation at low temperature side ?	Electrical characteristics change
(6) Frequency characteristics	Checked circuit operation at high frequency range ?	Electrical characteristics change
(7) Surge (Inrush)	No repeated surge or inrush current of over 100 A ?	Shorter life, short-circuit

※ Capacitor breakdown : Appearance change(Sealing part transformed) ・ Electrolyte will be considered.

(1) Excessive voltage

☆ Point

Excessive voltage over the rated should not be applied.

Note 1) In short time (with in 1sec), surge voltage can be applied.

Note 2) If there is inductance on the circuit, voltage of both side of capacitor may rise up more than expected. Especially, check reoccurred current on motor thoroughly.

If the excessive voltage over the rated is applied, oxide film self-repairing action of capacitor described in 4-1 (1) air tightness failure of the vent may cause capacitance reduction, tan δ increase and breakdown.

(2) Reverse voltage

☆Point
Reverse voltage should not be applied.
Note) Use bi-polar capacitor if the reverse voltage is applied including ON/OFF of power supply, etc. (AC circuit can not be used.)

As described in 2-1, generally, aluminum electrolytic capacitor has anode oxidized only on one side because of its construction. It is polarized construction formed oxide film.

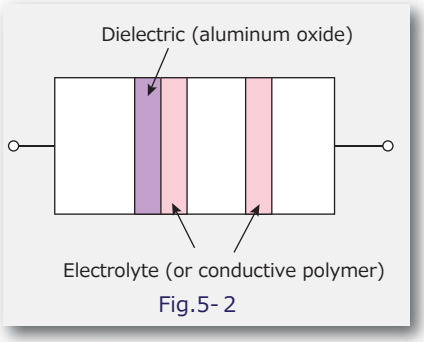


Fig.5- 2

Withstand voltage is decided by the thickness of oxide film. Therefore, when applying reverse voltage, the following reaction is occurred by film selfrepairing action because of no oxide film on the cathode.

$$2A\ell + 3H_2O \rightarrow 6e^- \longrightarrow A\ell_2O_3 + 6H^+$$
$$2H^+ + 2e^- \longrightarrow H_2$$

Therefore, applying long-term reversed voltage, excessive voltage and continuous pulse cycle reversed voltage may Fig.5-2 cause capacitor breakdown, such as short, open.

(3) Ripple current

☆Point
Use a capacitor designed for higher rated ripple current than circuit ripple current.
Note 1) Ripple current requires frequency correction.
Note 2) Check the heat generation of capacitor if ripple current on the circuit is hard to measure. Self heating should be within 5℃.

① Frequency correction method for ripple current

The frequency correction factor for ripple current is an extremely significant to determine more appropriate lifetime for all frequency range.
As shown in Fig.5-3, the resistance (equivalent series resistance, ESR) which affects heat generation by ripple current tends to decrease as the frequency increases.
Therefore, the higher the frequency is, the easier it is to flow off the ripple current.
Theoretically, where the equivalent series resistance

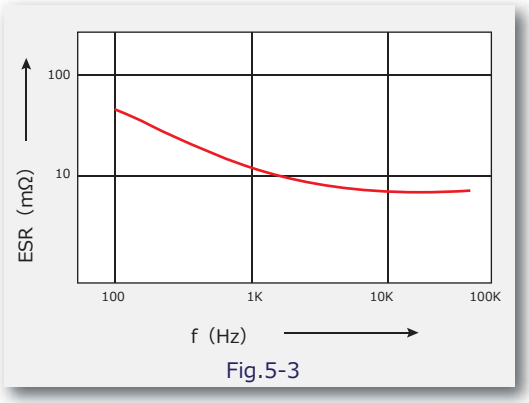


Fig.5-3

at a certain frequency f is ESR (f Hz) and the ripple current i (f Hz), and each at 120 Hz are ESR (120 Hz) and i (120 Hz), and heat generated due to ripple current is the same.

$$i^2\ (120\ Hz) \cdot ESR\ (120\ Hz) = i^2\ (f\ Hz) \cdot ESR\ (f\ Hz) \qquad (Equation2)$$

From this equation, ripple current i (f Hz) at f (Hz) is

$$i\ (f\ Hz) = \sqrt{\frac{ESR\ (120\ Hz)}{ESR\ (f\ Hz)}} \times i(120\ Hz)$$

Where, $\sqrt{\frac{ESR\ (120\ Hz)}{ESR\ (f\ Hz)}}$ is the frequency correction factor.

As Panasonic, we obtain the above value for each series and group them within certain rated voltage ranges in our catalogs to simplify the listing.

② Hand measuring of circuit ripple current

Where the ripple current of circuit is hard to measure, measure the heat generation of capacitor itself. For aluminum capacitor, maximum heating specifies 5℃. If more than 5℃, life calculation described in 5-1 can not be made, and the life may be extremely shorten.

(4) Charge / Discharge

☆Point
Can not be used in the circuit which repeats charge / discharge so often.

General aluminum electrolytic capacitors have almost no current flown and no neating in normal condition. However, when charge and discharge, it generates heating due to the current fling. Therefore, if that happens often, self heating temperature may short the life. For worst cases, sudden increase of leakage current and capacitor damage (electrolyte leakage, etc.) will be caused.

(5) Temperature characteristics

☆Point
Electrical characteristics changes by temperature. See the environment of equipment, and check / select the capacitor.

