6. Use technique of Aluminum Electrolytic Capacitors

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

6 – 1 Life Design

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 6-2 become the reason to shorten the life under the abnormal condition, but don't cause any problems under the normal condition.

There fore, "85℃ 2000 hours" is described as an example of guaranteed life of aluminum electrolytic ca-

85℃ 2000 h

- **Ambient temperature of aluminum electrolytic capacitor**
- **+ Heat generation of aluminum electrolytic capacitor by ripple current**

→ Temperature of aluminum electrolytic capacitor

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

1) Low ripple current

When ripple current of capacitor is lower than rated ripple current (normally, less than 1/3 of rated value), ignore the heat generation and think ambient temperature as the temperature of aluminum electrolytic capacitor.

However, it should be the condition which electronic equipment is working and the most heat generated.

If there are parts which have large heat generation on back of the board and the temperature of capacitor terminal (below part) is higher, make sure it will be the capacitor temperature.

2) High ripple current

If ripple current is high, the heat generation can not be ignored. Theoretically, calculation seems possible, but it's actually not because of unknown factor. Therefore, for high ripple current, you can stick thin thermocouple on the top of aluminum electrolytic capacitor of wound unit center, etc. and mesure the

(2) 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 100℃. Therefore, expected life at operating temperature can be described in equation (1). Also, for quick calculation, see Fig.13.

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

L :Expected life of capacitor (hour)
T :Temperature of capacitor (for above (1))
L_0 :Guaranteed life of capacitor
T_0 :Mazimum guaranteed temperature of capacitor

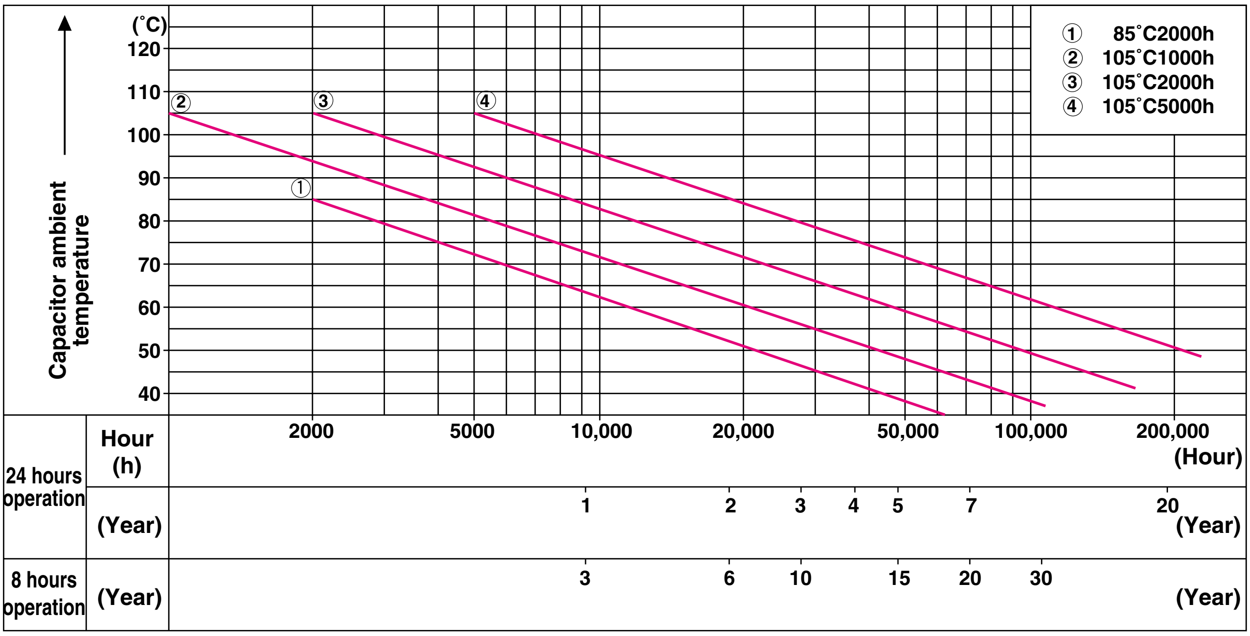


Fig.13 Delating Life Time Quick Reference Guide

- **Example**
  1) Expected life of equipment (requested life)

