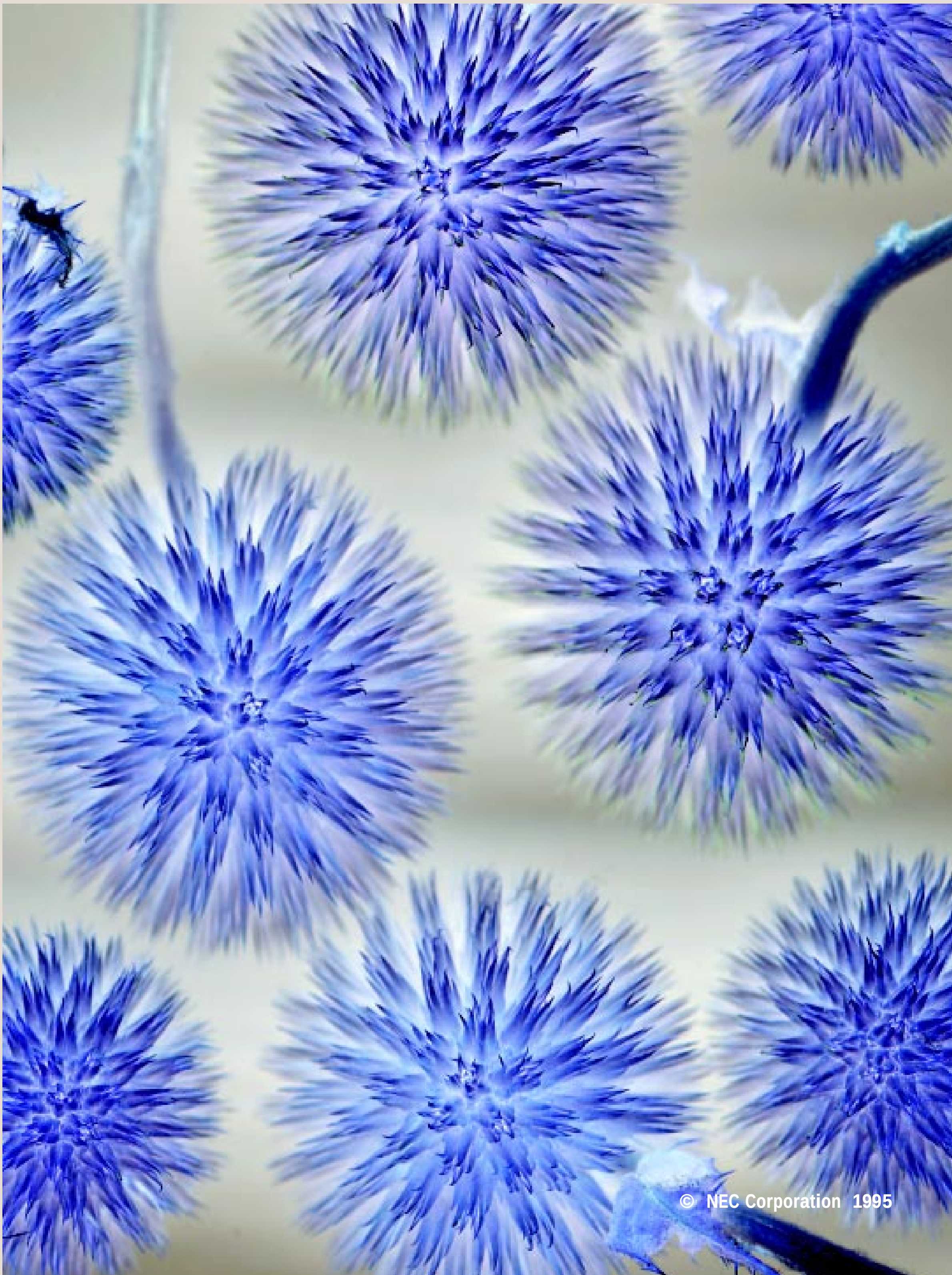
NEC

CAPACITORS

DATA BOOK



PREFACE

Since the development of solid electrolyte tantalum capacitor having excellent performance in 1955, NEC has been advancing research into new materials and improved production technologies, and has introduced many products to the market.

In 1970's, NEC released resin coated tantalum capacitor. In 1981, NEC succeeded in developing resin molded chip tantalum capacitor first in the world. NEC also succeeded first in the world in the development of epoch-making tantalum capacitor (NEOCAPACITOR) having conductive polymer electrode as its cathode.

As the result of NEC's active research and development programs, NEC's tantalum capacitors including NEOCAPACITOR can offer the designer the most advanced technologies and excellent performance characteristics for filtering, by-passing, coupling, decoupling, blocking and R-C timing applications.

The tantalum capacitor is inherently very reliable and there is significant evidence that reliability improves with age. Capacitance loss with age and other problems often associated with liquid electrolytes are non-existent in solid tantalum capacitors.

The process used further to improve reliability of tantalum capacitors is to burn them in at elevated voltages at elevated temperature for extended period of time, thus eliminating high-leakage and other undesirable characteristics. This process is based on the fact that the failures of solid electrolyte tantalum capacitors do not conform to exponential distribution, but instead exhibit a constantly decreasing failure rate.

This data book shows more adequate methods for using various NEC tantalum capacitors equipped with such characteristics and advantages described above.

If you specify NEC's tantalum capacitors, you can feel confident that you are getting the best possible quality, reliability and prices available.

Notes on the Tantalum Solid Electrolyte Capacitor

(1) If a voltage higher than the rated voltage is applied to the capacitor, a failure such as short-circuiting may take place.

(2) This capacitor is a polarized device. If a reverse voltage is applied, a current flow is higher than when forward voltage is applied, and a frequent failure such as short-circuiting occurs.

(3) This capacitor has an equivalent series resistance. If the capacitor is used at a high frequency, it is heated by Joule energy causing short-circuiting or fuming. Be sure to use the capacitor so that the specified permissible ripple voltage is not exceeded.

(4) If a current supplied to the capacitor exceeds 1 A when the capacitor is short-circuited, the tantalum element is burned, and frequently the printed circuit board is damaged.

(5) If an external force exceeding the permissible level is applied to the capacitor, loose contact and short-circuiting may occur.

(6) When the capacitor is soldered and the specified soldering temperature of time is exceeded, the internal solder may melt and the capacitor may be strained by the thermal expansion force.
Consequently, short-circuiting may occur.

(7) The initial failure modes of this capacitor are mainly short circuit failures and are an initial failure mode. NEC conducts screening to improve reliability after mounting the capacitor on an application set.

(8) If two or more capacitors are connected in series with a voltage higher than the rated voltage applied to one of them, the applied voltage is divided by the difference in series resistance among the capacitors. Therefore, do not connect the capacitors in series when a voltage higher than the rated voltage is applied.

(9) If the capacitor is stored without any voltage applied for a long time at 40˚C, 60% RH or more, short-circuiting may occur because of silver ion migration.

CONTENTS

[MEMO]

SOLID TANTALUM CAPACITORS

1. HISTORY

Capacitors that use a metal oxide film having a valve effect as a dielectric are known as electrolytic capacitors and have been used for a long time in a wide range of applications.

Because their dielectric film is extremely thin, electrolytic capacitors are the smallest of all capacitors in terms of volume per unit capacitance.

Compared with other types of capacitors, however, electrolytic capacitors have some demerits such as (a) poor frequency characteristics and (b) low insulation resistance, and therefore, their application circuits are accordingly limited in various ways.

In the meantime, the invention of the transistor has promoted the miniaturization of circuits, and as a result, electrolytic capacitors have been increasingly used.

In the past, many electrolytic capacitors used a liquid electrolyte solution. But the liquid leaked out if they were incompletely sealed or the housing aged, which meant that these capacitors could not maintain a high reliability over a long period.

Consequently, research and development of solid-state capacitors, which would take the place of capacitors using liquid electrolyte, was promoted. In 1955, Bell Telephone Laboratories in the United States succeeded in developing a solid tantalum capacitor, with NEC Corporation in Japan following closely behind.

In Japan, a hermetically sealed capacitor housed in a metal case was put into practical use for the first time in 1959, mainly employed in industrial electronic equipment. Since 1970, when inexpensive resin coated type capacitors were released, solid tantalum capacitors have rapidly become widely used in consumer electronic systems, Since 1981 when resin-molded type capacitors (R series) were marketed, use of tantalum chip capacitors has grown remarkably. They now constitute the mainstream of solid tantalum capacitors as surface mount technology (SMT) has made progress and application systems have become increasingly slim and compact.

Higher frequency operation, degitalization and smaller power consumption for electric equipment have required capacitors to reduce its equivalent series resistance (ESR). In order to meet this demand, NEC has developed NEOCAPACITOR using polypyrrole which had 100 times higher conductivity than that of MnO_2 in 1994.

Today, as many as 12 billion solid tantalum capacitors are produced worldwide each year, and it is expected that demand for these capacitors will further grow as miniaturization of application systems is promoted.

2. CONSTRUCTION AND PRINCIPLE

Figure 1 shows the construction and operating principle of the BTL type. This construction is employed for solid tantalum capacitors all over the world.

Tantalum oxide (Ta_2O_5) is formed by electrochemical technique on tantalum (Ta) as the metal electrode, which serves as the dielectric. On top of the tantalum oxide a manganese dioxide layer (MnO_2) is formed as electrolyte. In contrast to conventional electrolytic capacitors whose electrolyte is liquid, solid tantalum capacitors derive their qualifier from the fact that MnO_2 is solid. To make sure that this MnO_2 is electrically connected, a graphite layer is provided to create a metal layer that serves as a cathode.

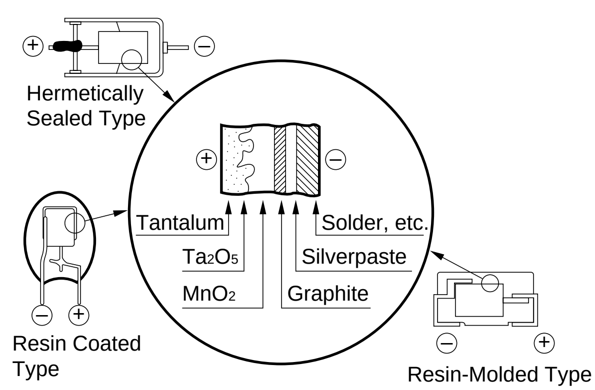


Figure 1 Construction and Operating Principle of Solid Tantalum Capacitors

A solid tantalum capacitor has a rectification characteristic, but there is no theory yet that can fully explain the rectification mechanism. Nevertheless, this Data Book briefly introduces the rectification mechanism explained by H.E. Haring[1] and Ishikawa[2] from the viewpoint of semiconductor rectification.