Compared to solid electrolyte for ceramic capacitor, aluminum electrolytic capacitor used liquid electrolyte has more conductivity change. It makes temperature change worse, Fig.5-4 shows the general electrical characteristics change by temperature.

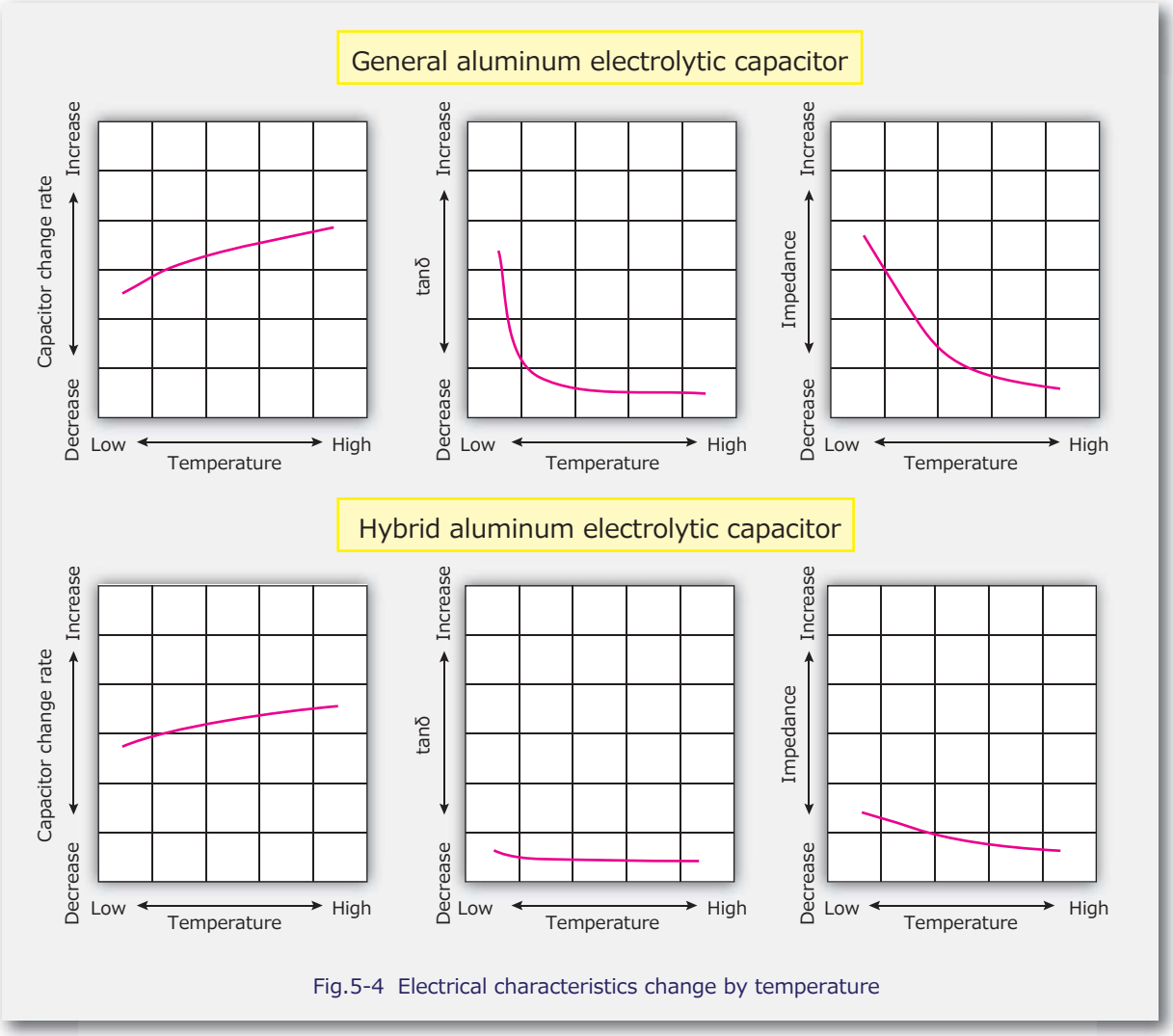


Fig.5-4 Electrical characteristics change by temperature

(6) Frequency characteristics

☆Point
Electrical characteristics change by frequency・consider the frequency of equipment, and check / select the capacitor.

As the same with temperature characteristics, frequency characteristics is not good because of liquid electrolyte to solid electrolyte. Fig.5-5 shoes the general electrical characteristics change by frequency change.