     A:10 years with 24h operation B:10 years with 8h operation a day

  2) Ambient temperature of capacitor

     65˚C (Check • no heat generated part on reverse or around)

- **Life calculation**
  1) For use 85˚C 2000h guarantee

     $L = 2000 \times 2^{\frac{85-65}{10}}$

     $= 2000 \times 2^{2} \doteqdot 8000$ Use temperature 65˚C & expected life 8000h

  2) For use 105˚C 2000h guarantee

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

     $= 2000 \times 2^{4} \doteqdot 32000$ Use temperature 65˚C & expected life 32000h

- **Capacitor selection**
  1) A : For 10 years with 24h operation

     L = 24(hour)X 365(day)X 10(year)

     = 87600(hour) ← Working hours for 10 years

     105˚C 2000h product does not satisfy the expected life, so that ambient temperature should be more lower.

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

     L = 8(hour)X 365(day)X 10(year)

     = 29200(hour) ← Working hours for 10 years

     105˚C2000h product can be used, not 85˚C 2000h product.

6 – 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. Design redundant or secondary circuits where is possible to assure continued operation in case of main circuit failure.

The following six points should be considered for circuit design when using 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 OK ?	Shorter life, capacitor breakdown
(4) Charge/ Discharge	The circuit is not often repeated charge discharge ?	Shorter life, leakage current increase, capacitor breakdown
(5) Temperature characteristics	Especially, checked circuit operation at low temperature side ?	Electrical characteristics change
(6) Frequency characteristics	Checked circuit operation at high frequency range ?	Electrical characteristics change

※ Capacitor breakeown:Appearance change (Sealing part transformed) • Electrolyte leakage 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 reoccured current on motor through-

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

(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.

Withstand voltage is decided by the thickness of oxide film. Therefore, when applying reverse voltage, the following reaction is occured by film self-reparing action because of no oxide film on the cathode.

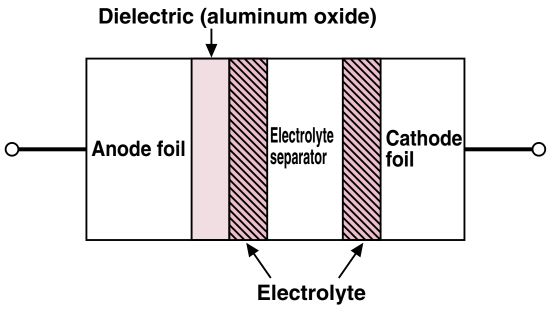


Fig.14

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

$$2H^+ + 2e^- \longrightarrow H_2\uparrow$$

Therefore, applying long-term reversed voltage, excessive reversed voltage and continuous pulse cycle reversed voltage may 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 value in that gives the ripple current stress occuring at all the frequencies which affect life the same coefficient.

As shown in Fig.15, 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.

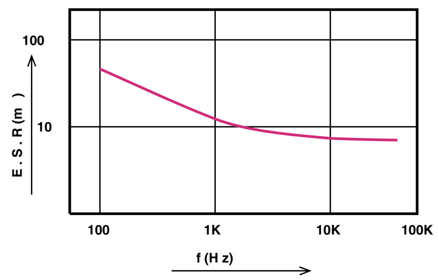


Fig.15 ESR vs frequency
(Populer characteristics change)

Theoretically, where the equivalent series resistance at a certain frequency f is ESR (f Hz) and the ripple current i (f Hz), and each at 120 Hz are

$$i^2 (120Hz) \cdot ESR(120Hz) = i^2 (fHz) \cdot ESR(fHz) \quad \text{(Equation 2)}$$

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

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

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

At 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) Hard 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 design described in 6-1 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 tantalum electrolytic capacitor, aluminum electrolytic capacitor used liquid electrolyte has more conductivity change. It makes temperature change worse, Fig.16 shows the general electrical characteristics change by temperature.