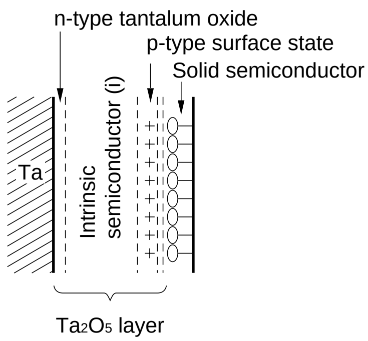


Figure 2 Semiconductor Model

As shown in Fig. 2, the portion adjacent to the metal side of the oxide film is an n-type oxide tantalum layer that contains excessive tantalum atoms of more than the chemical equivalent weight of Ta_2O_5, and this layer is estimated to be as thin as 5 to 10 nm. The layer that follows the n-type oxide tantalum layer is regarded as an intrinsic semiconductor with a composition of an equivalent weight to Ta_2O_5. This layer has a thickness proportional to the anodization voltage and serves as the dielectric that determines the capacitance. However, it is considered that a p-type oxide tantalum is induced by ions attracted to the surface of the oxide film or a solid substance (e.g., manganese dioxide) adhering to the surface of the oxide film which creates a surface state. It is therefore considered that the microstructure of the cathode oxide film forms a p-i-n junction, and that this oxide film has a rectification characteristics that provides excellent insulation and dielectric strength despite being very thin.

3. FEATURES

Table 1 shows the main features of solid tantalum capacitors.

Table 1 Features of Solid Tantalum Capacitors

Dielectric	Tantalum Pentoxide (Ta_2O_5)
Dielectric Constant	27
Film Thickness (Å/V)	17
Electrolyte	Solid Electrolyte
Features	• Small Size and High Capacitance
	• Long Life (Semi-Permanent)
	• Stable Performance
Shape	• Resin Molded Exterior Chip
	• Resin Coated Exterior Radial Leads
	• Resin Molded Exterior Radial Leads
	• Resin Sealed Axial Leads in Metal Case
	• Hermetically Sealed Axial Leads in Metal Case
Others	• Reliability Influenced by Voltage Derating
	• Polar Type

4. CHARACTERISTICS

4.1 Impedance

The conceptual construction of the solid tantalum capacitor is as follows:

Ta_2O_5 is provided on the anode effective surface, which is formed by fine sintered tantalum powder with an extremely high hole ratio, as a dielectric film layer. The cathode is made of MnO_2, and the external electrode terminal is led out via graphite, silver paste, and solder layers. This construction is illustrated in a simplified manner in Fig. 3.

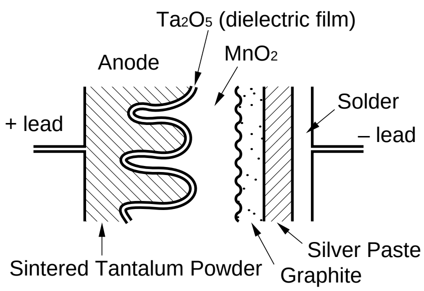


Figure 3 Construction of Solid Tantalum Capacitors

(1) Frequency Characteristics

Figure 4 shows the equivalent circuit of a general capacitor, where:

$R_{eq.s}$ = Equivalent Series Resistance
C = Capacitance
L = Inductance

Therefore, impedance Z is expressed as follows:

$$Z = \frac{1}{j\omega C} + j\omega L + R_{eq.s} \quad (1)$$

Figure 4 Equivalent Circuit of Capacitor

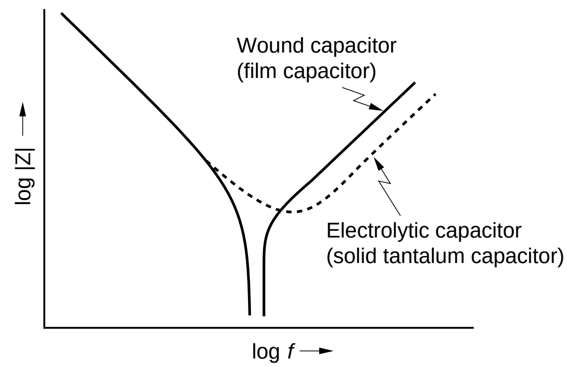


Figure 5 Frequency Characteristics of Impedance of Capacitors

The high-frequency impedance of such a capacitor as a wound capacitor is mainly governed by inductance (L) and is solved by means of noninductive winding. However, the high-frequency impedance of an electrolytic capacitor is mainly influenced by $R_{eq.s}$ as shown in Fig. 5.

In the case of a sintered solid tantalum capacitor, $R_{eq.s}$ consists of the following elements:

$R_{eq.s}$ =
- R_f (tanδ peculiar to Ta_2O_5 film and virtual equivalent series resistance of the dielectric film calculated from the molecules attracted to the interface)
- R_0' (external equivalent series resistance other than that of Ta_2O_5 film)

Furthermore, R_0' consists of the following elements:

R_0' =
- R_0 (factor related to distributed constant resistance and that changes with the specific resistance of MnO_2 and the shape of the hole)
- R_{ext} (resistance of MnO_2 on external surface. Contact resistance of MnO_2/graphite/silver paste/solder layer/lead terminal and resistivity of substance)

Therefore,

$$\begin{aligned} R_{eq.s} &= R_f + R_0' \\ &= R_f + R_0 + R_{ext} \quad (2) \end{aligned}$$

Rewriting expression (2) with $R_{eq.s}$ as a function of frequency (ω),

$$R_{eq.s}(\omega) = (\tan\delta)_f/\omega C + R_0'(\omega) = (\tan\delta)_f/\omega C + R_0(\omega) + R_{ext} \quad (3)$$

because,

$$\tan\delta = \omega C\, R_{eq.s} = \omega C\,(R_f + R_0) = (\tan\delta)_f + \omega C\, R_0' \quad (4)$$

where, $(\tan\delta)_f$ is a dielectric loss that is determined by the nature of dielectric film Ta_2O_5 and is almost constant vis-a-vis frequency f in the operating frequency region.

$R_0(\omega)$ is constant at low frequencies and decreases to 0 in the high-frequency region. Let's discuss this phenomenon in more detail.

Figure 6 shows the gap of the sintered anode, expressed as an equivalent circuit of C and R. According to an analysis by Mr. Nishitani, the frequency characteristic of the distributed constant resistance of a cylindrical sintered body in the low-frequency region is:

$$R_0(\omega) = R_{00}\ \text{(const)} \quad (5)$$

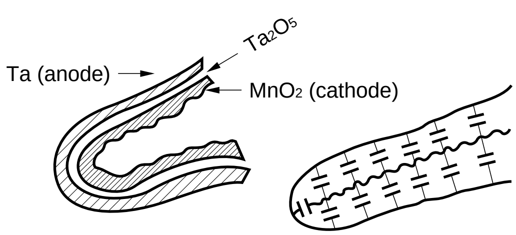


Figure 6 Model of Gap

In the high-frequency region,

$$R_0(\omega) = \left(\frac{R_{00}}{\omega C_f}\right)^{1/2}\left(1 + \frac{\tan\delta_f}{2}\right) \quad (6)$$

where,

C_f : capacitance in low-frequency region (const)

$\tan\delta_f$: $\tan\delta$ of dielectric film

$R_0(\omega)$ rapidly increases with frequency if the frequency is higher than a specific level.

This means that $|Z|$ of the resistance of MnO_2 is mainly determined by the external surface at high frequencies and that the internal distributed constant resistance R_0 is not included.

Figure 7 shows the conceptual frequency characteristics of $R_{eq.s}$.

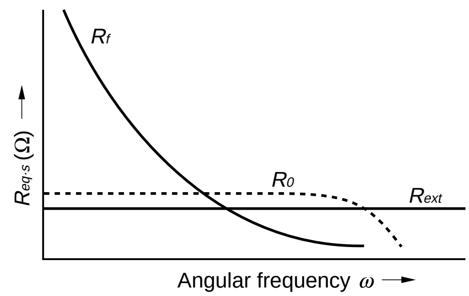


Figure 7 Frequency Characteristics of $R_{eq.s}$

Figure 8 shows NEOCAPACITOR's typical frequency characteristics of capacitance, and the capacitance starts to decrease at around 100 kHz which is almost 10 times higher than conventional tantalum capacitor and aluminum electrolytic capacitor.

As the counter electrode of electrolytic capacitor has resistivity, equivalent circuit of the capacitor is expressed as distributed constant circuit, and its apparent capacitance will decrease at higher frequencies.

Because the resistance of PPy, which is cathode material of NEOCAPACITOR, is quite low, NEOCAPACITOR can maintain its capacitance up to 10 times higher frequency than conventional tantalum capacitor and aluminum electrolytic capacitor.

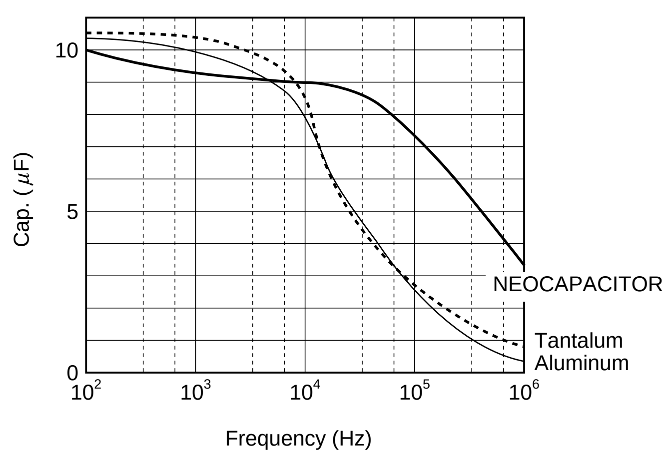


Figure 8 Frequency Characteristics of Capacitance

(2) Temperature Characteristics

Figure 9 below shows an example of dependency of |*Z*| on temperature. Figure 10 shows the characteristics in Figure 9 with the horizontal axis in Figure 9 rewritten to 1/T. As is evident from Figure 10, samples with the higher |*Z*| (i.e., lower *CV*) have a linear relationship with 1/T, like semiconductors. Also shown in Figure 10 are the temperature characteristics of MnO_2 for the sake of comparison, and the curve of the 35-V, 2.2-μF sample, which exactly matches the curve of MnO_2. This demonstrates that the main determinant of the dependency on temperature of |*Z*| is MnO_2.