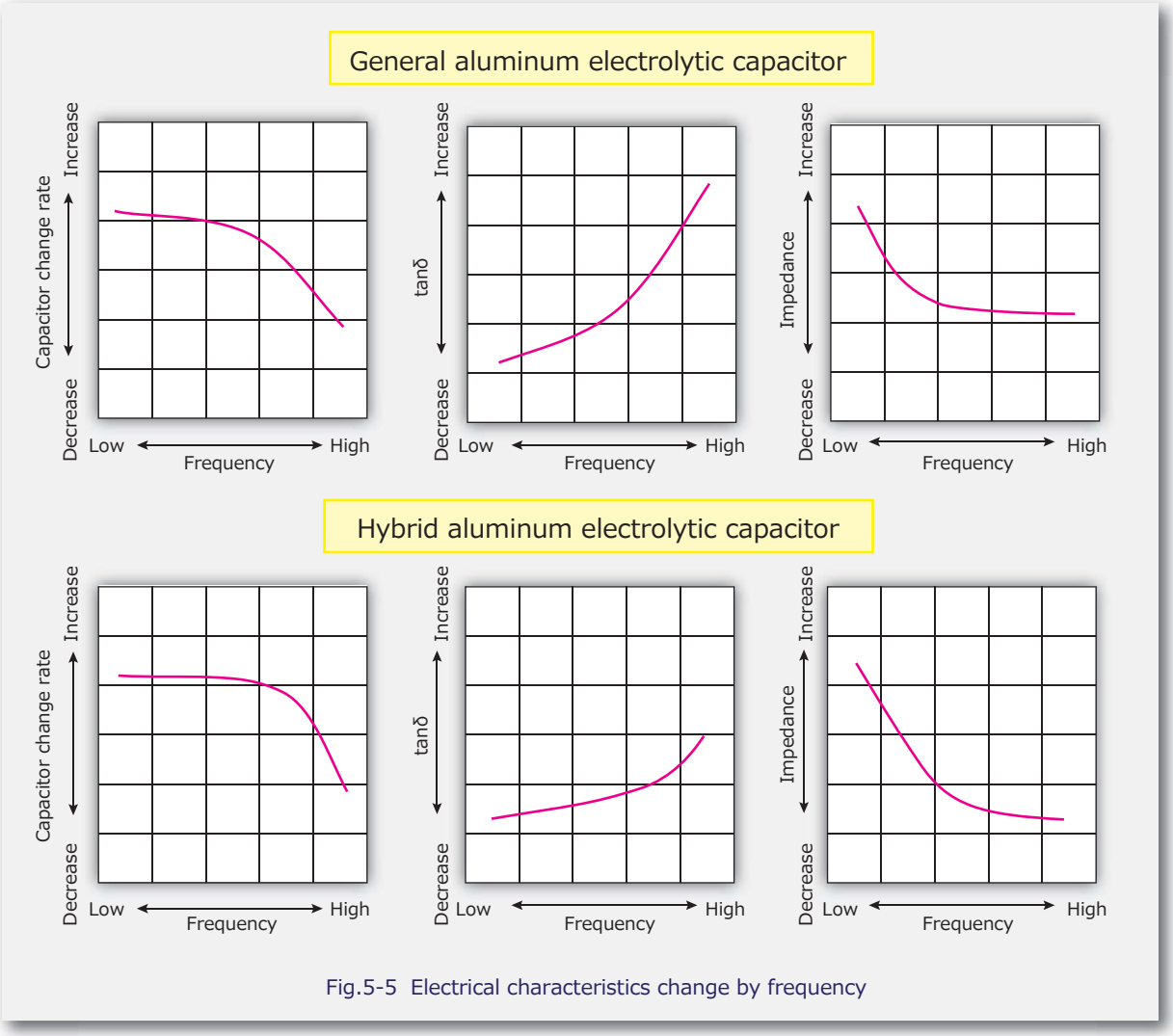


Fig.5-5 Electrical characteristics change by frequency

(7) Using two or more capacitors in series or parallel

① Capacitors connected in parallel

The circuit resistance can closely approximate the series resistance of the capacitor causing an imbalance of current loads within the capacitors.
Careful design of wiring methods can minimize the possibility of excessive ripple currents applied to a capacitor.

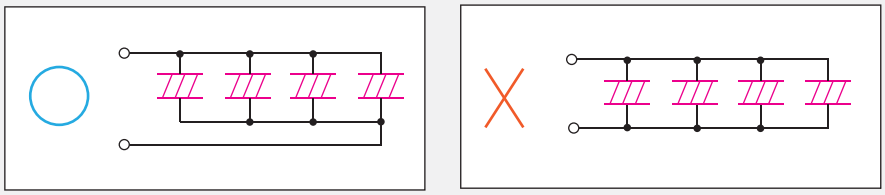


Fig.5-6 Connected in parallel

② Capacitors connected in series

Considering voltage imbalance, less than rated voltage should be applied to each capacitor (UR) voltage balance lose, and excessive voltage may apply.
To avoid the excessive voltage, the voltage divider shunt resistors with consideration to leakage currents be set in series with each capacitor.

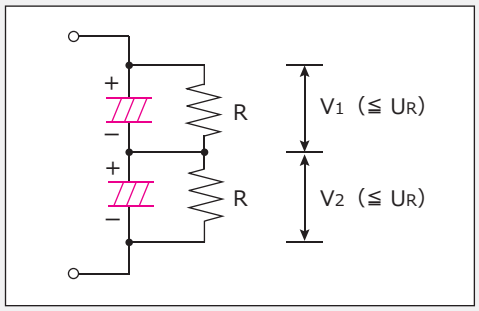


Fig.5-5

5-3. Installation design

Especially, following six points should be noted for installation of aluminum electrolytic capacitor.

	Precaution on design	Phenomenon (Influence)
(1) Wiring directly under capacitor	No wiring pattern under the sealing part of capacitor ?	Disconnection・Short circuit (migration)
(2) Place of heating components	No heating component placed around the capacitor ?	Greatly influence on life (capacitance reduction tan δ increase)
(3) Land design	Ambient temperature of capacitor is clear ?	Disconnection・Short circuit (increase of leakage current)
(4) The space with adjoining part	Design the correct hole spacing to adjust terminal size of capacitor ? Avoid wiring or pattern above the pressure relief vent ?	Secondary disaster such as explosion, set damage, etc. Disconnection & ignition of wiring
(5) Consideration to the pressure relief vent	Capacitor case, the terminals and circuit pattern are isolated ? Other parts and wiring not isolated by outer sleeve ?	Disconnection, short circuit, circuit abnormality Short circuit
(6) Consideration of vibration and a shock	Is it confirmed although vibration-proof and shock nature have a difference according to a mounting state with the mounting direction or other parts about a field surface-mounted component?	Lead fracture

(1) Consideration for wiring pattern under the capacitor

☆Point
Try to avoid wiring pattern just under the capacitor.
Note 1) If pattern wiring is required, coat with resist materials (heat curing) that have protective effects against electrolyte corrosion.
Double resists are also effective.
However, It might become a problem in the environments where water could condense.
Note 2) Avoid pattern wiring because it easily becomes a problem if Ag materials are used for conductor on ceramic board such as hybrid IC.

