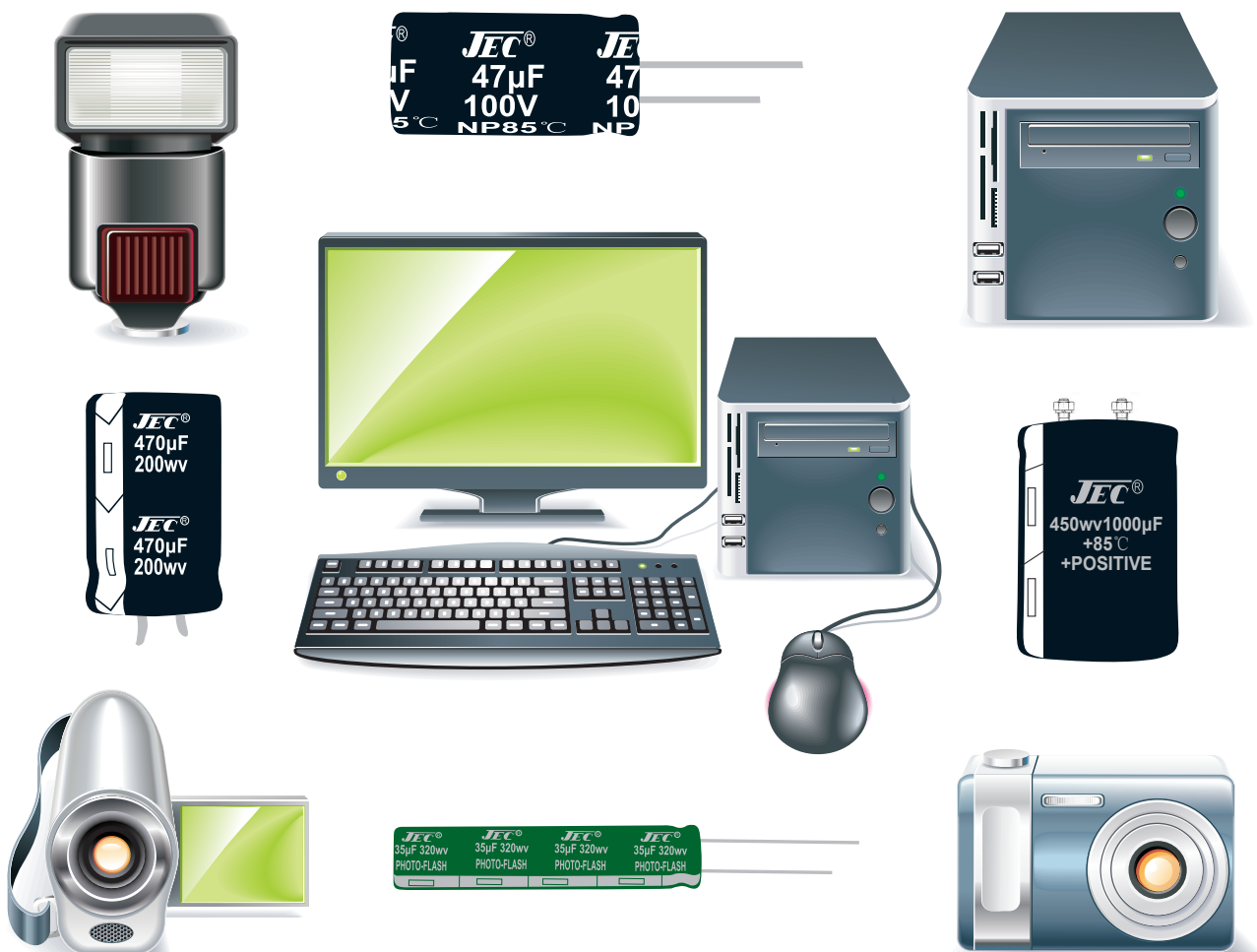




Aluminum Electrolytic Capacitors

CATALOGUE



JOHNSON ELECTRIC ENTERPRISE CO.,LTD.(T.W)

DONGGUAN JOHNSON ELECTRIC CO.,LTD.(CHINA)

鋁電解電容器規格一覽表

ALUMINUM ELECTROLYTIC CAPACITORS LIST OF PRODUCTS

類別 Regimentation	系列	電器特性	定格電壓	靜電容量	溫度範圍	頁次
	SERIES	Electrical Characteristics	RATED VOLTAGE(V)	RATED CAPACITANCE (uF)	CATEGORY TEMPERATURE RANGE(°C)	PAGE
Photo-Flash Lead Wire	STM	55°C For Photo-Flash lead wire	300-360	30-300	-20+55	19
Photo-Flash Lead Wire Mini size	STMS	55°C For Photo-Flash lead wire	300-330	10-80	-20+55	22
Photo-Flash Lead Wire	STMF	55°C For Photo-Flash lead wire (special shapes)	300-330	10-80	-20+55	25
Photo-Flash Snap-in	STL	55°C For Photo-Flash Snap-in	330-360	220-6800	-20+55	27
For Flash Lamps	STK	70°C Long Life under rapid charge and discharge use snap-in	360-450	220-2500	-20+70	29
General Purpose	RM	105°C Standard 1000 hours	10-250	1-10000	-40+85	31
			350-450	2.2-220	-25+105	
	KM	105°C Standard 2000 hours	10-250	1-10000	-40+105	34
			350-450	2.2-220	-25+105	
	LM	105°C Mini Size Standard 2000 hours	10-63	10-10000	-40+105	37
			160-450	1-220	-25+105	
Long Life	LX-H	105°C Long life 3000 hours	160-450	22-330	-25+105	40
	LX	105°C High Frequency,Low impedance 3000 hours	6.3-50	220-6800	-40+105	42
	LX-L	105°C High Frequency,Low impedance 5000 hours	6.3-50	47-5600	-40+105	44
	LF	105°C miniature size slim volume 5000 hours	250-450	33-390	-25+105	46
	LH	105°C High ripple,Long life 8000 hours	160-450	4.7-150	-25+105	49
	LH-L	105°C High ripple, Long life 3000-8000 hours	6.3-100	22-6800	-40+105	51
	HR	105°C High ripple,Long life 10000 hours	160-450	10-330	-25+105	54

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	SERIES	Electrical Characteristics	RATED VOLTAGE(V)	RATED CAPACITANCE	CATEGORY TEMPERATURE RANGE(°C)	PAGE
				(uF)		
Long Life	HR-L	105°C High ripple, Long life 4000-10000 hours	6.3-100	22-6800	-40+105	56
	HX-L	125°C Long Life 3000 hours	6.3-50	47-4700	-40+125	59
	HX	125°C Long Life 3000 hours	160-450	4.7-150	-40+125	61
Snap-in Type	RS	85°C Snap-in type 2000 hours	16-450	47-68000	-25+85	63
	KS	105°C Snap-in type 2000 hours	16-450	47-68000	-25+105	66
	RP	85°C Low profile 20mm 2000 hours	160-450	33-470	-25+85	69
	KP	105°C Low profile 20mm 2000 hours	160-450	33-470	-25+105	71
Lug Terminal Type	KSL	105°C With horizontal mounting snap-in 3000 hours	160-450	68-1500	-25+105	73
Screw Terminal Type	SWR	85°C Standard screw terminal typr 3000 hours	50-100	2200-150000	-40+85	75
			160-450	270-33000	-25+85	
	SWK	105°C Standard screw terminal typr 3000 hours	50-100	2200-150000	-40+105	77
			160-450	270-33000	-25+105	
Non Polarized Aluminum Electrolytic Capacitors	RKP	NP for Speaker Crossover Network	50-100	1-1000	-40+85	79
	RNP	General NP for Crossover Network	50-100	100-1000	-40+85	81
	TKP	Axial NP for Speaker Crossover Network	50-100	1-1000	-40+85	83
	TNP	Axial General NP for Crossover Network	50-100	100-1000	-40+85	85
	AKP	Axial Spot NP for Speaker Crossover Network	50-100	1-1000	-40+85	87

Aluminum Electrolytic Capacitors

Standard

RM
105°C

KM
105°C

LM
105°C

High Reliability

LF 105°C
Miniature Size Slim Volume
Long Life, High Ripple;