In contrast, the curves of the samples with the lower |*Z*| (i.e., higher *CV*) are gentler than those with the higher |*Z*|.

It is therefore estimated that a large percentage of the constituents of |*Z*| have low temperature dependence.

This means, when viewed in terms of material, that $R_{eq.\,s}$ can be divided into the following constituents:

$R_{eq.s} =$
- R_f (specific tanδ of Ta_2O_5 film and virtual equivalent series resistance calculated from molecules attracted to the interface)
- R_{MnO2} (semiconductor resistance by MnO_2)
- R_{Metal} (resistance by metal and graphite)

If these constituents are viewed in more detail, and if the relation of $R_0' = R_0 + R_{ext}$ is rewritten giving consideration to the dependency on temperature of R_0',

$$\begin{aligned} R_0' &= R_0 + R_{ext} \\ &= R_0 + R_1 + R_2 \\ &= R_{MnO2} + R_2 \\ &= R_{MnO2} + R_{Metal} \qquad (7) \end{aligned}$$

where,

R_1: resistance of external surface MnO_2

R_2: resistance other than that of MnO_2

Here, the temperature characteristics of MnO_2 can be expressed as follows because both the inside and outside MnO_2 are semiconductors:

$$R_{MnO_2} = R_{0\,(MnO_2)} \cdot \exp\,(E/kT) \qquad (8)$$

where,

E: activation energy of MnO_2 (eV)

T: absolute temperature (°K)

k: Boltzmann's constant

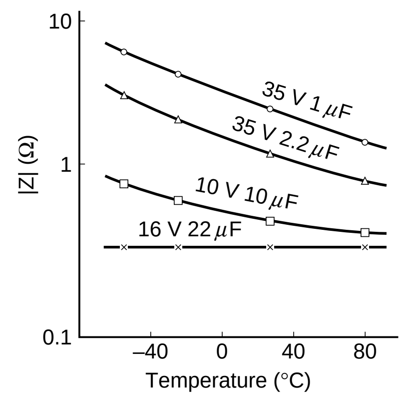


Figure 9 Temperature Characteristics of Impedance

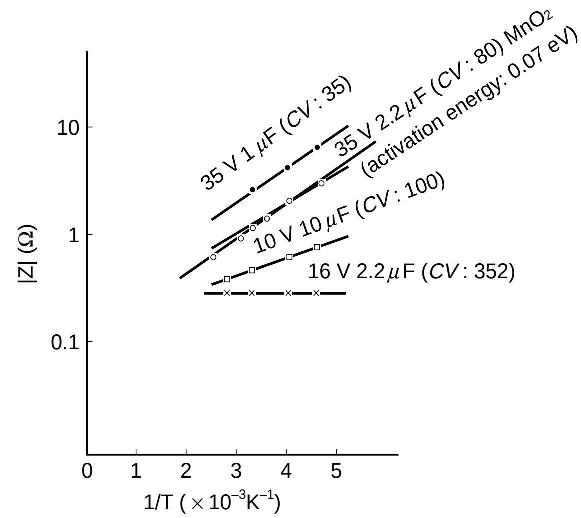


Figure 10 Temperature Characteristics of Impedance

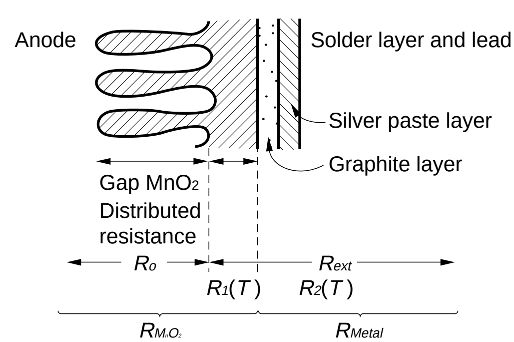


Figure 11 Division Between R_{MnO2} and R_{Metal}

In contrast, R_{Metal} is expressed as follows because it can be considered as function $R_{Metal}(T)$ that has positive temperature characteristics:

$$R_0'(T) = R_{0(MnO_2)} \cdot \exp(E/kT) + R_{Metal}(T) \quad (9)$$

This means that MnO_2 has negative temperature characteristics and that the resistance components other than MnO_2 have positive temperature characteristics.

Consequently, which of R_{MnO2} or R_{Metal} is dominant can be judged by measuring the temperature characteristics of R_0.

This is shown in Figure 11.

Figure 12 and Figure 13 show NEOCAPACITOR's impedance - temperature characteristics, and they show that its impedance changes moderately with temperature.

The activation energy E of NEOCAPACITOR is estimated at 0.015 eV and is almost 1/5 of conventional tantalum capacitor. From this fact, NEOCAPACITOR especially has a feature that its characteristics are quite stable at low temperature below 0˚C.

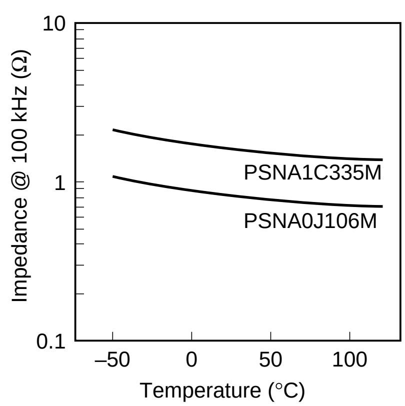


Figure 12 Impedance - Temperature Characteristics

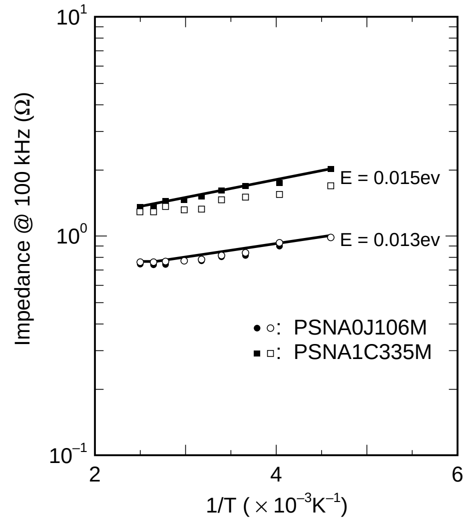


Figure 13 Impedance - Temperature Characteristics

4.2 DC Currents Fowing into Capacitor

(1) Types of DC Current

Generally, the currents flowing through an electrolytic capacitor that uses an anode oxide film as the dielectric can be broadly classified into the following three types:

(a) Dielectric absorption current (I_D)

(b) Intrinsic leakage current (I_I) (hereafter referred to as "leakage current")

(c) Surface leakage current (I_R)

Of these, the dielectric absorption current is due to the polarization distortion of the dielectric and decreases with time to 0. This current poses a problem in CR circuits (such as those used in timers).

The leakage current flows constantly through the insulation film and may affect reliability.

The surface leakage current flows constantly, like the leakage current, through the bypass of the dielectric and is affected by moisture.

(2) Changes in DC Currents with Time

Figure 14 shows an example of DC current fluctuation with time.

In this figure, curve 1 shows the characteristics of a capacitor with a relatively high leakage current, curve 2 shows those of a capacitor with the medium leakage current, and curves 3 and 4 are for capacitors with the lower leakage current.

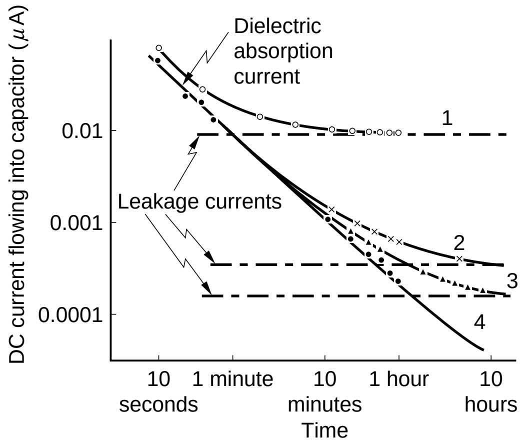


Figure 14 Changes in DC Currents with Time

The currents of all the samples decrease at a specific rate until a certain time has elapsed. After that, they will show constant values (The currents may increase or decrease depending on thermal degradation or recovery effect of the dielectric film in some cases, however.)

This phenomenon occurs because the DC current is the sum of dielectric absorption current that decreases at a specific rate and leakage current that is at a constant level from the onset.

The dielectric absorption current can be generally expressed as follows:

$$I_D = CV\varphi(t) \qquad (10)$$

where,

- C : capacitance
- V : applied voltage
- $\varphi(t)$: after-effect function (determined only by physical nature of dielectric)

It was confirmed, through experiments, that $\varphi(t)$ of the solid dielectric can be expressed as follows (where > 10s):

$$\varphi(t) = At^{-n} \qquad (11)$$

With a tantalum capacitor, n is in the range of 0.85 to 1.0, satisfying the relations of expression (10).

(3) Current vs. Voltage Characteristics

As indicated by expression (10), the dielectric absorption current (I_D) increases in proportion to the applied voltage, but the leakage current (I_L) becomes increasingly dominant as time passes. Generally, the leakage current poses a problem when a capacitor is constantly biased.

This paragraph therefore describes the current vs. voltage characteristics of the leakage current (I_L).

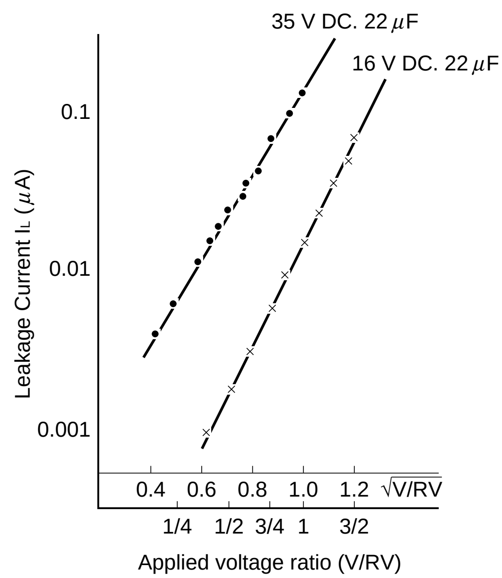


Figure 15 Voltage Characteristics of Leakage Current

Figure 15 shows an example of the voltage characteristics of leakage current I_L. According to this figure, a relation of "logI_L is proportional to $V^{0.5}$" is established over a wide range of the applied voltage, and the tilting angles of the two curves in the figure almost match when the horizontal axis indicates a ratio of the applied voltage to the rated voltage (RV). This relation is explained by a conductive mechanism of Schottky type.