As explained in Fig.4-3, characteristics of aluminum electrolytic capacitor are changed by electrolyte penetration and evaporation. Electrolyte is penetrated to the bottom of capacitor with the time passing for route a in Fig.4-4. However, It' s mostly the solvents in electrolyte and almost no possibility to become a problem due to a very little amount.
However, due to the following other factors, corrosion of pattern wiring and ion migration between pattern wiring may occur.

① Moisture accelerates corrosion and migration.

Especially the influence extremely arise in dew condensation, so moisture proof coating is required or pattern wiring under the capacitor is prohibited.

② Electric strength (potential difference)

Corrosion occurs without electric potential, but it can accelerate the corrosion as well as migration. Also, large electric strength (voltage) makes corrosion fast.

③ Halogen

Halogen if activated agents and cleaning solvents in soldering contain halogenated substance, remnants of halogenated substance accelerate corrosion.

④ Conductor material

Conductor materials the order to easily become a problem in the materials for general use; Ag » Cu > Solder.

Therefore, if the influences of disconnection and short circuit are critical for devices, pattern wiring should be avoided.

(2) Consideration for placing heat components around or reverse side

☆Point
Try to avoid placing heat components (power transistor, power IC, solid resistor, etc.) to the periphery or reverse side of circuit board (under the capacitor).
Note) For placing, check the temperature of capacitor (top, side, terminal, etc.)

As shown in 5-1, life calculation can be generally determined by ambient temperature. However, if there are heat components close-by, the temperature of capacitor may rise more than ambient temperature due to heat radiation. And, if the heat components are placed on the reverse of circuit board mounted capacitors, the neat transfers to the terminals via pattern wiring of the board, the temperature of capacitor may rise. Either cases, be careful for misjudgment in life calculation at ambient temperature. It differs more than 5℃ between ambient temperature and capacitor temperature, temperature, which affect the life.

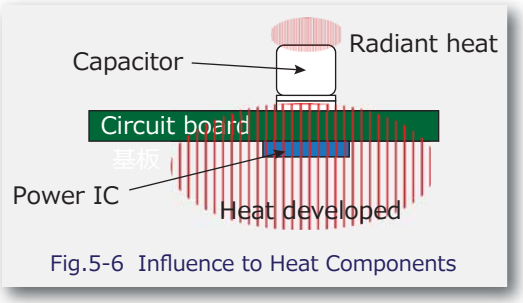


Fig.5-6 Influence to Heat Components

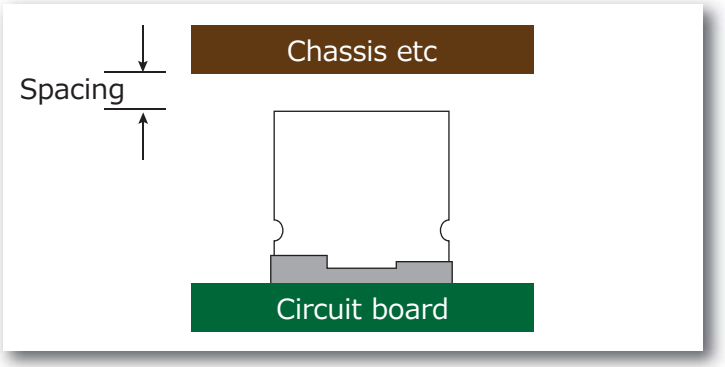
(3) Circuit board hole spacing

When the capacitor is inserted to the print circuit board holes spacing that does not match the capacitor lead wire, the, may cause pushing stress to internal elements and damage the capacitor. Also this may lead the airtight defects and electrolyte leakage, increase of leakage current and short circuit electrically.
For lead terminal products, terminal processed products.

(4) Consideration for the pressure relief vent

・Capacitors with case mounted pressure relief vents require sufficient clearance to allow for abnormal.

Product dia φ	6.3 to 16 mm	18 to 35 mm	Over 40 mm
Spacing	Over 2 mm	Over 3 mm	Over 5 mm

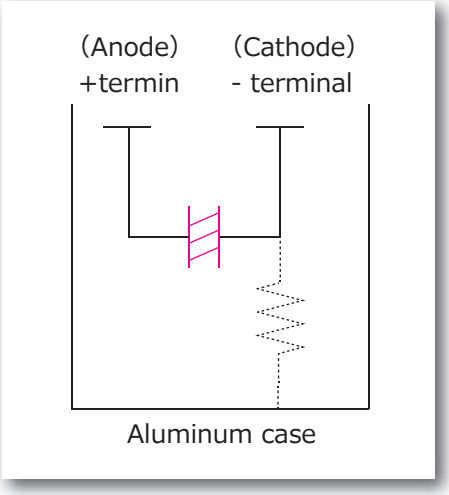


・Avoid wiring and circuit pattern above the pressure relief vent. Flammable, high temperature gas exceeding 100℃ may be released which dissolve the wire insulation and ignite.