Power Supply Or High Frequency Use

LH-L 105°C
Low Voltage
8000 HRS

LH 105°C
Long Life 8000
HRS

LX-L 105°C
Low Voltage
5000 HRS

LX-H 105°C
3000 HRS

LX 105°C
Low Voltage
3000 HRS

HR 105°C
Long Life
10000 HRS

HR-L 105°C
Low Voltage
10000 HRS

RS 85°C
Snap-in Type
2000 HRS

KSL 105°C
Lug Terminal
Type 3000HRS

KP 105°C
Snap-in Type
H=20mm 2000 HRS

RP 85°C
Snap-in Type
H=20mm 2000 HRS

KS 105°C
Snap-in Type
2000 HRS

High Temperature

HX 125°C
3000 HRS

HX-L 125°C
3000 HRS

PHOTO-FLASH

STM
55°C

STMF
55°C

STL
55°C

STMS
55°C

STK
70°C

Aluminum Electrolytic Capacitors**SCREW TERMINAL TYPE****SWR 85°C
3000 HRS****SWK 105°C
3000 HRS****NON POLARIZED FOR CROSSOVER NETWORK****TNP 85°C
Axial General NP
For Crossover
Network****TKP 85°C
Axial NP For
Speaker Crossover
Network****RNP 85°C
General NP For
Crossover
Network****RKP 85°C
NP For Speaker
Crossover
Network****AKP 85°C
Axial Spot NP For
Speaker Crossover
Network****NP 85°C
Standard**

產品編號

PARTS NUMBER SYSTEM

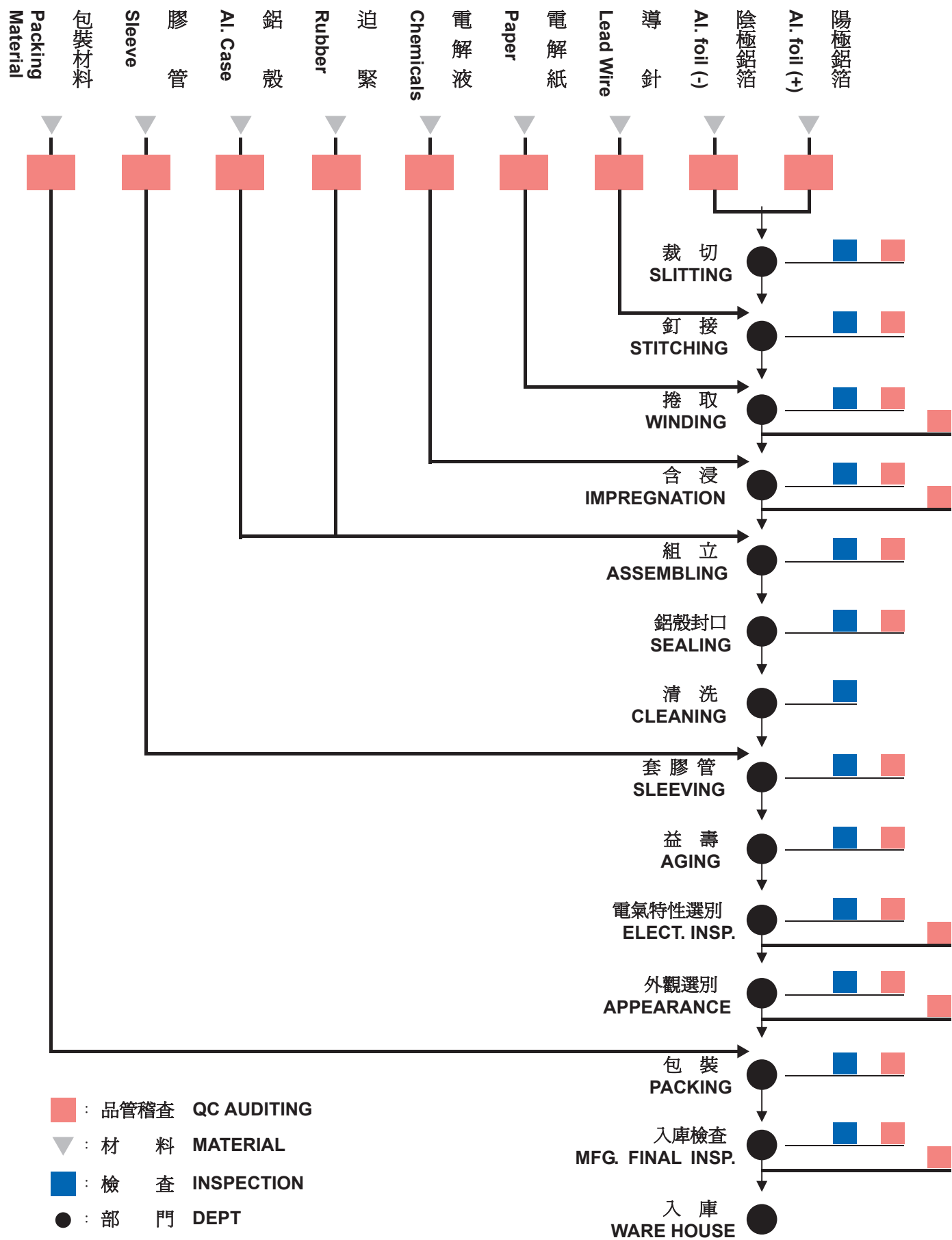
標準編號

1	2	3	4	5	6	7	8	9	10	11	12	13
E	K	M	1	0	1	M	4	0	0	L	3	6
E.CAP	SERIES		CAPACITANCE (μ F)			CAP. TOL.	VOLTAGE (w.v.)		CASE (ϕ D mm)		SIZE (L. mm)	

Series	Cap.	Code	Tolerance %	Code	Voltage	Code	Diameter	Code
LM	0.47	R47	+10	K	4	004	4	C
RM	1	1R0	-10		6.3	6.3	5	D
KM	2.2	2R2	+15	L	10	010	6	W
LX	3.3	3R3	-15		16	016	8	F
LX-L	4.7	4R7	+20	M	25	025	9.2	E2
LX-H	10	100	-20		35	035	9.5	E5
RS	22	220	+20	V	50	050	10	G
KS	33	330	-10		63	063	10.6	G6
HX	47	470	+5	J	80	080	11	S
HX-L	100	101	-5		100	100	12	H
LF	220	221	+20	R	160	160	12.5	H5
LH	330	331	-0		200	200	13	J
HR	470	471	+20	H	250	250	13.5	J5
RP	1000	102	-5		300	300	14	V
KP	2200	222			330	330	14.5	V5
KP	3300	332			360	360	15	Y
KSL	4700	472			400	400	16	K
SWR	10000	103			450	450	18	L
SWK	22000	223					20	M
STM	33000	333					22	N
STL	47000	473					25	O
STK	68000	683					30	P
STMS							35	Q
STMF							40	R
							50	T
							63	U
							76	X

電解電容器製造工程圖

ELECTROLYTIC CAPACITOR FLOW CHART



Designing Device

(1) Select the capacitors to suit installation and operating conditions, and use the capacitors to meet the performance limits prescribed in this catalog or the product specifications.

(2) Polarity

Aluminum Electrolytic Capacitors are polarized.

Apply neither reverse voltage nor AC voltage to polarized capacitors. Using reversed polarity causes a short circuit or venting. Before use, refer to the catalog, product specifications or capacitor body to identify the polarity marking. (The shape of rubber seal does not represent the directional rule for polarity.) Use a bi-polar type of non-solid aluminum electrolytic capacitor for a circuit where the polarity is occasionally reversed.

However, note that even a bi-polar aluminum electrolytic capacitor must not be used for AC voltage applications.

(3) Operating voltage

Do not apply a DC voltage which exceeds the full rated voltage. The peak voltage of a superimposed AC voltage (ripple voltage) on the DC voltage must not exceed the full rated voltage.

A surge voltage value, which exceed the full rated voltage, is prescribed in the catalogs, but it is a restricted condition, for especially short periods of time.

(4) Ripple current

The rated ripple current has been specified at a certain ripple frequency. The rated ripple current at several frequencies must be calculated by multiplying the rated ripple current at the original frequency using the frequency multipliers for each product series.

For more details, refer to the paragraph of Life of Aluminum Electrolytic Capacitors.

(5) Category temperature

The use of a capacitor outside the maximum rated category temperature will considerably shorten the life or cause the capacitor to vent.

The relation between the lifetime of aluminum electrolytic capacitor and ambient temperature follows Arrhenius' rule that the lifetime is approximately halved with each 10°C rise in ambient temperature.

(6) Life expectancy

Select the capacitors to meet the service life of a device.

(7) Charge and discharge

Do not use capacitors in circuits where heavy charge and discharge cycles are frequently repeated. Frequent and sharp heavy discharging cycles will result in decreasing capacitance and damage to the capacitors due to generated heat. Specified capacitors can be designed to meet the requirements of charging-discharging cycles, frequency, operating temperature, etc.

(8) Failure mode of capacitors

Non-solid aluminum electrolytic capacitors, in general, have a lifetime which ends in an open circuit, the period is dependent upon temperature. Consequently, lifetime of capacitors can be extended by reducing the ambient temperature and/or ripple current.

(9) Insulating

a) Electrically isolate the following parts of a capacitor from the negative terminal, the positive terminal and the circuit traces.