However, a current of space charge limited type may be observed depending on the surface condition of the oxide film, in which case the relation of "I_L is proportional to V^2" is established.

(4) Capacitor's *CV* Value and Leakage Current

Generally, the DC current flowing into a capacitor when the rated voltage is applied to the capacitor is proportional to the *CV* value (product of the capacitance and rated voltage), which is distributed in the range of 0.02 *CV* [nA] to 0.01 *CV* [μA] (5 minutes after the rated voltage has been applied). Because the lower-limit value is determined by the dielectric absorption current, it differs depending on the time of measurement.

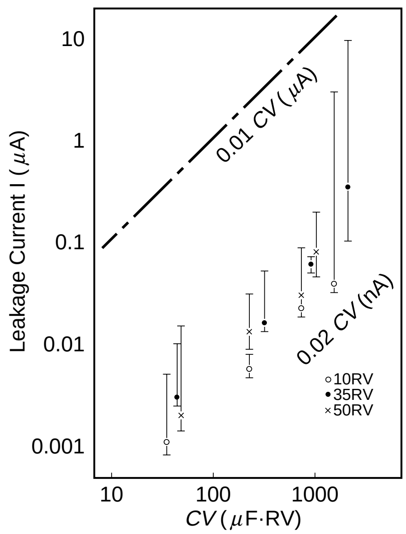


Figure 16 Relation Between CV Value and Leakage Current of Capacitor

Figure 16 shows an example of the relation between the *CV* value and leakage current of a capacitor. The above relation is established because the *CV* value is in direct proportion to the effective surface area of the anode. Therefore,

$$C = \varepsilon_S \varepsilon_0 \frac{S}{d} \qquad (12)$$

where,

- C : capacitance
- ε_S : dielectric constant of tantalum oxide film (approx. 27)
- ε_0 : vacuum dielectric constant (8.854×10^{-12} F/m)
- d : thickness of tantalum oxide film
- S : effective surface area of anode

$$d = \alpha_0 V_f = \alpha_1 V_{RV} \qquad (13)$$

where,

- α_0, α_1 : constants (because V_f and V_{RV} are generally designed to be at a constant ratio)
- V_f : voltage generated by oxide film
- V_{RV} : rated voltage

From expressions (12) and (13) above,

$$CV_{RV} = \varepsilon_S \varepsilon_0 \frac{S}{\alpha_1} \qquad (14)$$

Therefore,

CV_{RV} is proportional to S.

5. PRODUCTION PROCESS

This section describes the production process of capacitors in accordance with the block diagram shown in Figure 17. The production process shown in this figure is for the resin-molded chip type tantalum capacitor (R Series).

Sintered tantalum with a porosity of 40 to 70% is obtained by compressing and molding tantalum powder at a density of 4 to 9 and sintering this powder in vacuum at 1500 to 2000˚C.

Tantalum oxide is formed electrochemically on the surface of the sintered tantalum and is used as the dielectric. Unlike when an electrolytic solution is used, the tantalum oxide is subject to high temperatures in subsequent processes, which may lead to cracking on the oxide film, causing the leakage current to increase. Therefore, the anode is oxidized at a voltage three to five times higher than the rated voltage.

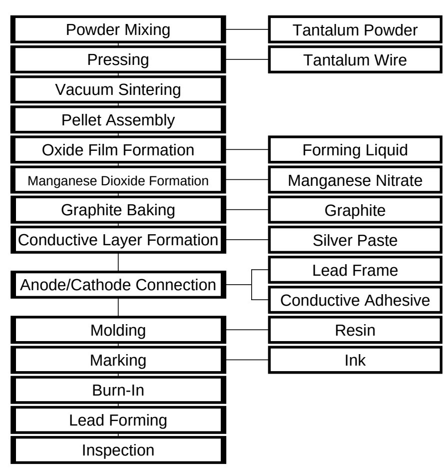


Figure 17 Block Diagram of Production Process (R Series)

The anode is dipped into a water solution of manganese nitrate, and is heated in a high-temperature atmosphere of 200 to 400˚C. This heating decomposes manganese nitrate into manganese dioxide.

$$Mn(NO_3)_2 \rightarrow MnO_2 + NO_2 + NO + O$$

The manganese dioxide layer is formed by repeating the above processes several times.

After manganese dioxide layer is formed, the anode is coated with graphite and silver layer.

In case of R series the capacitor element is connected with anode and cathode terminals and resin molded consequently.

This resin molded chip capacitor has good reputation in the market and is widely used in many applications.

6. RELIABILITY AND QUALITY CONTROL

As electronic systems become increasingly complicated, demand has grown for electronic devices and components that can provide extremely high reliability. To satisfy this demand, NEC's solid tantalum capacitors are subjected to stringent controls to maintain and improve their quality and reliability.

For this purpose, NEC constantly reviews and improves its reliability designing.

6.1 Reliability Designing

In addition to structural designing, the following factors are equally important in determining the quality and reliability of a solid tantalum capacitor:

(a) Effective Surface State of Tantalum Anode
(b) Uniformity of Oxide Film (Ta_2O_5)
(c) Formation Method of Manganese Dioxide
(d) Lead Connection to Anode and Cathode
(e) Handling and Mounting of Product
(f) Appropriate Application

The targeted reliability of the product is not achieved unless (a) through (d) are strictly controlled and observed in the production processes and (e) and (f) are adequately managed by the user.

(1) Effective Surface State of Tantalum Anode

If the shape of the effective surface of the anode is not correct or if impurities are doped to the anode surface, the dielectric oxide film (Ta_2O_5) may not be uniform. Especially, existence of sharp projections, different heavy metals, or excessive oxygen may adversely affect the leakage current (LC) characteristics of the capacitor.

In the production process of NEC's capacitors, tantalum powder with a purity of 99.99% or higher is used and sintered in vacuum at about 2000˚C. Therefore, heavy metals such as Fe, Cu, and Ni, which are contained in a relatively high percentage, are eliminated almost completely except when they are contained in the molecular bond state. The sharp projection is melted in the vacuum sintering process to create a smooth surface on the anode.

(2) Uniformity of Oxide Film (Ta_2O_5)

Uniformity of the oxide film that serves as the dielectric has a significant influence on the reliability of a solid tantalum capacitor. The oxide film is created by means of electrochemical oxidation, and non-uniformity or defect of the film are likely to occur, which heavily affects the reliability of the capacitor.

To create a uniform oxide film, therefore, stringent control of anode oxidation conditions is essential. Especially, the inside of the anode is directly joined with the surface through small gaps, and in order to create a uniform oxide film even inside these gaps, gap electrolytic reaction, which is generally considered difficult, must be carried out effectively.

Non-uniformity of the oxide film in the film thickness direction may cause degradation of reliability especially for the parts with higher rated valtage; therefore, the anode oxidation conditions must be determined and controlled with utmost care.

(3) Formation Method of Manganese Dioxide

Manganese dioxide (MnO_2) that forms the cathode is released by pyrolyzing manganese nitrate ($Mn(NO_3)_2$). A large quantity of high-temperature gas is generated during decomposition of the manganese nitrate, which may cause chemical damage to the anode oxide film (Ta_2O_5), substantially lower the insulation, and considerably degrade reliability.

Therefore, the gas must be eliminated as quickly as possible by releasing the pressure in the furnace.

However, because the route through which the generated gas goes is narrow in the gap inside the anode, the gas cannot be eliminated at the right time and damage to the oxide film is unavoidable. The damaged portion of the oxide film must therefore be recovered by carrying out the oxidation reaction again.

This recovery process must be performed as many times as manganese dioxide thermal decomposition is performed.

(4) Lead Connection to Anode and Cathode

To connect the anode lead, a solder-plated lead that can be soldered by the user is connected by means of welding to the tantalum wire because the tantalum wire cannot be soldered. If this soldering is inappropriate, the capacitor may be open or noise may be generated; therefore, the soldered joint of the anode must have a specially high reliability. Soldering must be stringently controlled before starting connection of the anode lead to ensure the connection reliability. The stability of NEC's soldering process control has been demonstrated by the past record.

The cathode cannot be soldered and directly connected to a lead because manganese dioxide is fragile by nature; therefore, it is generally connected by soldering a conductive material such as silver paste or by a conductive adhesive. The manganese dioxide and silver paste are connected on the surface. If the contact between the two is inappropriate, dissipation factor may increase due to an increase in equivalent series resistance, or noise may be generated. Consequently, the reliability of the joint between the capacitor element and cathode lead is as important as in the case of the anode lead. NEC stringently controls its cathode lead connecting process, so that its products provide a high reliability.

(5) Handling and Mounting of Product

The oxide film (Ta_2O_5) created by anode oxidation contains elements slightly different from those of mica or organic film.

Because the oxide film is energetically in a high state, electrochemical reaction is likely to take place inside the oxide film due to external electric field stress, and if the stress exceeds a specific level, the oxide film may be substantially degraded. The insulation resistance of the oxide film is at the same level as that of the semiconductor materials used, and avalanche current may flow through the weakest point of the oxide film. In consequence, crystal transformation may locally occur due to the joule heat generated by the avalanche current, and the oxide film may be cracked by a stress caused by a crystal density difference. This may result in defective short circuiting.

To stabilize the oxide film, NEC conducts screening and aging by applying a voltage higher than the rated voltage to the sample for a long time at high temperature in order to accelerate degradation of the unstable portion of the oxide film.

It is important that adequate consideration be given to the mechanical or physical stress imposed on the solid tantalum capacitor because the construction and constituent materials of this type of capacitor are susceptible to such a stress; if excessive stress is applied to the capacitor, the reliability is degraded.

6.2 QC and QA Systems

High reliability of a solid tantalum capacitor is ensured through the implementation of stringent quality controls that must be performed at every production process including designing, material selection, production, and shipment, in order to detect and reject defective products if any.

The NEC's quality assurance (QA) and quality control (QC) systems are approved by ISO9001 and 9002.

Figure 18 is a flowchart illustrating how NEC conducts its QA and QC.