(5) Electrical isolation of the capacitor

・Completely isolate teach of the followings, case, anode, cathode terminal, and other circuit terminals.

・The sleeve is not meant to insulate the capacitor.



5-4. Soldering and chemical conditions

(1) Installation

The followings should be noted when installing aluminum electrolytic capacitor.

	Precaution on mounting	Phenomenon (influence)
Mounting	Verify the polarity of capacitor	Capacitor breakdown by applying the reverse voltage, such as blowout, short cir-
Soldering	・For manual soldering, if It' s not specified, do not exceed 350℃ for 3 seconds or less. ・For flow soldering, if it' s not specified, do not exceed 260℃ for 10 seconds or less. ・For heat curing, do not exceed 150℃ for max 2 minutes.	Appearance change due to the rise of internal pressure, blowout crack of vinyl sleeve, contraction.

(2) Cleaning, Additives, Coating

	Precaution on Cleaning, Mounting adhesives, Coating	Phenomenon(influence)
Circuit board cleaning	Halogenated (especially, chrdine) cleaning solvents can not be used. When cleaning, use the capacitor with guarantee.	Corrosion, disconnection
Mounting adhesives, coating	・Halogenated (especially, chroline) mounting adhesives and coating materials can not be used. ・Dry cleaning solution well before using mounting adhesives and coating materials. ・Over 1/3 of sealing part should not be sealed.	Corrosion, disconnection

☆Point
Don' t use halogenated(especially, chroline)cleaning solvents・adhesives・coating agents.

If halogenated (especially, chroline) materials are used and its chroline is liberated. Internal aluminum of capacitor gets corrosion and characteristics deterioration show in the following mechanism.

① Chroline liberated process

Example of cleaning solvents chlorosen (1.1.1-Trichloroethane). Even though it contains chrorine, no problem if it doesn' t become free-chrorine. Also, cleaning solvents don' t permeates to internal capacitor soon. It adheres to the outside of seal and is trapped, gradually, permeates to inside.
Therefore, most problems occur in the market, not soon after cleaning.

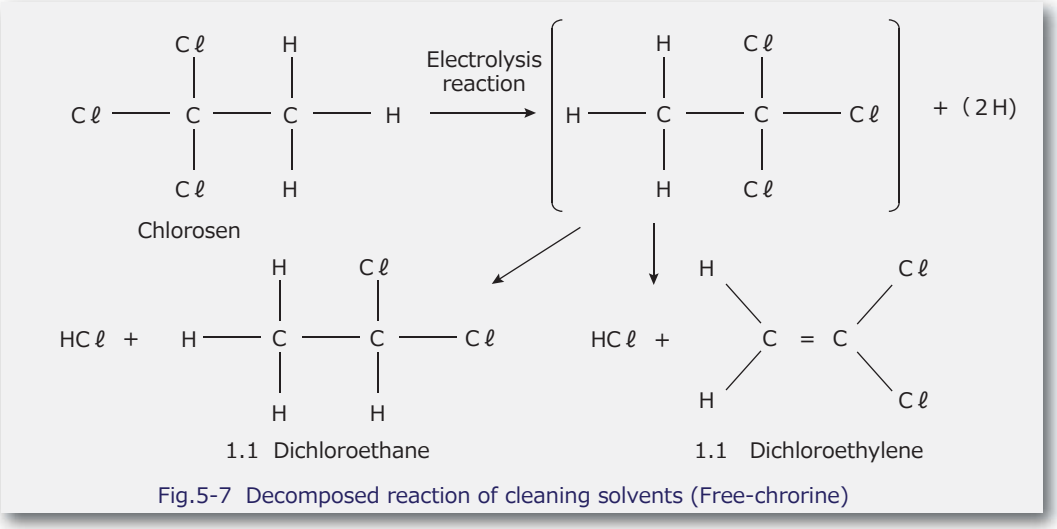


Fig.5-7 Decomposed reaction of cleaning solvents (Free-chrorine)

② Reaction of free-chlorine and aluminum

Combined free-chlorine and hydrogen become hydrochloric acid, but it has high dissociation and mostly becomes chlorine ions. These chlorine ions react with aluminum. The order of the reactions is shown below.

(A) Hydration of oxide film

$$A\ell_2O_3 + 3H_2O \rightarrow 2A\ell(OH)_3$$

(B) Reaction of hydrated oxide film and chlorine (Dissolution of film)

$$A\ell(OH)_3 + 3HC\ell \rightarrow A\ell C\ell_3 + 3H_2O$$

(C) Reaction of aluminum and hydrochloric acid (Dissolution of aluminum)

$$A\ell + 3HC\ell \rightarrow A\ell C\ell_3 + \frac{3}{2}H_2$$

(D) Precipitation of aluminum hydroxide

$$A\ell C\ell_3 + 3H_2O \rightarrow A\ell(OH)_3 + 3HC\ell$$

(A) to (D) Reaction complied (A) through (D)

$$A\ell + A\ell_2O_3 + 3HC\ell_3 + 3H_2O \rightarrow 2A\ell(OH)_3 + A\ell C\ell_3 + \frac{3}{2}H_2$$

Therefore, the compounds produced by the reactions are aluminum hydroxide, aluminum hydroxide and hydrochloric acid in reaction (D), the hydrochloric acid is not consumed and acts as a catalyst.
Table 5-1 and 5-2 show the propriety of cleaning solvents.
Do not use ozone destructive substance as a cleaning solvents in order to protect the global environ.