- The outer can case of a non-solid aluminum capacitor.
- The dummy terminal of a non-solid aluminum capacitor, which is designed for mounting stability.
- The dummy terminal of a surface mount type capacitor such as non-solid type capacitors.

b) The outer sleeve of a capacitor is not assured as an insulator. For applications that require an insulated outer sleeve, a custom-design capacitor is recommended to.

(10) Condition

Do not use/expose capacitors to the following conditions.

- a) Oil, water, salty water take care to avoid storage in damp locations.
- b) Toxic gases such as hydrogen sulfide, sulfurous acid, nitrous acid, chlorine or its compounds, and ammonium.
- c) Ozone, ultraviolet rays or radiation.
- d) Severe vibration or mechanical shock conditions beyond the limits prescribed in the catalogs or the product specification.

(11) Mounting

a) The paper separators and the electrolytic-conductive electrolytes in a non-solid aluminum electrolytic capacitor are flammable.

Leaking electrolyte on a printed circuit board can gradually erode the copper traces, possibly causing smoke or burning by short-circuiting the copper traces.

Verify the following points when designing a PC board.

·Provide the appropriate hole spacing on the PC board to match the terminal spacing of the capacitor.

·Make the following open space over the vent so that the vent can operate correctly.

Case diameter	Clearance
Φ6.3 to Φ16mm	2mm minimum
Φ18 to Φ35mm	3mm minimum
Φ40mm and up	5mm minimum

·Do not place any wires or copper traces over the vent of the capacitor.

·Installing a capacitor with the vent facing the PC board needs an appropriate ventilation hole in PC board.

·Do not pass any copper traces beneath the seal side of a capacitor. The trace must pass 1 or 2mm to the side of the capacitor.

·Avoid placing any heat-generating objects adjacent to a capacitor or even on the reverse side of the PC board.

·Do not pass any via holes or underneath a capacitor.

·In designing double-sided PC boards, do not locate any copper trace under the seal side of a capacitor.

b) Do not mount the terminal side of a screw mount capacitor downwards. If a screw terminal capacitor is mounted on its side. Make sure the positive terminal is higher than the negative terminal.

Do not fasten the screws of the terminals and the mounting clamps over the specified torque prescribed in the catalog or the product specification.

c) For a surface mount capacitor, design the copper pads of the PC board in accordance with the catalog or the product specifications.

(12) Others

a) The electrical characteristics of capacitors vary in respect to temperature, frequency and service life. Design the device circuits by taking these changes into account.

b) Capacitors mounted in parallel need the current to flow equally through the individual capacitors.

c) Capacitors mounted in series require resistors in parallel with the individual capacitors to balance the voltage.

Installing Capacitors**(1) Installing**

- a) Used capacitors are not reusable, except in the case that the capacitors are detached from a device for periodic inspection to measure their electrical characteristics.
- b) If the capacitors have self charged, discharge in the capacitors through a resistor of approximately 1K Ω before use.
- c) If capacitors are stored at a temperature of 35°C or more and more than 75% RH, the leakage current may increase. In this case, they can be reformed by applying the rated voltage through a resistor of approximately 1K Ω .
- d) Verify the rated capacitance and voltages of the capacitors when installing.
- e) Verify the polarity of the capacitors.
- f) Do not use the capacitors if they have been dropped on the floor.
- g) Do not deform the cases of capacitors.
- h) Verify that the lead spacing of the capacitor fits the hole spacing in the PC board before installing the capacitors. Some standard pre-formed leads are available.
- i) For pin terminals or snap-in terminals, insert the terminals into PC board and press the capacitor downward until the bottom of the capacitor body reaches PC board surface.
- j) Do not apply any mechanical force in excess of the limits prescribed in the catalogs or the product specifications of the capacitors.

Also, note the capacitors may be damaged by mechanical shocks caused by the vacuum/insertion head, component checker or centering operation of an automatic mounting or insertion machine.

(2) Soldering and Solderability

- a) When soldering with a soldering iron
 - Soldering conditions (temperature and time) should be within the limits prescribed in the catalogs or the product specifications.
 - If the terminal spacing of a capacitor does not fit the terminal hole spacing of the PC board, reform the terminals in a manner to minimize a mechanical stress into the body of the capacitor.
 - Remove the capacitors from the PC board, after the solder is completely melted, reworking by using a soldering iron minimizes the mechanical stress to the capacitor.
 - Do not touch the capacitor body with the hot tip of the soldering iron.
- b) Flow soldering
 - Do not dip the body of a capacitor into the solder bath but only dip the terminals in. The soldering must be done on the reverse side of PC board.
 - Soldering conditions (preheat, solder temperature and dipping time) should be within the limits prescribed in the catalogs or the product specifications.
 - Do not apply flux to any part of capacitors other than their terminals.
 - Make sure the capacitors do not come into contact with any other components while soldering.
- c) Reflow soldering
 - Soldering conditions (preheat, solder temperature and dipping time) should be within the limits prescribed in the catalogs or the product specifications.
 - When setting the temperature infrared heaters, consider that the infrared absorption causes material to be discolored and change in appearance.
 - Do not solder capacitors more than once using reflow.

If you need to twice, be sure to consult us.

- Make sure capacitors do not come into contact with copper traces.
- d) Do not re-use surface mount capacitors which have already been soldered.

In addition, when installing a new capacitor onto the assembly board to rework, remove old residual flux from the surface of the PC board, and then use a soldering iron within the prescribed conditions.

(3) Handling after soldering

- Do not apply any mechanical stress to the capacitor after soldering onto the PC board.
- a) Do not lean or twist the body of the capacitor after soldering the capacitor onto the PC board.
- b) Do not use the capacitors for lifting or carrying the assembly board.
- c) Do not hit or poke the capacitor after soldering to PC board. When stacking the assembly board, be careful that other components do not touch the aluminum electrolytic capacitors.
- d) Do not drop the assembly board.

(4) Cleaning PC board

- a) Do not wash capacitors by using the following cleaning agents;
 - Solvent-proof capacitors are only suitable for washing under the cleaning conditions prescribed in the catalogs or the product specifications. In particular, ultrasonic cleaning will accelerate damaging capacitors.
 - Halogenated solvents; cause capacitors to fail due to corrosion.
 - Alkali category solvents; corrode (dissolve) an aluminum case.
 - Petroleum category solvents; cause the rubber seal material to deteriorate.
 - Xylene solvents; cause the rubber seal material to deteriorate.
 - Acetone solvents; erase the marking.
- b) Verify the following points when washing capacitors.
 - Monitor conductivity, Ph, specific gravity, and the water content of cleaning agents. Contamination adversely affects these characteristics.
 - Be sure not to expose the capacitors under solvent rich conditions or keep capacitors inside a closed container. In addition, please dry the solvent sufficiently on the PC board and the capacitor with an air knife (temperature should be less than the maximum rated category temperature of the capacitor) over 10 minutes.

Aluminum electrolytic capacitors can be characteristically and catastrophically damaged by halogen ions, particularly by chlorine ions, though the extent of the damage mainly depends upon the characteristics of the electrolyte and rubber seal material. When halogen ions come into contact with the capacitors, the foil corrodes when voltages applied. This corrosion causes extremely high leakage current which causes in line with venting and an open circuit.

Global environmental warnings (Greenhouse effects and other environmental destruction by depletion of the ozone layer), new types of cleaning agents have been developed and commercialized as substitutes for CFC-113, 1, 1, 2-trichloroethylene and 1, 1, 1-trichloroethylene. The following are recommended as cleaning conditions for some of new cleaning agents.

—Higher alcohol category cleaning agents

Recommended cleaning agents:

Pine Alpha ST-100S (Arakawa Chemical)

Clean Through 750H, 750K, 750L and 710M (Kao)

Technocare FRW-14 through 17 (Toshiba)

Cleaning conditions:

Using these cleaning agents, capacitors are capable of withstanding immersion or ultrasonic cleaning for 10 minutes at a maximum liquid temperature of 60°C. Find optimum condition for washing, rinsing and drying. Be sure not to rub the marking off the capacitor by contacting any other components or the PC board. Note that shower cleaning adversely affects the markings on the sleeve.

-Non-Halogenated Solvent Cleaning

AK225AES (Asahi Glass)

Cleaning Conditions:

Solvent-proof capacitors are capable of withstanding any one of immersion, ultrasonic or vapor cleaning for 5 minutes, except some series, the cleaning duration of which is specified by product specifications. However, from a view of the global environmental problems, these types of solvent will be banned in near future. We would recommend not using them as much as possible.

Isopropyl alcohol cleaning agents

IPA (Isopropyl Alcohol) is one of the most acceptable cleaning agents; it is necessary to maintain a flux content in the cleaning liquid at a maximum limit of 2 Wt. %.