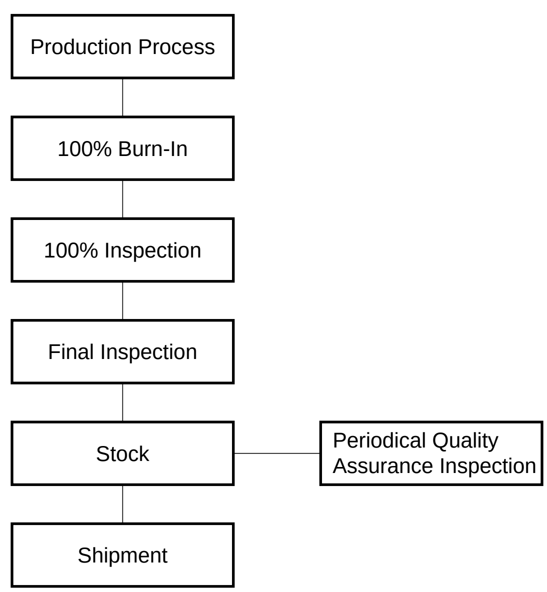


Figure 18 NEC's QA and QC Systems

6.3 Confirming Reliability

NEC conducts various tests to check the following points and thereby to ensure the reliability of its solid tantalum capacitors:

(a) Operation life expectancy
(b) Mechanical durability and environmental durability
(c) Failure rate under accelerated condition
(d) Field failure rate

(1) Operation Life Expectancy Test

The life expectancy test is conducted with the sample subjected to the maximum permissible temperature and the maximum permissible voltage (rated voltage) under continuous operation conditions. The temperature and voltage are the important parameters that determine the failure mode, and test conditions that show the failure mode matching the field failure mode must be selected.

Therefore, if the sample is tested at a temperature and voltage higher than the permissible values, the field failure cannot be checked accurately.

Regarding the resin-coated solid tantalum capacitor, a humidity test is also conducted in addition to the operation life expectancy test at a high temperature, because reliability of the resin coating is lower than that of a metal case with sealed glass terminal and, therefore, a test must be conducted by taking moisture effect into consideration. Table 2 outlines the operation life expectancy test conducted by NEC.

Table 2 Conditions of Operation Life Expectancy Test

Test Method	Tempera-ture	Applied Voltage	Test Time	Circuit Resistance	Criteria		
					Changes in Capacitance	tanδ and LC	Failure Rate
IEC 60384-1	85±2˚C	Rated Voltage	2,000 h	Series Resistance, 3 Ω max.	Recovery: 1 h to 2 h ±10%	tanδ : Initial Requirement LC : Initial Requirement × 125%	Must satisfy designed failure rate level (CL60%)
	125±2˚C	Category Voltage (Reted Voltage × 63%)	2,000 h				

(2) Mechanical Durability and Environmental Durability Tests

Generally, an electronic component is not always used in the field under ideal envionmental conditions. It is usually subjected to constantly changing external stress and ambient environments and must be able to endure any condition in the field. Therefore, NEC conducts strict mechanical (physical) stress and environmental an important tests.

If the sample is tested under too strict stress conditions, the test is meaningless; if the test conditions are relaxed too much, the quality level of the sample cannot be accurately evaluated.

Therefore, determining the appropriate test conditions is an important task.

NEC conducts mechanical and environmental durability tests to prove the reliability of its solid tantalum capacitors in compliance with the MIL standards. In old days, MIL-STD-202 has been used for the test method of solid tantalum capacitors. Recently, in accordance with the introduction of IEC Std, Pub68/60/384-1 has been popular. Refer to Table 3. Table 4 shows an example of the results of an in-house test conducted by NEC.

(3) Failure Rate Test Under Accelerated Condition

NEC tests the failure rate of its solid tantalum capacitors by means of PRT. With PRT, the failure rate can be confirmed in a short time because it uses accelerated conditions.

Here are the test conditions:

Ambient temperature : 85˚C
Test circuit resistance : 3 Ω max.
Applied voltatge : accelerating voltage

Table 5 and Figure 19 show relations between the voltage stress and acceleration coefficient.

Figure 20 shows an example of the failure rate of each type of solid tantalum capacitor.

Table 3 Methods and Conditions of Mechanical (Physical) Durability and Environmental Durability Tests

Parameter	Method	Conditions
Shock	IEC68-2-27	3 times in 6 directions, 100 G
Vibration (I)	IEC68-2-6	10 to 55 Hz, amplitude: 1.5 mm, in 2 directions for 4 h
Vibration (II)	IEC68-2-6	10 to 2000 Hz, amplitude: 1.5 mm, 20 G, in 2 directions for 4 h
Rapid change of temperature (I)	IEC68-2-14	–55 to +125˚C, 5 cycles
Rapid change of temperature (II)	IEC68-2-14	–55 to +85˚C, 5 cycles
Immersion cycle	JIS C 5102 (9.4) MIL STD 202 (104A)	Hot water (65^{+5}_{0}˚C) → saturated salt water (25^{+10}_{0}˚C), 2 cycles
Salt mist	IEC68-2-11 MIL STD 202 (101D)	5%, NaCl sol., 0.3 to 5 ml/h, 48 h
Solderability (I)	IEC68-2-20	230±5˚C,
Solderability (II)	JIS C 5102 (8.13)	235±5˚C, 2 s
Resistance to soldering (I)	IEC68-2-20	260 ±5˚C, 10 s, 1.5 to 2 mm from sample
Resistance to soldering (II)	JIS C 5102 (8.14) (solder dipping)	immersing for 10 sec, at 235 ±5˚C
Resistance to soldering (III)	JIS C 5102 (8.14) (reflow)	240±5˚C, 10 s
Resistance to solvents	IEC68-2-45	20 to 25˚C, isopropyl alcohol, dipped for 30 s
Damp heat, steady state	IEC68-2-3	40˚C, 90 to 95% RH/60˚C, 90 to 95% RH
Humidity cyclic test	IEC68-2-38	Including –10 to +65˚C temperature cycle, 98% RH max. 10 cycles
Terminal strength (I)	IEC68-2-21	Pulling force: 5 to 10 N, 10 s Bending force: 0.25 to 0.5 kg, 90˚/3 s, 2 cycles Twisting: 360˚, 3 times
Terminal strength (II)	JIS C 5102 (8.11)	Bending of PWB: 1 mm
Characteristics at high and low Temperature	JIS C 5102 (7.12)	–55 to 125˚C (or 85˚C)
Surge voltage (I)	MIL C 39003	85˚C, U_R × 1.3, 30 s ON/30 s OFF, 1000 cycles, 33 Ω
Surge voltage (II)	JIS C 5102 (7.14)	85˚C, U_R × 1.3, 30 s ON/5.5 min OFF, 1000 cycles, 1 kΩ
Charge/discharge cycle	JIS C 5102 (7.17)	Room temperature, U_R × 1 0.5 s ON/0.5 s OFF, 1000 cycles

Table 4 Mechanical (Physical) Durability and Environmental Durability Tests of Solid Tantalum Capacitors

Type of Sample	Resin Coated Exterior Type	Resin Mold Exterior Chip Type
Part Number	DN Series DN0J101M1S DN1H01M1S	R Series NRA475M04
Test Parameters	Defects/Samples	Defects/Samples
Shock	–	–
Vibration (I)	0/6	–
Vibration (II)	–	–
Rapid Change of Temperature (I)	–	0/18
Rapid Change of temperature (II)	0/6	–
Immersion Cycle	–	–
Salt Mist	–	–
Solderability (I)	0/6	–
Solderability (II)	–	0/5
Resistance to Soldering (I)	0/6	–
Resistance to Soldering (II)	–	0/12
Resistance to Solvents	0/6	–
Damp Heat, Steady State	0/6	0/9
Humidity Cyclic Test	–	–
Terminal Strength (I)	0/6	–
Terminal Stength (II)	–	0/12
Characteristics at High and Low Temperature	0/6	0/15
Surge Voltage (I)	0/6	–
Surge Voltage (II)	–	0/6

Table 5 Voltage Stress and Acceleration Coefficient of Solid Tantalum Capacitor

(Temperature: 85˚C)

Acceleration Coefficient	Test Voltage/Rated Voltage
1	1.00
10	1.16
100	1.32
1 000	1.475
10 000	1.63
100 000	1.79

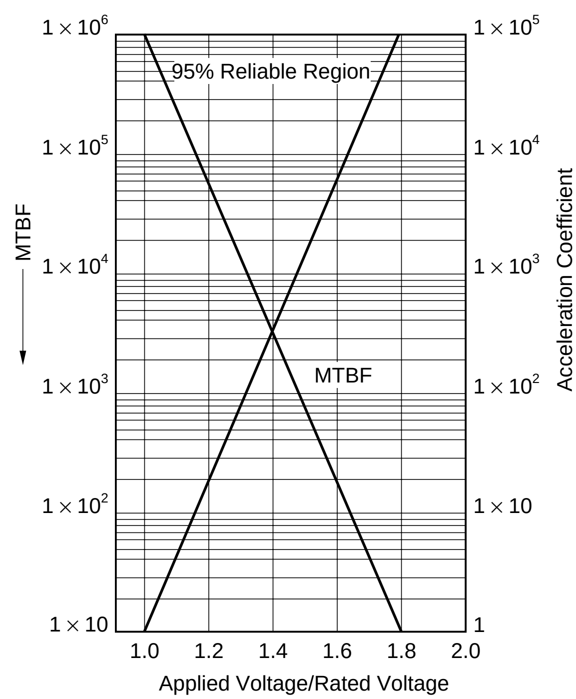
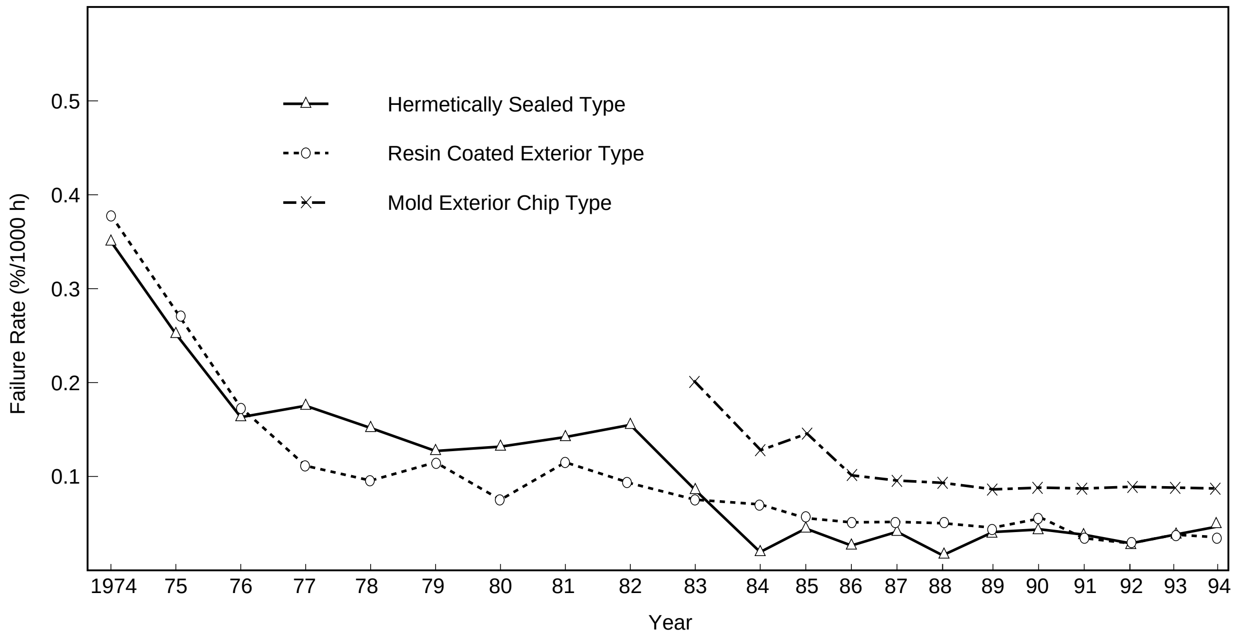