a. Cleaning solvents

Composition	Boiling point (℃)	Common name (example)
1.1.1-Trichloroethane	74.1	Chlorosen
Trichloroethane	87.2	Trichlene
Tetrachloroethlene	121.1	Perchloroethylene

Table 5-1 Solvents that can' t be used

		Solvents name	Manufacture	Judgment mark	Remark
Water base	Water	Pure water	-	◎	No problem
	Allaline soponifying agent	Aqua cleaner 210SEP	Sanei Kagaku	○	No problem Readout might erased Aviod using blush
	Surface active agent	Pine Alpha ST-100S	Arakawa Kasei Kogyo	○	
		Clean-thru 750H	Kao corp	○	
		Clean-thru 750L		○	
		Clean-thru 710M		○	
		Sun-elec B-12	Sanko Kasei	○	
		DK be-clear CW -5790	Dai-Ichi Kogyo Seiyaku	○	
Solvent base	Petroleum based hydrocarbon	Cold-cleaner P3-375	Henckel Hakusui	△	Large swelling on sealing rubber Rinse and dry right After washing
		Techno-cleaner 219	Seiwa Sangyo	△	
		Axarel 32	Mitsui DFC	△	
	Alcohol base	Isoproypyle alcohol	-	◎	No problem
	Silicon base	Techno-care FRW-17	Toshiba Corp.	△	No problem if you use These combination
		Techno-care FRW-1			
		(Techno-care FRV-100)			
	Halogenated hydrocarbon	Asashi-clean AK-225AES	Ashahi Glass	△	CF base solution Not recommended, be hamful to the environment
		HCFC141b-MS	Daikin Kogyo	△	
	Telpen base	Telpen-cleaner EC-7R	Nippon Alpha Metals	△	Swellihg sealing rubber May swell, poor ejecting

Table 5-2 The propriety of replace

(Reference of judging mark)

Judgment mark	Contents
◎	Cleaning is possible
○	Cleaning is possible(but the indication of part number may becomes unclear)
△	Cleaning is possible(Use caution. For recommendation, ◎and ○ are better)

b. Influence of coating

When using coating materials for insulation, waterproofing, dustproofing, rustproofing, etc., the material selected and how it is used may cause internal corrosion (chlorine reaction with aluminum) while the capacitor is being used, so be sure to observe the following.

● Corrosion reaction

Corrosion occurs when a halogen solvent infiltrates inside the capacitor through the rubber seal and it releases chlorine which reacts with the aluminum inside the capacitor.

● Criteria for selecting a coating

・It is necessary to select a coating material that contains no chlorine.
The composition of a coating can be mainly divided up into the main ingredient (urethane resin, acrylic resin or other polymer),solvent and various additives (flameproofing agent, etc.).
・The solvent dries and also diffuses (infiltrates) into the rubber seal, and therefore coating materials containing chloride (halogenated) hydrocarbon solvents should not be used.
・As with the solvent, additives can also infiltrate inside the capacitor through the rubber seal. However, their composition is often not known, so special care should be taken.

● Others

・The solvent, additives, etc., are sometimes changed without notice, so use caution.
・Avoid coating a substrate after cleaning it with a halogentated hydrocarbon solvent (the coating will prevent remaining solvent from diffusing, which may cause corrosion).

c. Influence of adhesives for anchoring

When adhesives for anchoring are used to improve resistance to vibration, the adhesive selected and how it is used may cause internal corrosion (chlorine reaction with aluminum) while the capacitor is being used, so be sure to observe the following.

● Criteria for selecting an adhesive

・An adhesive must be selected that does not contain chlorine. The composition of an adhesive can be mainly divided up into the main ingredient (rubber, resin or other polymer) and the solvent.
・The adhesive dries and also diffuses (infiltrates) into the rubber seal, and therefore adhesives containing chloride (halogenated) hydrocarbon solvents should not be used. Also, if the adhesive material containing organic solvents, such as xylene and toluene, are used. By sealing rubber and welling, you must be careful because you may want to influence the properties by entering the internal capacitor.

● Others

・Some solvents are often changed, so use caution.
・Avoid using an adhesive on a substrate after cleaning it with a halogenated hydrocarbon solvent. (The adhesive will prevent remaining solvent from diffusing, which may cause corrosion)
・The above adhesives were found to have no effect on electrolytic capacitors. Therefore, when using any of them. Make sure they present no problems (corrosion of copper foil on printed circuit board, effect other parts, current leakage due to moisture absorption by the adhesive, etc.) on the actual substrate to be used.
When applying adhesives and coating after cleaning, a thorough drying soon after cleaning is required to remove residual cleaning solvents which may be trapped between the capacitor sealing part and the print circuit board. For the surface of adhesives and coating, over 1/3 of sealing part should not be sealed.

5-5. Other precautions

(1) Environmental conditions

Capacitor should not be used and stored in the following environment. It may cause the failures, such as corrosion, disconnection and shot.

- Exceeded minimum & maximum temperatures.
- Direct contact with water, salt water, or oil.
- High humidity conditions where water could condense on the capacitor.
- Exposure to toxic gases (such as hydrogen sulfide, sulfuric acid nitric acid chlorine, or ammonia).
- Exposure to ozone, radiation, or ultraviolet rays.
- Vibration and shock conditions exceeding specified requirements in catalogs or specifications .