(5) Precautions for using adhesives and coating materials

- a) Do not use any adhesive and coating materials containing halogenated solvent.
- b) Verify the following before using adhesive and coating materials.
 - Remove flux and dust leftover between the rubber seal and the PC board before applying adhesive or coating materials to the capacitor.
 - Dry and remove any residual cleaning agents before applying adhesive and coating materials to the capacitors. Do not cover over the whole surface of the rubber seal with the adhesive or coating materials.
 - On permissible heat conditions for curing adhesives or coating materials, follow the instructions in the catalogs or the product specifications of the capacitors.
 - Covering over the whole surface of the capacitor rubber seal with resin may result in a hazardous condition because the pressure inside cannot be released completely. Also, a large amount of halogen ions in resins will cause the capacitors to fail because the halogen ions penetrate into the rubber seal and the inside of the capacitor.
- c) Some of coating material cannot be cured over the capacitor.

(6) Fumigation

In many cases when exporting or importing electronic devices, such as capacitors, wooden packaging is used. In order to control insects, many times, it becomes necessary to fumigate the shipments. Precautions during "Fumigation" using halogenated chemical such as Methyl Bromide must be taken. Halogen gas can penetrate packaging materials used, such as cardboard boxes and vinyl bags. Penetration of the halogenide gas can cause corrosion of electrolytic capacitors.

The Operation of Devices

- a) Do not touch a capacitor directly with bare hands.
- b) Do not short-circuit the terminals of a capacitor by letting it come into contact with any conductive object.
Also, do not spill electric-conductive liquid such as acid or alkaline solution over the capacitor.

- c) Do not use capacitors in circumstance where they would be subject to exposure to the following materials exist or expose.
 - Oil, water, salty water or damp location.
 - Direct sunlight.
 - Toxic gases such as hydrogen sulfide, sulfurous acid, nitrous acid, chlorine or its compounds and ammonium.
 - Ozone, ultraviolet rays or radiation.
 - Severe vibration or mechanical shock conditions beyond the limits prescribed in the catalogs or product specification.

Maintenance Inspection

- a) Make periodic inspections of capacitors that have been used in industrial applications. Before inspection, turn off the power supply and carefully discharge the electricity in the capacitors. Verify the polarity when measuring the capacitors with a volt-ohm meter. Also, do not apply any mechanical stress to the terminals of the capacitors.
- b) The following items should be checked during the periodic inspections.
 - Significant damage in appearance: venting and electrolyte leakage.
 - Electrical characteristics: leakage current, capacitance, $\tan\delta$ and other characteristics prescribed in the catalogs or product specifications.We recommend relacing the capacitors if the parts are out of specification.

In Case of Venting

- a) If a non-solid aluminum electrolytic capacitor expells gas when venting, it will discharge odors or smoke, or burn in the case of a short-circuit failure. Immediately turn off or unplug the main power supply of the device.
- b) When venting, a non-solid aluminum electrolytic capacitor blows out gas with a temperature of over 100°C. (A solid aluminum electrolytic capacitor discharges decomposition gas or burning gas while the outer resin case is burning.) Never expose the face close to a venting capacitor. If your eyes should inadvertently become exposed to the spouting gas or you inhale it, immediately flush the open eyes with large amounts of water and gargle with water respectively. If electrolyte is on the skin, wash the electrolyte away from the skin with soap and plenty of water. Do not lick the electrolyte of non-solid aluminum electrolytic capacitors.

Storage

We recommend the following conditions for storage.

- a) Do not store capacitors at a high temperature or in high humidity. Store the capacitors indoors at a temperature of 5 to 35°C and a humidity of less than 75% RH.
- b) Store the capacitors in places free from water, oil or salt water.
- c) Store the capacitors in places free from toxic gasses (hydrogen sulfide, sulfurous acid, chlorine, ammonium etc.)
- d) Store the capacitors in places free from ozone, ultraviolet rays or radiation.
- e) Keep capacitors in the original package.

Disposal

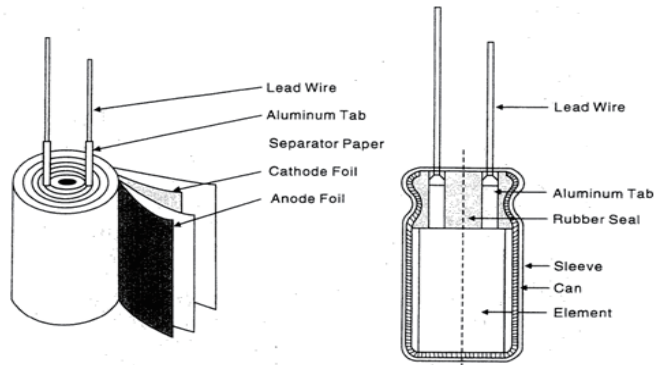
Please consult a local specialist regarding the disposal of industrial waste when disposing aluminum electrolytic capacitors.

Catalogs

Specifications in catalogs may be subject to change without notice. For more details of precautions and guidelines for aluminum electrolytic capacitors, please refer to Engineering Bulletin No. 634A.

Structure of Aluminum Electrolytic

The aluminum electrolytic capacitor contains an internal element of an anode foil, a cathode foil and paper separator rolled together, impregnated with an electrolyte, then attached to external terminals connecting the tabs with the anode or the cathode foils and sealed in a can case.



Among various types of capacitors, an aluminum electrolytic capacitor offers large CV to volume and features low cost. The capacitance [C] of aluminum electrolytic capacitors, as well as other capacitors, is expressed by the following equation:

$$C = 8.855 \times 10^{-8} \times \epsilon S/d \text{ (}\mu\text{F)}$$

Where: ϵ = Dielectric constant

S = Surface area of dielectric (cm²)

d = Thickness of dielectric (cm)

This equation shows that the capacitance increases in proportion as the dielectric constant becomes high, its surface area becomes large and the thickness of dielectric becomes thin. In aluminum electrolytic capacitors the dielectric constant of an aluminum oxide (Al₂O₃) layer is 8 to 10, which is not as high as compared with the other types of capacitors. However, the dielectric layer of the aluminum oxide is extremely thin (about 15Å per volt) and the surface area is very large. An electrochemical formed electrode foil makes the dielectric on the etched surface of aluminum electrode foil. Electrochemical etching creates 20 to 100 times more surface area as plain foil. Therefore, an aluminum electrolytic capacitor can offer a large capacitance compared with other types.

Primary of Composition Material

Anode aluminum foil:

First, the etching process is carried out electromechanically with a chloride solution which dissolves metal and increases the surface area of the foil; forming a dense network like innumerable microscopic channels. Secondly, the formation process is carried out with a solution such as ammonium borate which forms the aluminum oxide layer (Al₂O₃) as a dielectric at a thickness of about 1.1 to 1.5nm/volt. The process needs to charge more the rated voltage into the foil.

Cathode aluminum foil:

As in the first manufacturing process of the positive foil, the

cathode foil requires etching process. Generally, it does not require the formation process; therefore, the natural oxide layer of Al₂O₃, which gives a characteristic dielectric voltage of 1.0 volts, is formed.

Electrolyte and separator:

In a non-solid aluminum electrolytic capacitor, the electrolyte, an electrically conductive liquid, functions as a true cathode by contacting the dielectric oxide layer. Accordingly, the "cathode foil" serves as an electrical connection between the electrolyte and terminal.

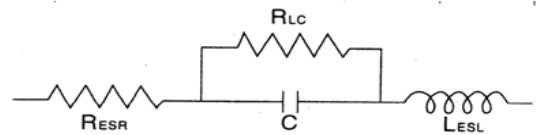
The separator functions to retain the electrolyte and prevent the anode and cathode foils from short-circuiting.

Can case and sealing materials:

The foils and separator are wound into a cylinder to make an internal element, which is impregnated with the electrolyte, inserted into an aluminum can case and sealed. During the service life of a capacitor, electrolyte slowly and naturally vaporizes under electrochemical reaction on the boundary of the aluminum foils. The gas will increase the pressure inside the case and finally cause the pressure relief vent to open or the sealing materials to bulge. The sealing material functions not only to prevent electrolyte from drying out but also to allow the gas to escape out of the can case in a controlled manner.

The Equivalent Circuit:

As the equivalent circuit of an aluminum electrolytic capacitor is shown below, it forms a capacitance, a series resistance, an inductance and a parallel resistance.