Figure 19 Voltage Stress and Acceleration Coefficient



Failure 20 Failure Rates

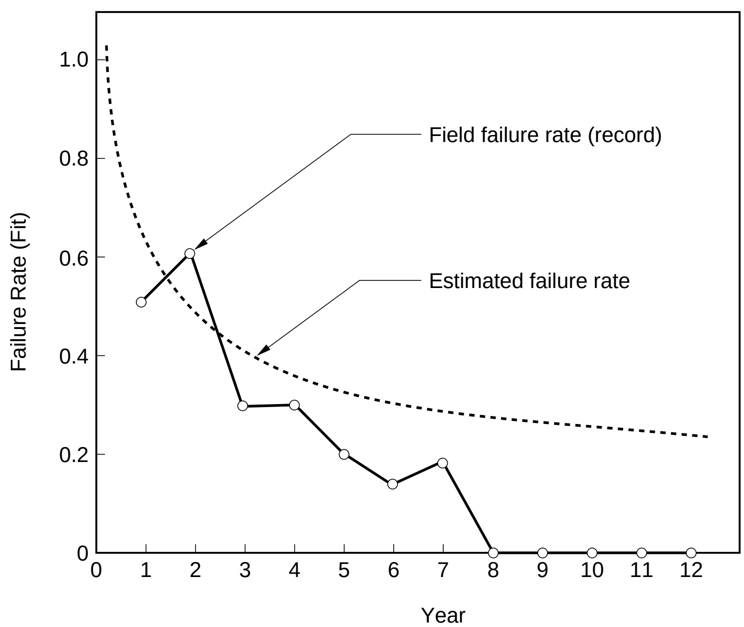


Figure 21 Field Data (Record) and Estimated Failure Rate

(4) Investigation of Field Failure Rate

NEC always checks the failure rate of its solid tantalum capacitors by keeping a record of the failures that occurred in the field through its claim feedback system.

The data on the failure rate obtained in this way are compared with the data resulting from evaluation tests to assure the reliability of NEC products.

Figure 21 shows an example of the failure rate of a metal-case, hermetically-sealed solid tantalum capacitor employed for a given application system.

Figure 22 shows an example of the failure occurrence pattern of solid tantalum capacitors (the data in this example are for solid tantalum capacitors actually used in a carrier transmission system). This figure indicates that the longer the time, the longer the MTBF.

Therefore, reliability in the field is closely related to the duration of the voltage aging performed during the manufacturing process of capacitors, and the voltage aging time must be extended if a very high reliability is required.

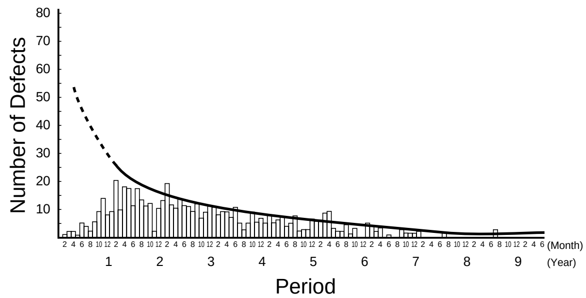


Figure 22 Failure Occurrence Pattern of Solid Tantalum Capacitors

7. GUIDE TO APPLICATIONS

7.1 Expecting Reliability

The applied voltage (working voltage) and ambient temperature are two factors that heavily affect the reliability of a capacitor.

The reliability (failure rate) is generally proportional to the power of the voltage ratio, and to exponential of the power of temperature.

Therefore,

$$\lambda_b = A\left[\left(\frac{S}{Ns}\right)^H + 1\right] e\left(\frac{T}{N_T}\right)^G \qquad (16)$$

where,

- λ_b : Failure Rate, when only voltage ratio and operating temperature are considered
- S : Ratio of Working Voltage to Rated Voltage
- T : Ambient Temperature (K)
- A : Capacitor Shape Factor
- Ns : Stress Coefficient
- N_T : Temperature Coefficient
- H, G : Acceleration Constants

Note, however, that there are many other factors involved that have an influence on the failure rate in addition to the voltage and temperature, and compensation must be made by adjusting these other factors.

As compensatory factors, (a) compensation of operating environments, (b) compensation by capacitance, (c) compensation by series resistance, (d) compensation by reliability level, and (e) compensation by case size and level must be taken into consideration. Where the compensatory coefficients for (a) and (e) are π_E, Σ_E, π_{CV}, π_{SR}, π_{ER}, and π_{CS}, the actual failure rate λ_p can be calculated by the following expression[3]:

$$\lambda_p = \lambda_b\,(\pi_E \times \pi_{CS} \times \pi_{CV} \times \pi_{SR} \times \pi_{ER}) \times \Sigma_E \qquad (17)$$

However, because it is extremely difficult to determine each compensatory factor, it is accordingly difficult to estimate the actual failure rate by using this expression. Yet, there is a method to estimate the failure rate in a simpler and more practical way.

Suppose that the failure rate of a capacitor is obtained at a certain temperature (T_0) and voltage (V_0) (generally, the maximum operating temperature and rated voltage), where the basic failure rate is λ_0. It is confirmed through experiment that the failure rate λ at the temperature (T) and working voltage (V) in the field is approximated by the following expression (4):

$$\lambda = \lambda_0\left(\frac{V}{V_0}\right)^n \bullet 2^{\left(\frac{T-T_0}{\theta}\right)} \qquad (18)$$

where n and θ are parameters determined by the type of the capacitor. For a solid tantalum capacitor, n = 3 and θ = 10, which has been confirmed through experiments.

Figure 23 illustrates expression (18) above. In this figure, the vertical axis indicates the actual failure rate vis-a-vis the failure rate λ_0 when a test is conducted at T_0 = 85˚C and V_0 = rated voltage, and the horizontal axis indicates the actual ambient temperature. The parameters in each graph are (actual operating voltage)/(rated voltage), which is generally called a derating ratio.

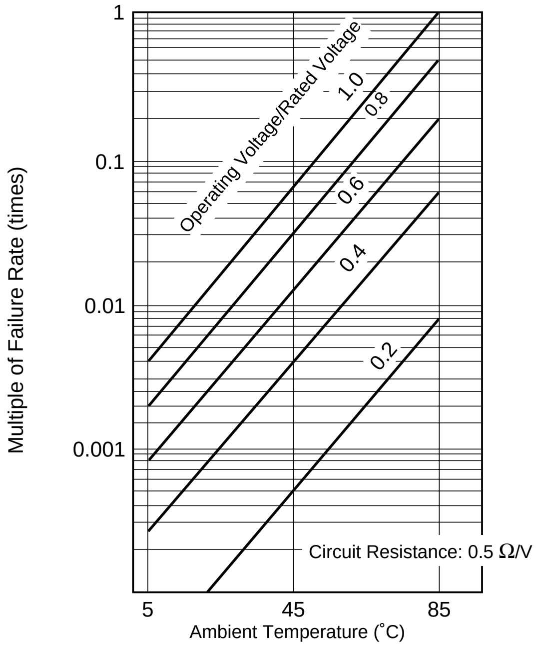


Figure 23 Relations Among Operating Temperature, Applied Voltage, and Failure Rate

Expression (18) is very useful for estimating the actual field failure rate and is extremely practical.

For your reference Figure 24 shows data from MIL Handbook[5]. The failure rate is 1%/10^3 h when measured at 85˚C and rated voltage. Table 6 shows an example of the field failure rate of a solid tantalum capacitor actually used in a carrier transmission system.

When the failure rate at a ratio of operating voltage to rated voltage of 50% and at an ambient temperature of 40˚C is estimated by using Figure 23, it is 0.005 times the failure rate measured at 85˚C and rated voltage, which is close to the actual failure rate. However, when the graph of MIL Handbook (Fig. 24) is used, the failure rate is 0.04 times, which is 1 digit greater.

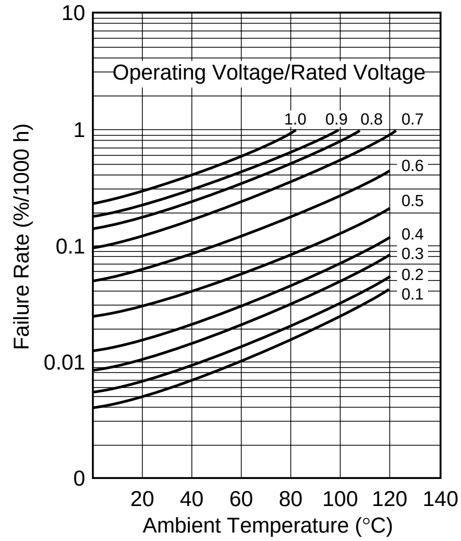


Figure 24 Relations Among Ambient Temperature, Applied Voltage, and Failure Rate in the Case of MIL Standard

Table 6 Field Failure Rate of Solid Tantalum Capacitor

(1981 to 1995)

Total Number of Samples	1, 130, 200 pcs.
Component Time	98.53×10^9 h
Number of Defects	21 pcs.
Failure Rate	0.21 Fit

Note The total number of samples indicates the number of capacitors used during the period from 1981 to 1988

Compared with expression (16), expression (18) has little theoretical background. Yet it can approximate the failure rate in the range of S (rate of working voltage to rated voltage), which is used in the actual field (for example, with S in the range of 20 to 70%).