Room temperature and humidity, with no direct sunlight should be kept.

(2) Long term storage

Leakage current of a capacitor increases with long storage times. This is due to the deterioration of formed film at no load condition. Applying voltage decreases leakage current, but film repairing current flows a lot first, and this current surge could cause the circuit to fail. Therefore, aging is required to repair the film in advance after long term storage.

6-1. Power supply circuits

Stable DC power supplies are divided into intermittent control types (switching regulator) and continuous control types (Dropper).
Recent trends have shown an overwhelming growth in switching regulators, and so we talk mainly about switching regulators below.
The capacitors used in switching regulators are selected depending on the circuit.
A forward switching regulator is shown as an example in Flg.6-1. Another type is a flyback regulator.

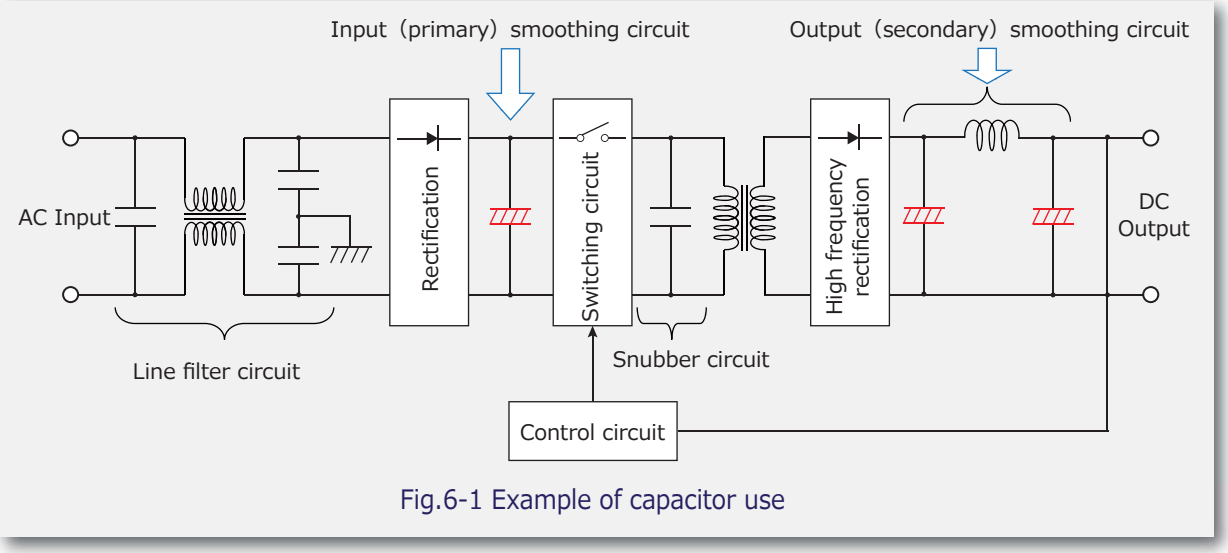


Fig.6-1 Example of capacitor use

[Examples of capacitor use]

① Line filter circuits	: Ceramic capacitors, Film capacitors
② Input smoothing circuits	: Aluminum electrolytic capacitors,(Laminated ceramic capacitors)
③ Snubber circuits	: Ceramic capacitors
④ Output smoothing circuits	: Aluminum electrolytic capacitors, Laminated ceramic capacitors, Film capacitors, Aluminum solid electrolytic capacitors, Tantalum electrolytic capacitors
⑤ Control circuits	: Ceramic capacitors, Film capacitors, Tantalum electrolytic capacitors, Aluminum electrolytic capacitors

(1) Aluminum electrolytic capacitors for input (primary) smoothing circuits

The Aluminum electrolytic capacitors for input smoothing circuits used on commercial voltages (100 V.AC, 200 V.AC) and commercial frequencies (60 Hz, 50 Hz) must have a high withstand voltage and a ripple current resistance complying with twice the commercial frequency (normally full-wave current).
These capacitors have large volumes (ground contact areas) compared to other components they are assembled with ,and so the demand for more compact capacitors, as well as power supplies, is strong. Another problem is the need for longer aluminum electrolytic capacitor lives, but products guaranteed for 5000 hours at 105℃ have recently been developed, thus realizing freedom from maintenance for 10 years.

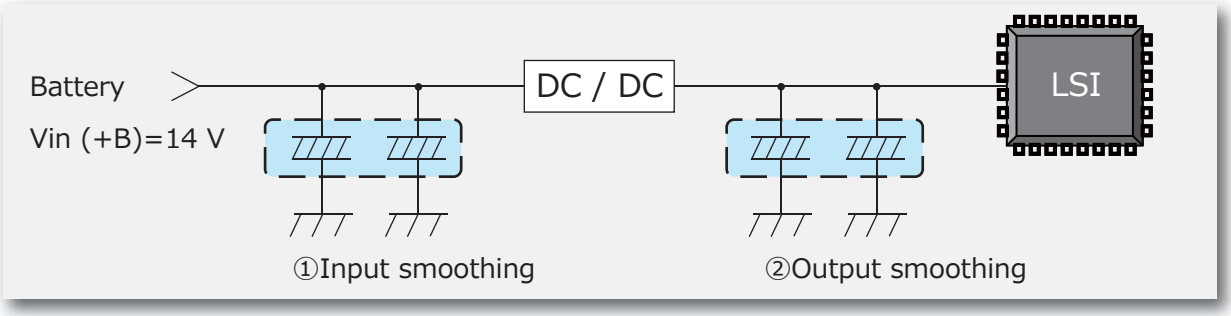
(2) Aluminum electrolytic capacitors for output smoothing circuits

The rated voltage of aluminum electrolytic capacitors used for smoothing at switching frequencies (20 k to 500 kHz) is determined by the output voltage, and they must have low impedance (low ESR) at switching frequencies.
Therefore aluminum electrolytic capacitors for output smoothing are designed to have low impedance at 20 k to 500 kHz, and the recent development of a low resistance electrolyte using new materials has resulted in products with 1/3 to 1/4 the impedance of conventional products with the same volume.
These low impedance products also have an extremely stable life.