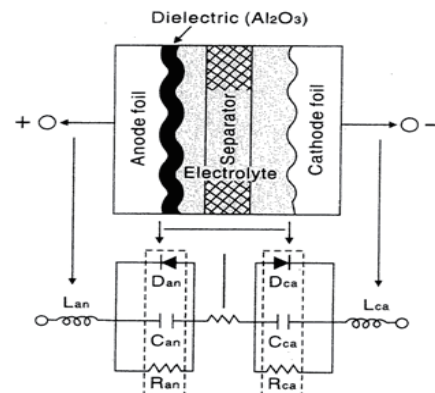


R_{ESR} = Equivalent series resistance (ESR)

R_{LC} = Resistance due to leakage current

C = Capacitance

L_{ESL} = Equivalent series inductance



From a material composition point of view, the equivalent circuit is subdivided as following:

Can, Cca = Capacitance due to anode and cathode foils

R = Resistance of electrolyte and separator

Ran, Rca = Internal resistance of oxide layer on anode & Cathode foils

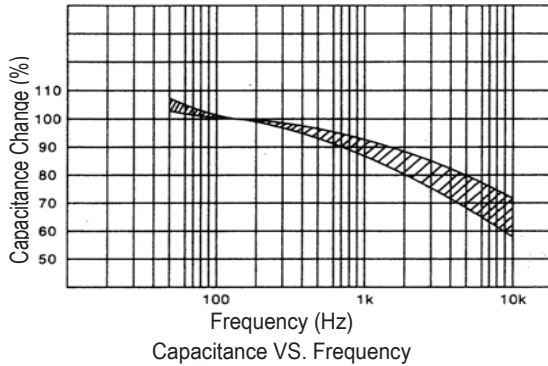
Dan, Dca = Diode effects due to oxide layer on anode & Cathode foils

Lan, Lca = Inductance due to anode & cathode terminals

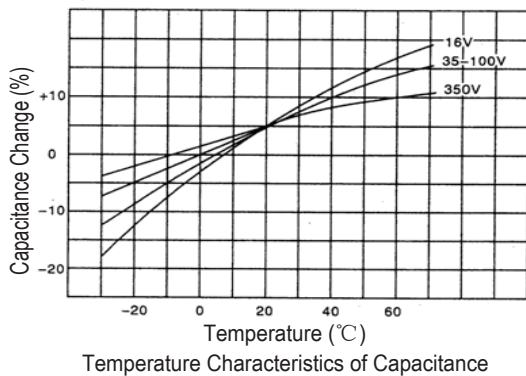
Basic Electrical Characteristics

Capacitance:

The capacitance of capacitor is expressed as AC capacitance by measuring impedance and separating factors. Also, the AC capacitance depends upon frequency, voltage and other measuring methods. In fact, JIS C 5101 prescribes that the series capacitive factor of an equivalent series ( circuit shall be the capacitance measured at a frequency of 120 Hz and applying a maximum AC voltage of 0.5Vrms with a DC bias voltage of 1.5 or 2.0 V to aluminum electrolytic capacitors. The capacitance of an aluminum electrolytic capacitor becomes smaller with increasing frequency. See the typical behavior shown below.



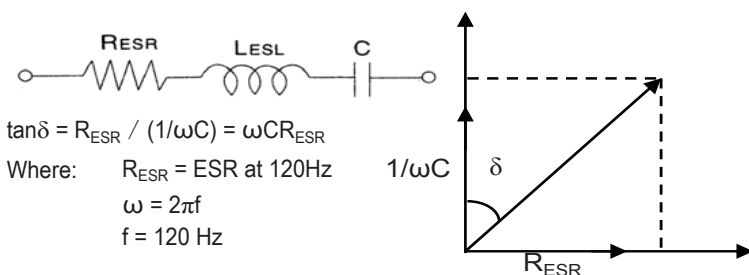
The capacitance value is highly dependent upon temperature and frequency. As the temperature decreases, the capacitance becomes smaller. See the typical behavior shown below.



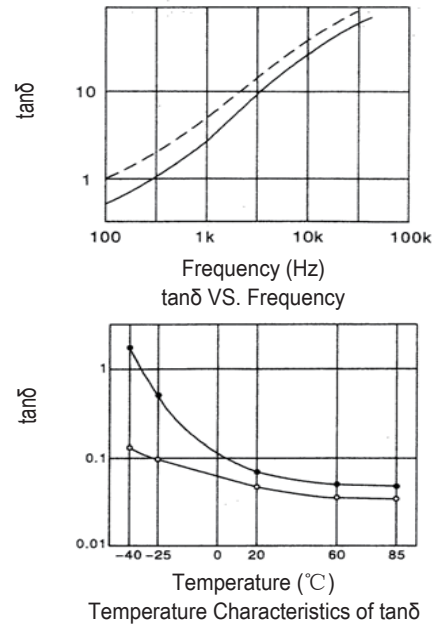
On the other hand, DC capacitance, which can be measured by applying a DC voltage, shows a slightly larger value than the AC capacitance at a normal temperature and has the flatter characteristic over the temperature range.

tanδ (tangent of loss angle or dissipation factor)

The tanδ is expressed as the ratio of the resistive component (R_{ESR}) to the capacitive reactance ($1/\omega C$) in the equivalent series circuit. Its measuring conditions are the same as the capacitance.



The tanδ shows higher value as the measured frequency increases and the measured temperature decreases.



Equivalent series resistance (ESR):

The ESR is the series resistance consisting of the aluminum oxide layer, electrolyte/separator combination and other resistance related factors, foil length. Foil surface area and others.

The ESR value depends upon the temperature. Decreasing the temperature makes the resistivity of the electrolyte increase and leads to increasing ESR.

As the measuring frequency increases, the ESR decreases and reaches an almost constant value that mainly dominates the frequency-independent resistance relating electrolyte/separator combination.

Impedance (Z):

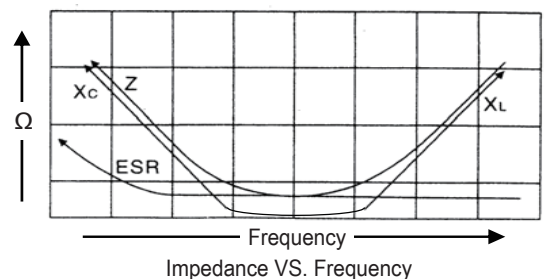
The impedance is the resistance of the alternating current at a specific frequency. It is related to capacitance [C] and inductance [L] in terms of capacitive and inductive reactance, and also related to the ESR. It is expressed as following:

$$Z = \sqrt{[ESR^2 + (X_L - X_C)^2]}$$

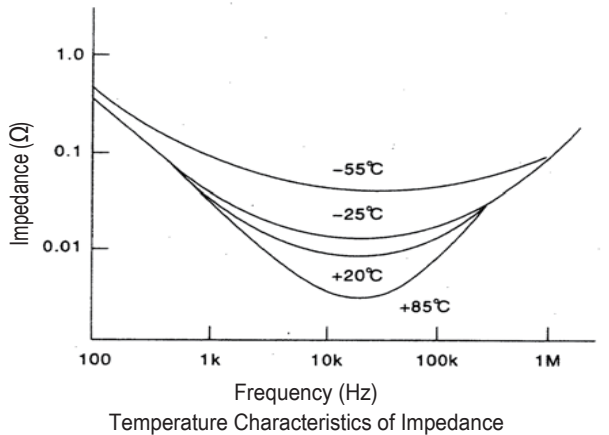
$$\text{Where: } X_C = 1/\omega C = 1/2\pi f C$$

$$X_L = \omega L = 2\pi f L$$

As shown below, the capacitive reactance (X_C) dominates at the range of low frequencies, and the impedance decreases with increasing frequency until it reaches the ESR in the middle frequency range. At the range of the higher frequencies the inductive reactance (X_L) comes to dominate, so that the impedance increases when increasing the measuring frequency.

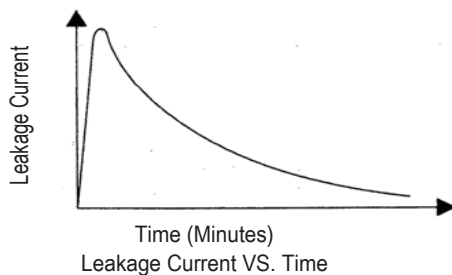


As shown at the next page, the impedance value varies with temperature because the resistance of the electrolyte is strongly affected by temperature.

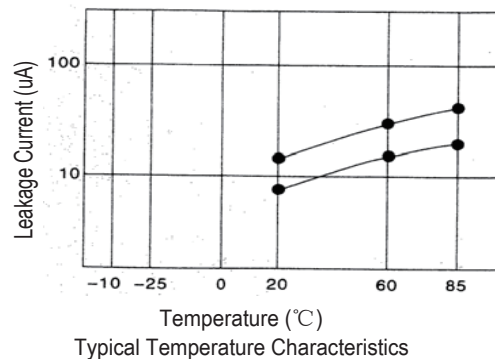


Leakage current:

The dielectric of a capacitor has a very high resistance that does not allow DC current to flow. However, due to the characteristics of the aluminum oxide layer that functions as a dielectric in contact with electrolyte, a small amount of current, called leakage current, will flow to reform and repair the oxide layer when a voltage is being applied. As shown below, a high leakage current flows to charge voltage to the capacitor for the first seconds, and then the leakage current will decrease and reach an almost steady-state value with time.



Measuring temperature and voltage influences the leakage current. The leakage current shows higher values as the temperature and voltage increase.