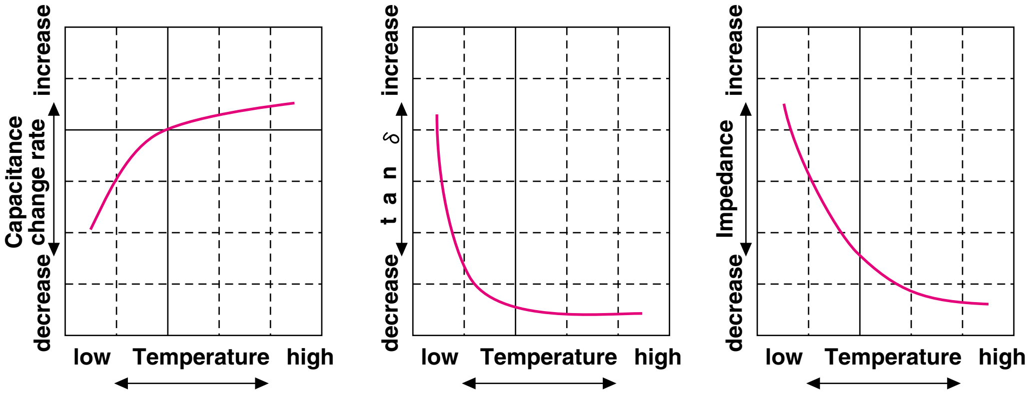


Fig.16 Electrical characteristics change by temperature

(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 compared to solid electrolyte. Fig.17 shows the general electrical characteristics

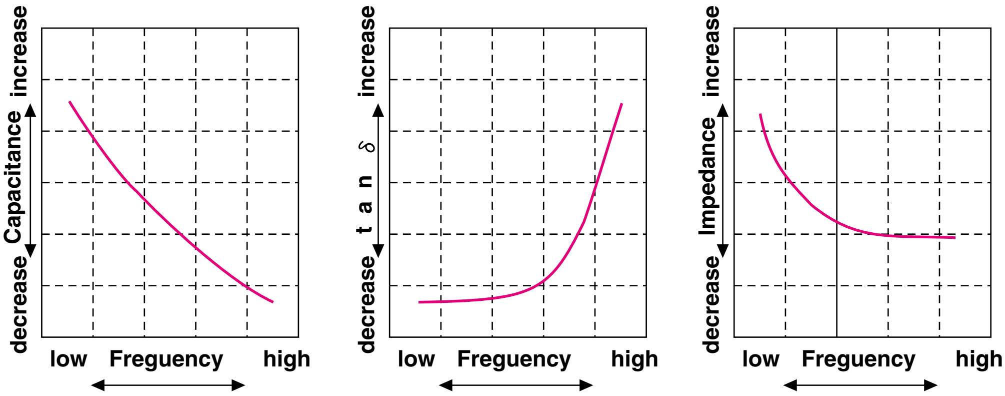


Fig.17 Electrical characteristics change by frequency

(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

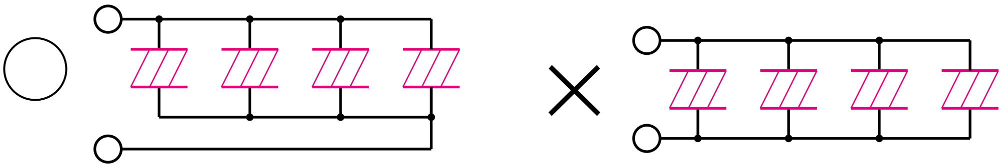


Fig.18 Connected in parallel

2) Capacitors connected in series

Considering voltage imbalance, less than rated voltage should be applied to each capacitor (U_R) voltage balance may lose, and excessive voltage may apply.

To avoid the excessive voltage, the voltage divider shunt resistors with consideration to leakage currents should be set in series with each capacitor.