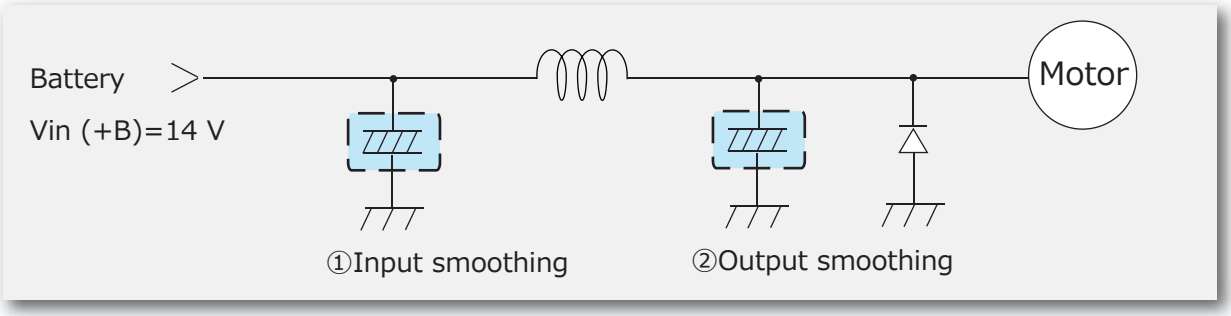
6-2. ECU for automotive

The electronization of in-vehicle control is accelerating these days.
ECU (electrical control unit) which carries out in-vehicle control is asked for high reliance, a miniaturization, and high quality, and many aluminum electrolytic capacitors are used for it.
A typical application example is shown below.

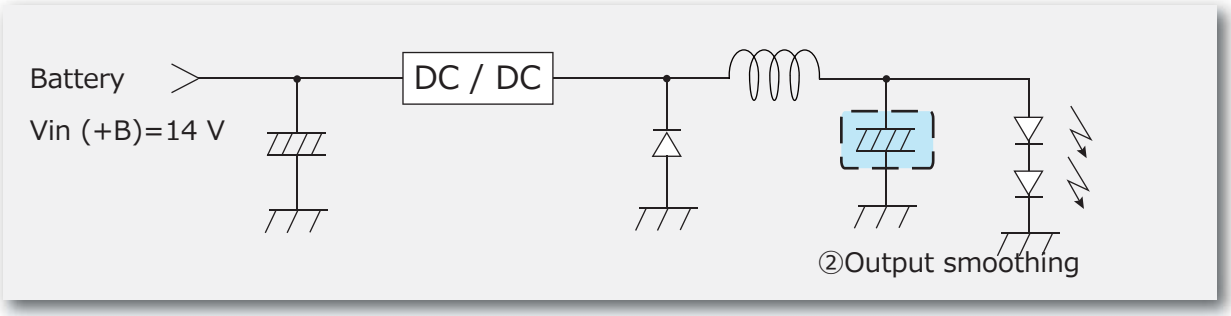
(1) Power train ECU (Engine、HV-Inverter etc.)



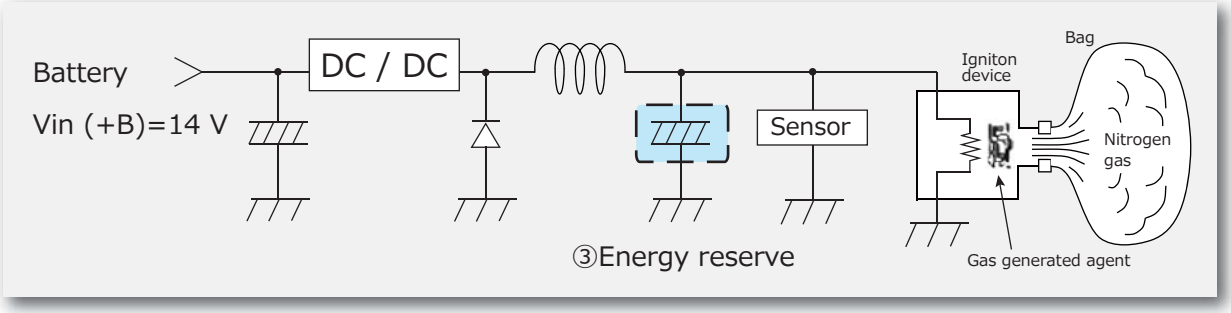
(2) Motor control ECU（Power steering, a blower / radiator fan motor, an electric pump etc.)



(3) LED lump



(4) Airbag



In automotive application, there are mainly an object for smoothing of input and output of the power supply of ECU and an object for energy reserve.
The rated voltage of 25 to 50 V.DC is mainly used.
Not only current aluminum capacitor, aluminum capacitor with conductive polymer and electrolyte is increasing due to improve quality, performance, with standing-voltage.
It contributes to the small size of ECU, and a weight saving these days.

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