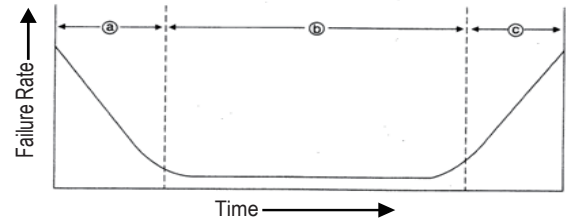


In general, the leakage current is measured at 20°C by applying the rated voltage to capacitor through a resistor of 1000Ω in series. The leakage current is the value several minutes later after the capacitor has reached the rated voltage. The catalog prescribes the measuring temperature and time.

Reliability

The bathtub curve:

Aluminum electrolytic capacitors feature failure rates shown by the following bathtub curve.



a) Infant failure period

This initial period accounts for the failures caused by deficiencies in design, structure, the manufacturing process or severe misapplications. In other words the initial failures occur as soon as the components are installed in a circuit. In the case of aluminum electrolytic capacitors, these failures do not occur at customers' field because aging process reforms an incomplete oxide layer, or eliminate the defective parts at the aging process and the sorting process. Misapplication of the capacitor such as inappropriate ambient conditions, over-voltage, reverse voltage, or excessive ripple current should be avoided for proper use of the capacitor in a circuit.

b) Useful life period

The random failure period exhibits an extremely low failure rate. These failures are not related to operating time but to application conditions. During this period, non-solid aluminum electrolytic capacitors lose a small amount of electrolyte. The electrolyte loss shows as a slow decrease in capacitance and a slow increase in $\tan\delta$ and ESR. Non-solid aluminum electrolytic capacitors still exhibit lower catastrophic failures than semiconductors and solid tantalum capacitors.

c) Wear-out failure period

This period reflects a deterioration in the component properties of the capacitor; the failure rate increases with time. Non-solid aluminum electrolytic capacitors end their useful life during this period.

Failure types:

The two types of failures are classified into catastrophic failures and wear-out failures as following.

1) Catastrophic failures

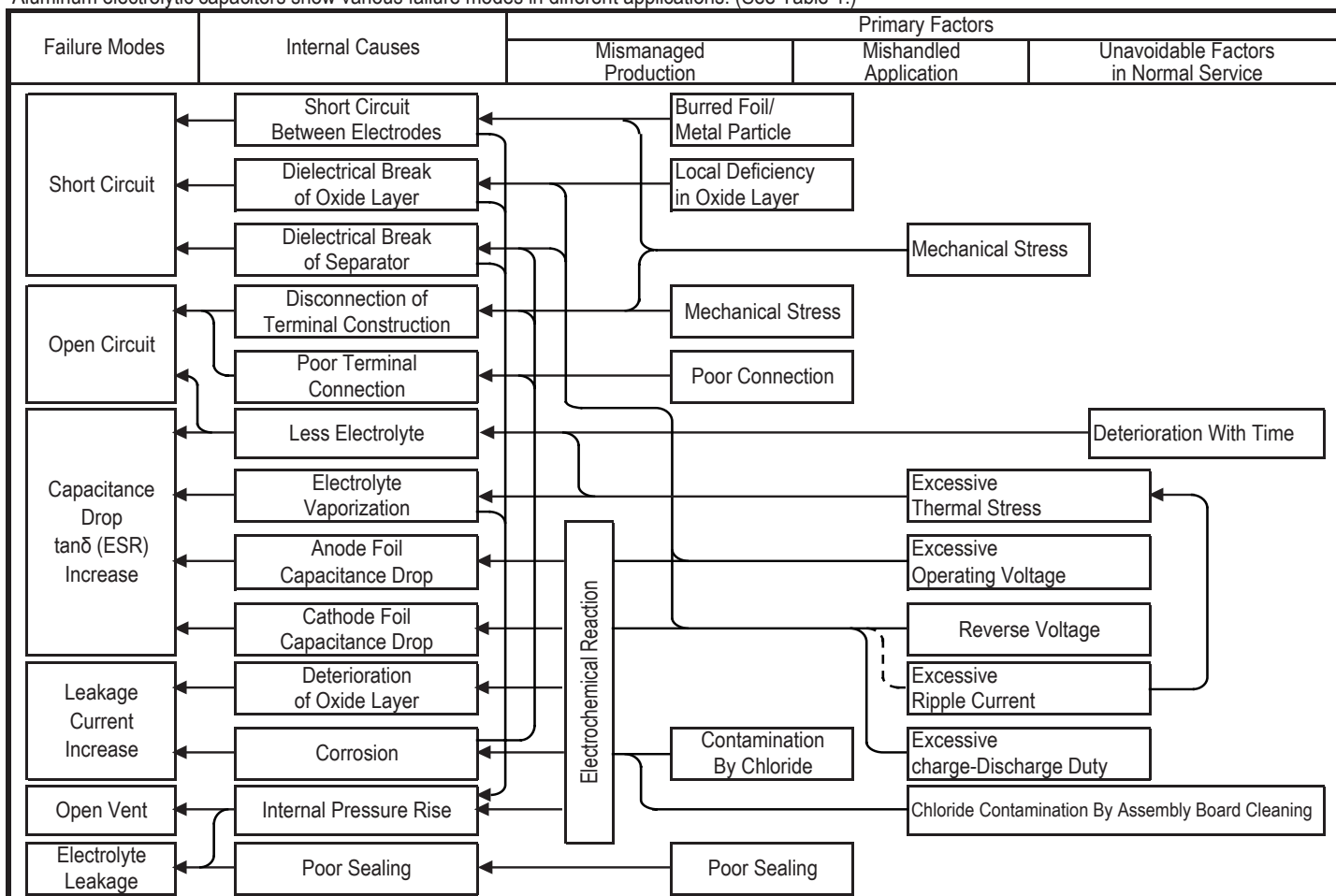
This is a failure mode that destroys the function of the capacitor like a short circuit or open circuit failure.

2) Wear-out failures

This is a failure mode where gradually deteriorates the electrical parameters of the capacitor. The criteria of judging the failures, vary with application and design factors. Capacitance decreases and $\tan\delta$ increases are caused by the loss of electrolyte in the wear-out failure period. This is primary due to loss of electrolyte by diffusion (as vapor) through the sealing material. Gas molecules can diffuse out through the material of the end seal. High temperature increase the electrolyte vapor pressure within the capacitor and the diffusion rate is therefore increased. This increases internal pressure may cause the seal to bulge due to temperature rise. This bulging may accelerate diffusion and mechanically degrade the seal. Factors that can increase the capacitor temperature, such as ambient temperature and ripple current, can accelerate the wear-out phase of capacitor.

Failure mode:

Aluminum electrolytic capacitors show various failure modes in different applications. (See Table 1.)



Life of Aluminum Electrolytic Capacitors

The life of aluminum electrolytic capacitor is largely dependent on environmental and electrical factors. Environmental factors include temperature, humidity, atmospheric pressure and vibration. Electrical factors include operating voltage, ripple current and charge-discharge duty cycles. The factor of temperature (ambient temperature and internal heating due to ripple current) is most critical to the life of aluminum electrolytic capacitors.

General formula to estimate lifetime:

The lifetime of non-solid aluminum electrolytic capacitors is generally expressed by using three elements, representing the effects of ambient temperature, applying voltage and ripple current, which is shown by the following equation.

$$L_X = L_0 \cdot K_{Temp} \cdot K_{voltage} \cdot K_{ripple}$$

Where: L_X = Lifetime of capacitor to be estimated

L_0 = Base lifetime of capacitor

K_{Temp} = Ambient temperature acceleration term

$K_{voltage}$ = Voltage acceleration term

K_{ripple} = Ripple current acceleration term

K_{Temp} (Effects of ambient temperature on life):

Because an aluminum electrolytic capacitor is essentially an electrochemical component, increased temperatures accelerate the chemical reaction producing gas within the capacitor which is diffused through the end seal, and consequently accelerates a gradual decrease in capacitance and a gradual increase in $\tan\delta$ and ESR. The following equation has been experimentally found to express the relationship between the temperature acceleration factor and the deterioration of the capacitor.

$$L_X = L_0 \cdot K_{Temp} = L_0 \cdot B^{(T_0 - T_X)/10}$$

$$K_{Temp} = B^{(T_0 - T_X)/10}$$

Where: L_X = Lifetime (hour) of capacitor to be estimated

L_0 = Base lifetime (hour) of capacitor

T_0 = Maximum rated category temperature (°C) of

T_X = Actual ambient temperature (°C) of capacitor

B = Capacitor shown in catalog

This equation is similar to Arrhenius' equation that expresses a relationship between chemical reaction rates and temperature, and called Arrhenius' rule of aluminum electrolytic capacitors.