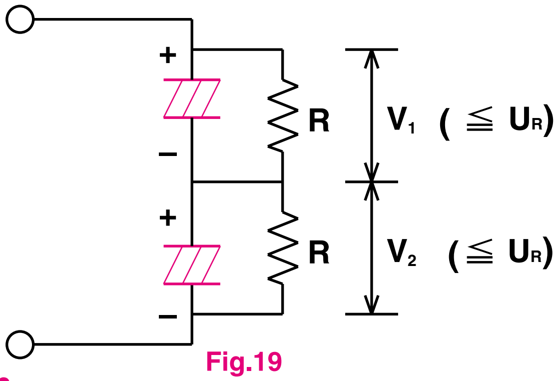


Fig.19

6 – 3 Installation Design

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

Precaution on design	Phenomenon (influence)
(1) No wiring pattern under the sealing part of capacitor ?	Disconnection • Short circuit (migration)
(2) No heating component placed around the capacitor ?	Greatly influence on life (capacitance reduction, tan δ increase)
(3) Ambient temperature of capacitor is clear ?	Disconnection, short circuit, increase of leakage current
(4) 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. Dissolution & ignition of wiring
(5) 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) Sealing part (screw terminal) is not using downward ?	Explosion due to non-working of the pressure relief vent

(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 environment 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.8, characteristics of aluminum electrolytic capacitor are changed by electrolyte penetration and emission. Electrolyte is penetrated to the bottom of capacitor with the time passing for route a in Fig.9. 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 wirings may occur.

1) Moisture 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 If activated agents and cleaning solvents in soldering contain halogenated substance, remnants of halogenated substance accelerate corrosion.

4) 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

(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 6-1, life design 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 misjudgement in life design at ambient temperature. It differs more than 5˚C between ambient temperature

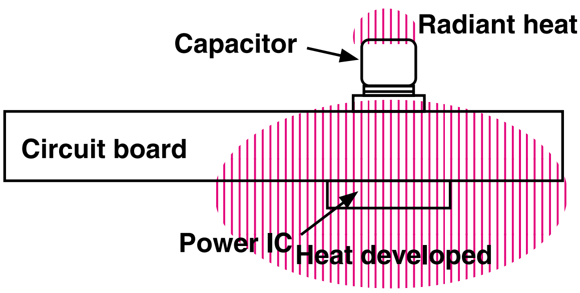
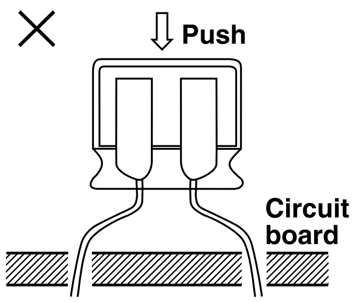


Fig.20 Influence to Heat Components

(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, this, 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.

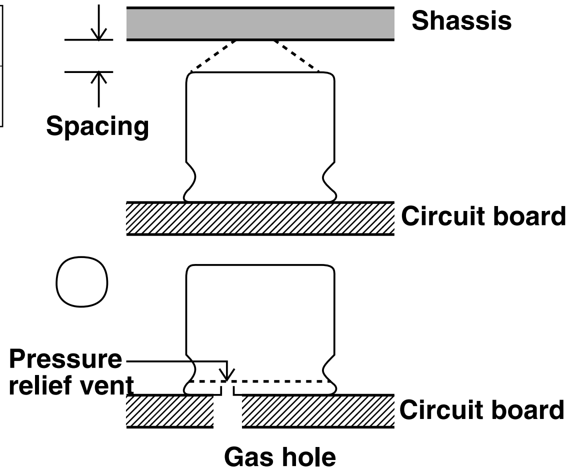
For lead terminal products, terminal processed products



(4) Consideration for the pressure relief vent

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

Product diameterø	6.3~16mm	18~35mm	Over 40mm
Spacing	Over2mm	Over3mm	Over5mm

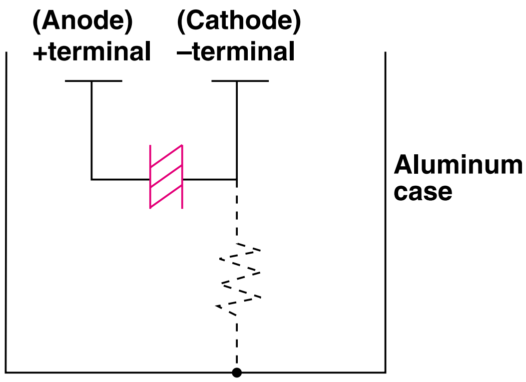


A hole in the circuit board directly under the seal vent location is required to allow proper release of pressure.