The failure rate is calculated by expression (16), where S = 0 (under no voltage load), as follows:

$$\lambda_{b(S=0)} = Ae\left(\frac{T}{N_T}\right)^G \quad (19)$$

The value calculated in this way, however, is too small and is not confirmed. Therefore, it is not taken into consideration in expression (18). In the case of expression (18), λ = 0 where (V/V_0) = 0. Actually, however, this is not 0 but a given small value.

Nevertheless, this value is too small and is negligible compared with λ when a voltage load is applied.

7.2 Failure of Solid Tantalum Capacitor

(1) Failure Mode

The failure mode of a solid tantalum capacitor is caused by an increase in leakage current and an increase in impedance, and accounts for more than 95% of the total number of failures. Especially, failures caused by the latter factor are fatal when the capacitor is used in a high-frequency signal transmission circuit. In other cases, the factor of increased leakage current is fatal.

(2) Mechanism of Failure Occurrence

There are many causes of failure occurrence. However, they can be broadly classified into two types: those inherent to the capacitor itself such as materials and production processes, and external causes such as handling and operating conditions. Figure 25 shows the relations between the cause and the process of a failure.

As can be seen from this figure, the causes related to leakage current considerably outnumber those related to impedance, indicating that the failures due to leakage current occur more frequently than those due to impedance. The failures caused by impedance are due to external factors most of the time, not due to the factors inherent to the capacitor.

The reliability of a tantalum capacitor is determined by the degree of the inherent causes (defects) of the capacitor. If these defects can be completely eliminated, the reliability of the capacitor can be improved infinitely and the failure can be decreased to zero. However, completely eliminating these defects is impossible with the present technologies (such as purification technology of raw materials and capacitor production technology).

Yet, the defects can be decreased down to the limit that can be realized with present technologies and, if necessary, capacitors having defects can be rejected by means of screening, to improve reliability. The actual problem to solve to improve and maintain reliability is, therefore, to minimize the defects to a level permissible for actual applications.

The reliability levels that are permissible at present are 0.5%10^3 h max. for application in industrial/ communications equipment and 1%/10^3 h max. for application in consumer appliances at an ambient temperature of 85˚C and rated voltage. For application in space satellite communication or submarine cables, however, a reliability of as high as 0.1 to 0.01%/10^3 h is demanded.

Generally, even capacitors having the same defects may take different times (can be considered to be equivalent to MTBF) until a failure occurs because the operating conditions (such as temperature, voltage, mechanical vibration, and shock) are different. Defects in the dielectric film grow more pronouncedly especially when temperature or electric field density is applied to the film. The temperature is in accordance with Arrhenius' chemical reaction speed.

The relations between the electric field intensity and degradation speed are understood as follows: as the defect in the dielectric film degrades, the field intensity (or insulation resistance) of that part decreases. When the degradation progresses to the point at which the capacitor can no longer endure the field intensity applied from an external source (this intensity can be taken as the applied voltage of the capacitor), a failure occurs. Therefore, the lower the working voltage, the higher the reliability.

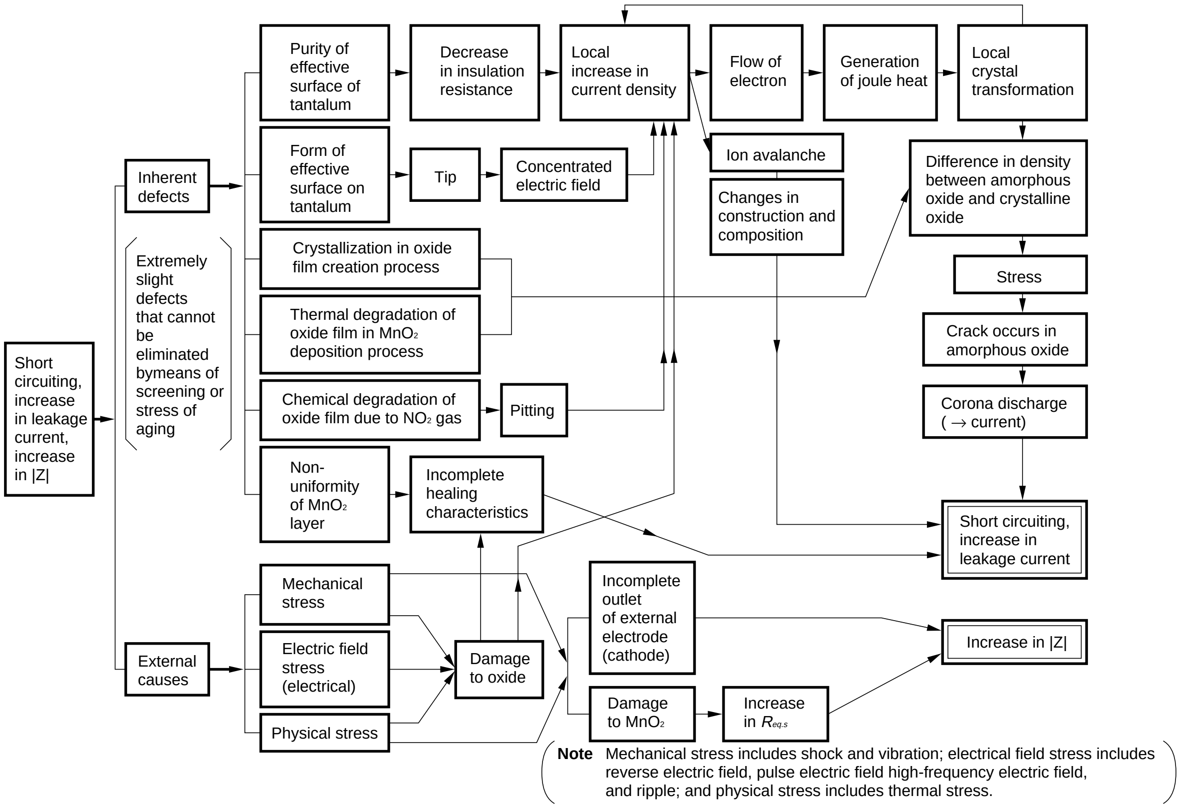


Figure 25 Causes and Processes of Failures of Solid Tantalum Capacitors (Short Circuiting, Increase in Leakage Current and Impedance)

The higher the temperature, the faster the degradation of the defect, and the shorter the MTBF. Consequently, the reliability drops.

Figure 26 explains this phenomenon. In this figure, curves A and B indicate degradation of the defects of a capacitor, and curve A is measured at the higher temperature than curve B (the tilting angle indicates the degradation speed. The more acute the angle, the higher the degradation speed). Curves C and D indicate the voltages applied to the capacitor. Failures occur at the intersections (a, b, c and d) of curves A, B, C and D.

It is easily understood that, from $T_1 > t_1$ and $T_2 > t_2$, the lower the temperature, the higher the reliability, and that, from $T_2 > T_1$ and $t_2 > t_1$, the lower the voltage ratio, the higher the reliability.

The process by which a failure actually occurs, however, cannot be explained with the above factors, and many other complicated factors such as interaction between temperature and voltage are difficult to explain theoretically.

7.3 CV Value and Reliability

Figure 27 shows an example of the relations between the CV value and the failure rate of a capacitor. As can be seen, the greater the CV value, the higher the failure rate. This is because the causes of the failure (those inherent to the capacitor) shown in Fig. 25 increase their influence in proportion to the effective surface area of the capacitor.

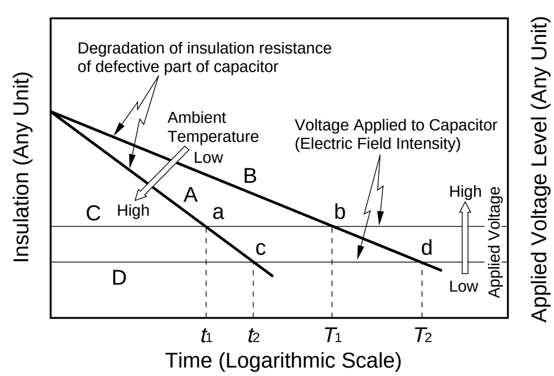


Figure 26 Relations Between Capacitor Operating Conditions and Time Until Failure Occurs

As can be seen from Figure 27, however, the failure rate is not directly proportional to the CV value. This is because the failure rate consists of failures that are directly proportional to the capacitor's effective surface area, and failures that are completely independent of the effective surface area.

The former includes failures caused by the purity of the tantalum, the shape of the effective surface, and degradation of the dielectric film due to NOx gas, the latter include failures caused by the lead terminal outlet (including the purity and surface condition of lead terminal materials and connection of the lead terminals). The relations among these factors are similar to the relations between the CV value and leakage current in terms of graph curve inclination and causes.

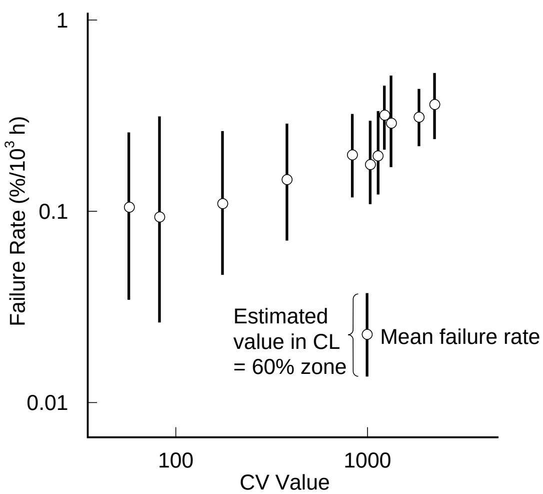


Figure 27 Relations Between CV Value and Failure (Example)

7.4 Factors Influencing Reliability and Failure Rate

The reliability of a solid tantalum capacitor is also affected by how the capacitor is handled or used (i.e., circuit design) by the user. Therefore, the reliability targeted in the capacitor design can be fully realized if the capacitor is handled and used under adequate quality control at the users.

The main factors that influence the reliability while the capacitor is used include shock, series resistance, ripple voltage, and reverse voltage. Adequate consideration must be given to these factors.

(1) Shock and Reliability

Generally, the reliability of a solid tantalum capacitor is likely to be affected if shock is applied to the capacitor, like the other electronic components. Therefore, care must be exercised that excessive force is not applied to the capacitor by dropping it onto the floor before it is used. The reliability of a capacitor to which shock has been applied probably drops; such a capacitor should not be used.