The temperature acceleration factor (B) is approximately 2 over an ambient temperature range (T_X) from 40°C to the maximum rated category temperature of each capacitor. It means that the lifetime is approximately halved with every 10°C rise in ambient temperature and can be extended by using the capacitors at lower temperatures. For an ambient temperature range (T_X) of 20°C to 40°C, the factor B will be close to 2 and the lifetime will actually be extended. However, operating and surrounding conditions, especially the operating conditions influence ambient temperatures mutually. The ambient temperature in this range will be very changeable; therefore, lifetime estimation under 40°C should use 40 as T_X .

K_{Voltage} (Effects of applying voltage to life):

Miniature and large sized aluminum electrolytic capacitors for popular applications, such as surface mount types, radial lead types, snap-in types and block types, have little voltage effect on their life. Other factors like temperature and ripple current determine the life in comparison with voltage, as long as the capacitors are used at voltages and temperatures within the specifications prescribed in the catalog. Consequently, $K_{Voltage} = 1$ is used for these capacitors. 350V and higher screw-mount terminal types of capacitors for custom-made power electronics applications allow the lifetime to extend by applying low voltage, relating to the characteristics of their aluminum oxide layer. For $K_{Voltage}$ values of the screw-mount products, please contact our company or sales agents.

K_{Ripple} (Effects of ripple current to life):

Aluminum electrolytic capacitors have higher $\tan\delta$ than any other types of capacitors; therefore, the ripple current gives aluminum electrolytic capacitors higher internal heat. Be sure to check the rated ripple current which is specified in the catalog for assuring the life. The ripple current through the capacitor produces heat by dissipating power from the capacitor. This leads to temperature increase. Internal heating produced by ripple current can be expressed by:

$$W = (I_{Ripple})^2 * R_{ESR} + V * I_{Leakage}$$

Where: W = Internal power loss

I_{Ripple} = R.M.S. Ripple current

R_{ESR} = Internal resistance (ESR) at ripple frequency

V = Applied voltage

$I_{Leakage}$ = Leakage current

Leakage current may be 5 to 10 times higher than the values measured at 20°C, but compared with I_{Ripple} , the leakage current value is very small and negligible. Thus, the above equation can be simplified:

$$W = (I_{Ripple})^2 * R_{ESR}$$

The following equation gives the internal heat rise; it's heat rise to stable condition. (It is necessary to input several factors):

$$(I_{Ripple})^2 * R_{ESR} = \beta * A * \Delta T$$

Where: β = Heat transfer constant

A = Surface area of can case

$$A = (\pi/4) * D * (D + 4L)$$

Where: D = Can case diameter

L = Can case length

ΔT = An increase in core temperature by internal heating

due to ripple current

(ΔT = Core temperature - Ambient temperature)

From the above equation, internal temperature rise (ΔT) produced by ripple current is given by:

$$\Delta T = (I_{Ripple})^2 * R_{ESR} / (\beta * A)$$

When the ripple frequency is 120Hz, R_{ESR} at 120Hz is expressed by

$$R_{ESR} = \tan\delta / (\omega * C)$$

$$\Delta T = (I_{Ripple})^2 * \tan\delta / (\beta * A * \omega * C)$$

Where: $\tan\delta$ = 120Hz value

$$\omega = 2\pi * f = 2\pi * 120\text{Hz}$$

C = 120Hz capacitance value

As above equation, ΔT varies with frequency of ripple, frequency and temperature dependent ESR and application on dependent β (even ripple current is constant). We really recommend that customers measure ΔT with a thermocouple at the actual operating conditions of the application in lieu of using the above equation. (Another approximation of ΔT will

be stated later.) As mentioned in the paragraph of K_{Temp} , aluminum electrolytic capacitors will slowly increase in $\tan\delta$ and ESR during their service life. The application without ripple current has no influence on the life of the capacitor even though the ESR will increase during life. In other words, the application with ripple current makes ΔT increase; furthermore, a ΔT increase results in ESR increase. The ESR increase then makes ΔT increase. It is a chain reaction. Theoretically, the ripple current acceleration term (K_{Ripple}) cannot be simply expressed like the ambient temperature acceleration term (K_{Temp}). Practically, the ripple current acceleration term (K_{Ripple}) can be approximately expressed by an equation using a ΔT initially measured. The following table shows the ripple current acceleration term (K_{Ripple}) for each capacitor design group. Note that a ΔT over a certain maximum limit may over-heat the capacitor, though the lifetime estimation will not give you practical lifetime. For instance, the following shows a guide limit of ΔT at each ambient temperature for 105°C maximum rated products.

Ambient temperature T_x (°C)	85	105
Guide limit of ΔT (°C)	15	5
Core temperature ($T_x + \Delta T$)	100	110

Approximation of ΔT

Estimation of the lifetime requires two temperature measurements; first obtain ΔT by actually measuring the core temperature, inserting the thermocouple inside the operating capacitor and secondary, the ambient temperature. A more convenient way to get the ΔT is to convert the surface temperature of the capacitor case and the ambient temperature by using a coefficient specified for each case diameter as following:

$$\Delta T = K_C * (T_s - T_x)$$

Where: K_C = Coefficient from table below

T_s = Surface temperature (°C) of capacitor can case

T_x = Ambient temperature (°C)

No air flow conditions

No air flow solutions								
Diameter (mm)	Φ5 to Φ8		Φ10	Φ12.5	Φ16	Φ18	Φ22	Φ25
KC	1.10		1.15	1.20	1.25	1.30	1.35	1.40
Diameter (mm)	Φ30	Φ35	Φ40	Φ50	Φ63.5	Φ76	Φ89	Φ100
KC	1.50	1.65	1.75	1.90	2.20	2.50	2.80	3.10

Also, you can roughly estimate a ΔT by using the following equation without measurement.

$$\Delta T = \Delta T_0 * (I_x / I_0)^2$$

Where: $\Delta T_0 = 5^\circ\text{C}$ for 105°C maximum rated capacitors

I_0 = Rated ripple current (I_{RMS}); If its frequency is different from operating ripple current I_x , it needs converting by using a frequency multiplier prescribed in the catalog.

I_x = Operating ripple current (I_{RMS}) actually flowing into a capacitor

Like switching power supplies, if the operating ripple current consists of commercial frequency element and switching frequency element(s), an internal power loss is expressed by the following equation:

$$W = (I_{f1})^2 * ESR_{f1} + (I_{f2})^2 * ESR_{f2} + \dots + (I_{fn})^2 * ESR_{fn}$$

Where: W = Internal power loss

$I_{f1} \dots I_{fn}$ = Ripple currents at every frequencies $f1 \dots fn$

$ESR_{f1} \dots ESR_{fn}$ = ESR's at every frequencies $f1 \dots fn$

The above equation can be transformed into another equation to get a ripple current value in accordance with the frequency of the rated ripple current, each of ESR_{f1} , ..., ESR_{fn} is approximately equal to ESR_{fo} divided by square value of the frequency multiplier (F_{f1} ... F_{fn}). Here ESR_{fo} is the value at the frequency of the rated ripple current and F_{f1} ... F_{fn} is a conversion coefficient from one frequency to another in accordance with the frequency f_1 ... f_n .

$$ESR_{f1} = ESR_{fo} / (F_{f1})^2$$

⋮

$$ESR_{fn} = ESR_{fo} / (F_{fn})^2$$

Relationship of $W = (I_{Ripple})^2 \cdot RESR$ leads IX as following:

$$IX = \sqrt{W / ESR_{fo}}$$

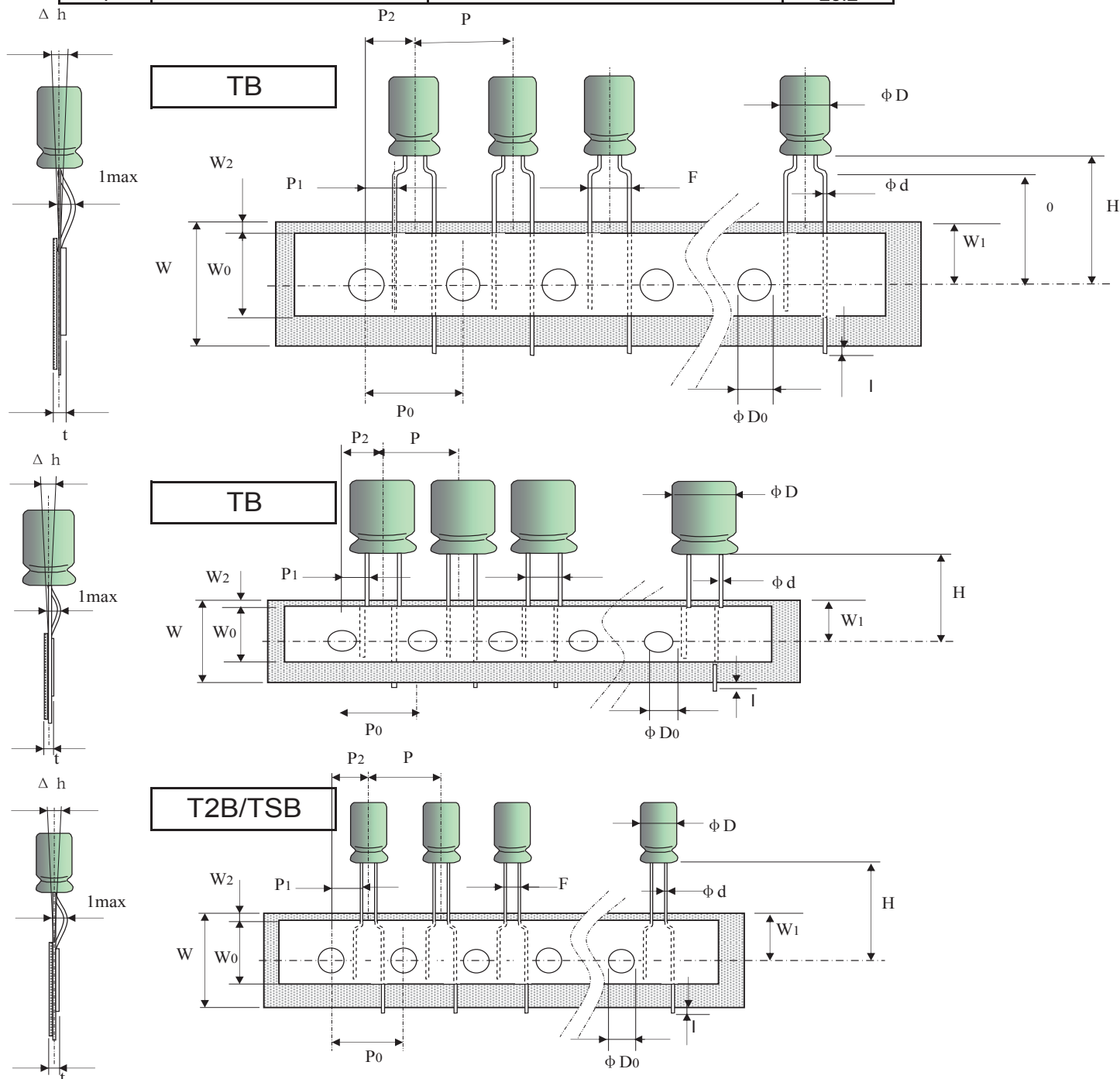
The above is rewritten in the following equation:

$$IX = \sqrt{(I_{f1}/F_{f1})^2 + (I_{f2}/F_{f2})^2 + \dots + (I_{fn}/F_{fn})^2}$$

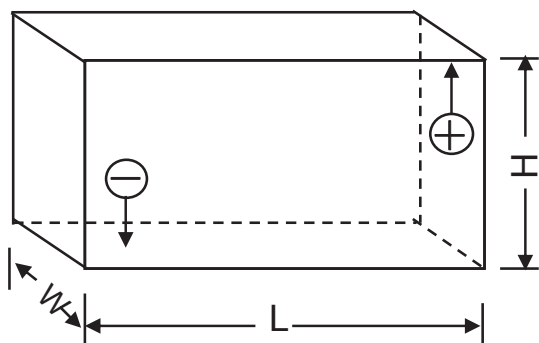
Where: IX = Ripple current in accordance with the frequency of the rated ripple current
 I_{f1} I_{fn} = Operating ripple currents at every frequency f_1 f_n
 F_{f1} F_{fn} = Frequency multipliers for every frequency f_1 f_n prescribed in the catalog, based on the fact that the internal resistance of a capacitor varies with frequency.

■ SPECIFICATIONS (CODE TB)

SYMBOL	TB			T2B	T2B	TSB	TB	TB	Tolerance
	Φ5X11	Φ6.3X11	Φ8X11.5	Φ5	Φ6.3	Φ8	Φ10	Φ13	
Φd		0.50			0.50		0.6		±0.05
P		12.70			12.7			25.4	±1.0
P0		12.70			12.7				±0.2
P1		3.85			5.1	4.85	3.85		±0.5
P2		6.35							±1.0
F		5.0			2.5	3.5	5.0		+0.8, -0.2
W		18.0				18.0			±0.5
W0		5.0				5.0			Min
W1		9.0				9.0			±0.5
W2		0-1.5				0-1.5			
H	18.5		20		18.5		19.0		±0.75
H0		16.0							±0.5
I		1.0				1.0			Max
ΦD0		4.0				4			±0.2
Δh		0				0			±1.0
T		0.7				0.7			±0.2



CODE "TB" AMMO-PACKAGING



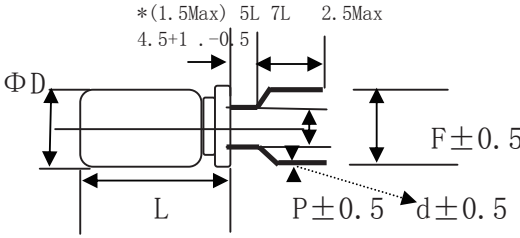
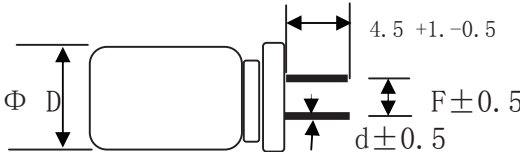
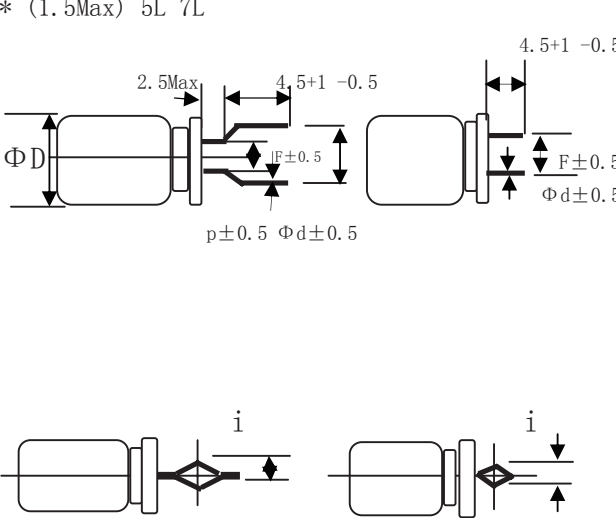
Case Size	Q'ty Per Box	L	H	W	Box Code
Φ4	2,000	335	190	53	P-4
Φ5	2,000	335	235	53	P-1
Φ6.3	2,000	335	300	53	P-2
Φ8	1,000	335	235	53	P-1
Φ10x12.5; Φ10x16	500	335	190	53	P-4
Φ10x20	800	335	300	55	P-5
Φ13x21	500	335	300	55	P-5
Φ13x25	500	335	300	61	P-3

Type Case Size	BULK Code NIL	TAPE/BOX T2B TB	Type Case Size	BULK Code NIL	TAPE/BOX Code TB
Φ4x5	500 ^{PCS}	2,000 ^{PCS}	Φ10x16	200 ^{PCS}	500 ^{PCS}
Φ5x5	500	2,000	Φ10x20	100	800
Φ6.3x5	500	2,000	Φ13x21	100	300
Φ4x7	500	2,000	Φ13x25	50	300
Φ5x7	500	2,000	Φ16x25	50	
Φ6.3x7	500	2,000	Φ16x31.5	50	
Φ5x9, Φ5x11	200	2,000	16x35.5	50	
Φ6.3x9, Φ6.3x11	200	2,000	Φ18x36	50	
Φ8x9, Φ8x11.5	200	1,000	18x40	50	
Φ10x9, Φ10x12.5	200	500	Φ22x36	25	
			Φ22x41	25	

Formed lead

Code "LF" "LC" "LK" "LM"

We also supply capacitors with formed leads and specially designed "KinK" formed leads to improve the efficiency of assembly process of customers. These special leads contribution of the time for insertion and soldering.

Formed lead code	Forming method	Dimensions (mm)				Shape
		ΦD	F	P	i	
LF	Forming and cutting	4	5	1.5	—	
		5	5	2.0	—	
		6.3	5	2.5	—	
		8	5	3.5	—	
LC	Cutting	10	5	5.0	—	
		13	5	5.0	—	
		16	7.5	7.5	—	
		18	7.5	7.5	—	
		20	10	10.0	—	
		22	10	10.0	—	
LK	"KinK" forming (Snap-in type forming)	4	5	1.5	1.1	(Φ 4. 5. 6.3. 8)
		5	5	2.0	1.1	
		6.3	5	2.5	1.1	
		8	5	3.5	1.3	
		10	5	5.0	1.3	
		13	5	5.0	1.3	
		16	7.5	7.5	1.3	
		18	7.5	7.5	1.3	

* Lead diameter (Φd) depends on capacitor specifications