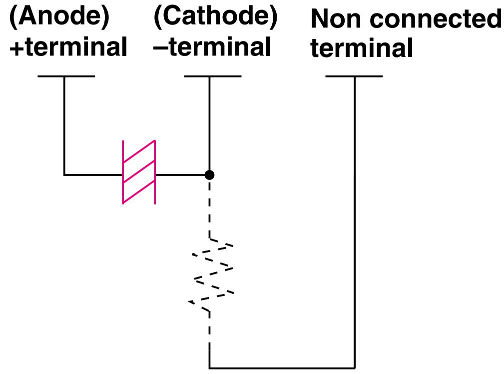
- Avoid wiring and circuit pattern above the pressure relief vent. Flammable, high temperature gas exceeding 100˚C may be released which could dis-

(5) Electrical isolation of the capacitor

- Completely isolate the capacitor as follows.
  1) Between the cathode terminal and the case (except for axially leaded type) and between the anode terminal and other circuit patterns.
  2) Between the extra mounting terminals and other anode terminals, cathode terminal, and circuit patterns.



- The sleeve is not meant to insulate the capacitor. If you like insulation by sleeve, please consult us showing voltage condition, etc.



6 – 4 Mounting method • condition

6 – 4 – 1 Installation

The followings should be noted when installing Aluminum electrolytic capacitor.

Precausion on mounting	Phenomenon (influence)
(1) Verify the polarity of capacitor.	Capacitor breakdown by applying the reverse voltage, such as blowout, short cir-
(2) • For manual soldering, if it's not specified, do not exceed 350°Cfor 3 seconds or less. • For flow soldering, if it's not specified, do not exceed 260°Cfor 10 seconds or less. • For heat curing, do not exceed 150°C for max 2 minutes.	Appearance change due to the rise of internal pressure, blowout Crack of vinyl sleeve, contraction
(3) • If the fastening torque of terminal screw is too strong, it will be damaged. Rotation torque should be max 3.0Nm. • The fastening torque of fixtures should be max 1.6Nm. (max 1.2Nm for M3 screw) • Over 1/3 of sealing part should not be sealed.	Large contact resistance Isolation withstand voltage of vinyl sleeve gets lower.

6 – 4 – 2 Cleaning, Additives, Coating

	Precaution on Cleaning, Mounting adhesives, Coating	Phenomenon (influence)
(1)Circuit board cleaning	• Halogenated (especially, chrdine) cleaning solvents can not be used. When cleaning, use the capacitor with guarantee.	Corrosion, disconnection
(2) 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 shown 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 permeate 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 the cleaning.

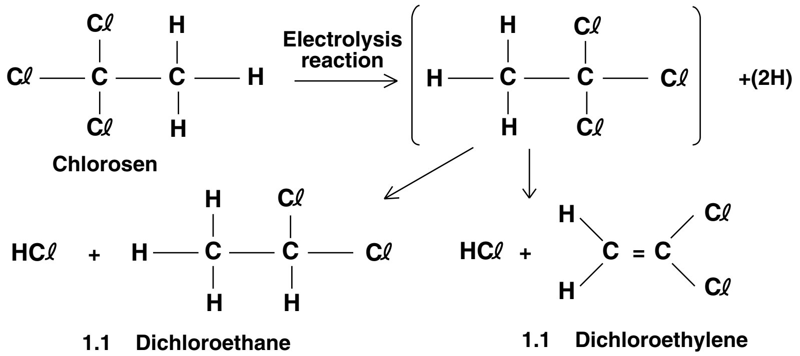


Fig.24 Decomposed reaction of cleaning solvents (Free-chrorine)

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

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)

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

D) Precipitation of aluminum hydroxide

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

A)~D) Reaction complied A) through D)

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

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-3 and 4 show the propriety of cleaning solvents. (Table-5 shows cleanable series by Table-4, replaced cleaning solvents.)

Do not use ozone destructive substance as a cleaning solvents in order to protect the global environ-

(1) Cleaning solvents

Table-3 Solvents that can't be used

Composition	Boiling point (°C)	Common name (example)
1.1.1-Trichloroethane	74.1	Chlorosen
Trichloroethylene	87.2	Trichlene
Tetrachloroethylene	121.1	Perchloroethylene

Table-4 The propriety of replace cleaning solvents

Kind of solvents		Solvents name	Manufacture	Judgement mark	Remark
Water base	Water	Pure water		◎	No problem
	Allaline soponifying agent	Aqua cleaner 210SEP	Sanei Kagaku	○	No problem Readout ink might be erased Aviod using blush
	Surface active agent	Pine Alpha ST-100S	Aralawa Kasei Kogyo	○	
		Clean-thru 750H	Kao corp.	○	
		Clean-thru 750L		○	
		Clean-thru 710M		○	
		Sun-elec B-12	Sanyo Kasei	○	
		DK be-clean 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 well right after washing
		Techno-cleaner 219	Seiwa Sangyo	△	
		Axarel 32	Mitsui DFC	△	
	Alcohol base	Isoproypyle alcohol		◎	No problem
	Silicon base	Techono-care FRW-17	Toshiba Corp.	△	No problem if you use these combination
		Techono-care FRW-1			
		(Techono-care FRV-100)			
	Halogenated hydrocarbon	Asashi-clean AK-225AES	Ashahi Glass	△	CF base solution Not recommended, might be hamful to the environment
		HCFC141b-MS	Daikin Kogyo	△	
	Telpen base	Telpen-cleaner EC-7R	Nippon Alpha Metals	△	Swelling sealing rubber may swell, poor ejecting

(Reference of judging mark)

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.)

Table-5 Cleanable series with Replaced Freon Cleaning Solvents
(Cleanable series with cleaning solvents in Table-4)

Type	Series	Cleaning
Chip	All V type	○
Lead wire type	SU	○(~250V)
	Bi-polar SU	○
	M	○ (~250V)
	KA	○
	Bi-polar KA	○
	KG	○
	KF	○
	HFQ	○
	HFZ	○
	FA	○
	FB	○
	FC	○
	GA	○
	NHE	○ (~100V)
	NHG	○ (~100V)
Snap-in type	TS typeUP	○ (~100V)
	TS typeHA	○ (~100V)

(2) Influence of Coating Materials

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 Material

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 halogenated hydrocarbon solvent (the coating will prevent remaining solvent from diffusing, which may cause corrosion).

•The coatings that can be used are listed in Table-6. These are coating which have been found by this company in the past 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 on other parts, etc.) on the actual substrate to be used.

Table-6 Coating Materials that Can Be Used
(These are materials confirmed by this company to present no problem)

Manufacturer	Material	Coating material name
Hitachi Chemical	Acrylic	Taffi-1141, Taffi-1147
	Urethane	Taffi-1154
Boxy Brown	Acrylic	Humi Seal 1B66
	Urethane	Humi Seal 1A27
Dow Corning	Silicon	Perugan Z, Perugan C
Nihon Zeon	Urethane	Quinate System 160B

If you have any other questions, please consult us.

(3) 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.

Table-7 Adhesives for Anchoring that Can Be Used
(These are adhesives confirmed by this company to present no problem)

Manufacturer	Material	Adhesive name
Cemedine	Nitrile rubber	210, 501, 540, 545N
Nogawa Chemical	Nitrile rubber	DN83K
	Polyamide	DA–3241
Konishi	Nitrile rubber	G103
	Urethane	G350

○ 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 o 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.

6 – 5 Operation and Storage

(1) Operation and storage environment

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

- 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

★ Point

● For the storage over 12 months, capacitor should be reconditioned by applying rated voltage. (Applying rated voltage in series with a 1000Ω, current limiting resistor for 30 minutes.)

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.

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