Figure 28 shows the relations between the height of free fall and reliability. The data shown in this figure was measured by dropping a sample repeatedly 10 times onto a concrete floor. The sample is a capacitor having a relatively high capacitance.

After the sample was dropped onto the floor, a life expectancy test was conducted and the failure rate was calculated. Because drop shocks of increasing magnitude were applied to the sample, the failure rate could be observed fairly clearly.

Note that if a sample is dropped only once, an extreme degradation of reliability as the one shown in this figure cannot be observed.

Figures 29 and 30 show testing results obtained using a shock tester, about the relations between shock and reliability, and changes in leakage current after the shock test was conducted. The same sample models as those in the drop test were used with shock applied to each sample five times in 6 directions, for a total of 30 applications. After that, a life expectancy test was conducted to calculate the failure rate. The leakage current did not change much even after a shock of 2000 G, but the reliability showed an outstanding decrease from around 1500 G.

Figure 31 shows the relations between the shock and leakage current for a chip tantalum capacitor. These data were measured by letting the sample fall onto a concrete floor from a height of 1 m. Little degradation of leakage current was observed even after the sample had been dropped 15 times.

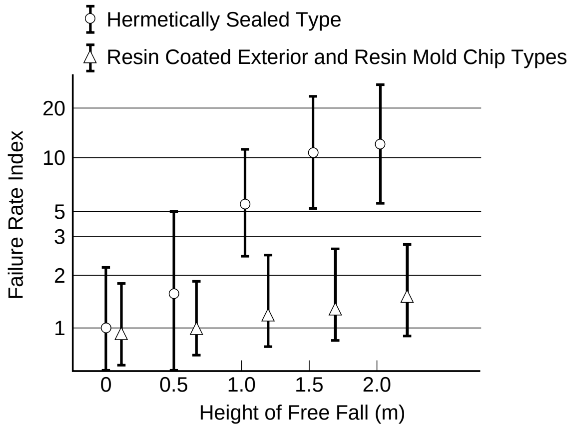


Figure 28 Relations Between Height of Free Fall and Failure Rate

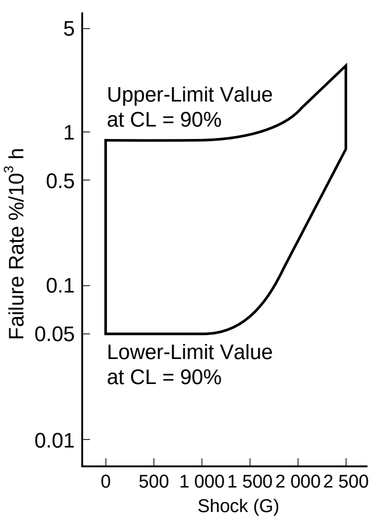


Figure 29 Relations Between Strength of Shock and Failure Rate (Hermetically-Sealed Type)

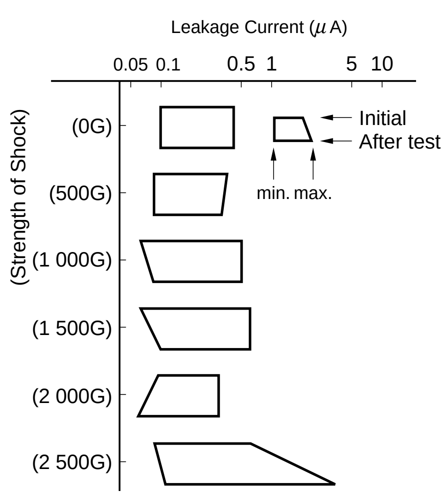


Figure 30 Changes in Leakage Current after Shock Test (Hermetically-Sealed Type)

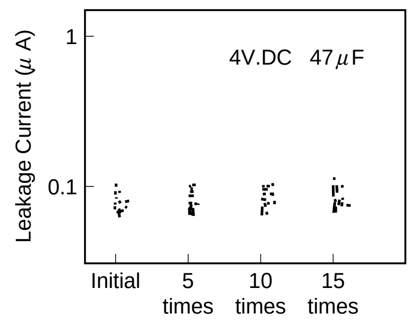


Figure 31 Relations Between Number of Drop Times and Leakage Current (Chip Tantalum Capacitor)

(2) Series Resistance and Reliability

A resistor connected in series with a capacitor mitigates the electric field stress (such as surge voltage and electric field shock) imposed on the dielectric film of the capacitor by suppressing the charging and discharging current of the capacitor. Therefore, the series resistance (referred to as Rs here) has an influence on the reliability of the capacitor. The higher Rs, the higher the reliability because the electric field stress on the dielectric film of the capacitor is small.

Figure 32 shows the relations between Rs and reliability (failure rate). The horizontal axis indicates resistance per applied voltage, and the vertical axis indicates a ratio where the failure at 3 Ω/V is 1.

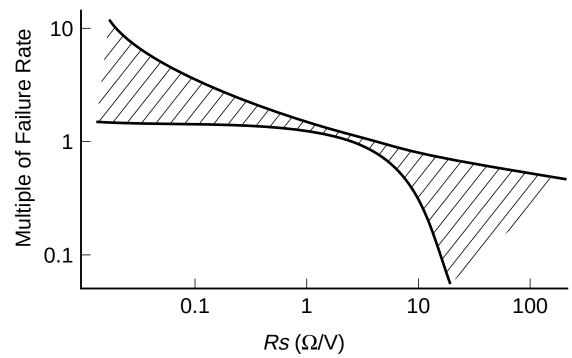
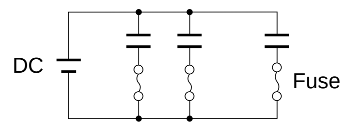
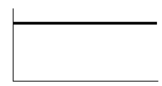
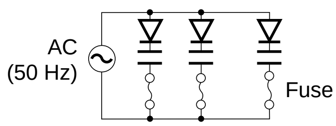
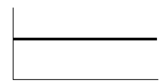
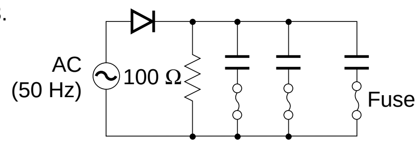
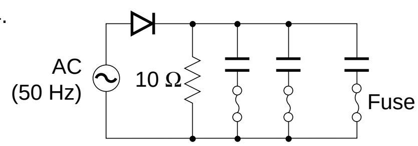
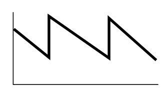


Figure 32 Relations Between Series Resistance and Failure Rate

Table 7 Failure Rate When Voltage Including Ripple is Applied to Capacitor

<table>
<tr><th>Test Circuit</th><th>Voltage Waveform Applied to Capacitor</th><th>Ratio of Failure Rate Where Failure Rate Measured With Test Circuit 1 is 1</th></tr>
<tr><td>1.
</td><td>
Ripple Component: 0%</td><td>1</td></tr>
<tr><td>2.
</td><td>
Ripple Component: 0%</td><td>1</td></tr>
<tr><td>3.
</td><td>
Ripple Component: 20%</td><td>8.09</td></tr>
<tr><td>4.
</td><td>
Ripple Component: 80%</td><td>56.7</td></tr>
</table>

(3) Ripple and Reliability

In the case of an aluminum electrolytic capacitor, a phenomenon called “dry-up”, in which the capacitance drops, occurs if too high a ripple voltage is applied. With a solid tantalum capacitor, degradation of the defects on the dielectric film is caused to progress by ripple current, the MTBF becomes short, and the reliability is degraded. These factors must be considered especially when the capacitors are used for smoothing in a rectifier circuit.

Table 7 shows an example of the result of a reliability test conducted in a circuit containing a ripple component.

The failure rate increases about eight-fold and 56-fold, respectively, if 20% and 80% ripple components are inciuded, as compared with the failure rate measured when no ripple occurs.

Therefore, the higher the ripple content, the greater the failure rate. Care must be exercised that the voltage applied to the capacitor contains no ripple.

(4) Reverse Voltage and Reliability

It is not desirable to apply a reverse voltage successively to a polar solid tantalum capacitor. If a capacitor must be used in a circuit in which a reverse voltage is applied, a non-polar solid tantalum capacitor is recommended.

Depending on the design of the circuit, however, there is a possibility that a reverse voltage might be applied to a polar solid tantalum capacitor. Figure 33 shows an example of the failure rate of a capacitor when various levels of reverse voltage were applied to it. The horizontal axis in this figure shows the ratio of the applied reverse voltage to the rated voltage. For example, in order to keep the failure rate to within 1%/10^3 h, the reverse voltage must be less than 5% of the rated voltage.

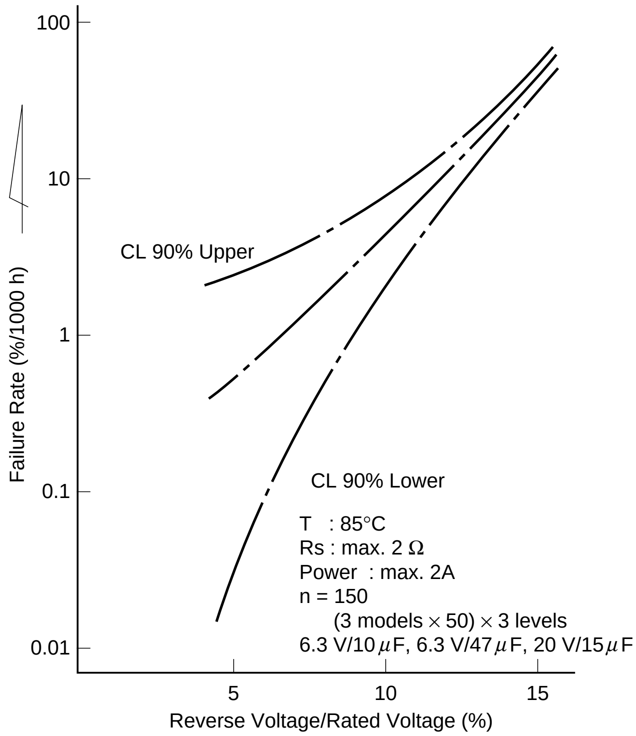


Figure 33 Failure Rate when DC Reverse Voltage is Successively Applied to Capacitor

References

(1) R. L. Taylar and H. E. Haring; "A Metal Semi-conductor Capacitor": J. ElectrocheSoc., Vol. 109 Nov. 1956 pp. 611

(2) Ishikawa and Sasaki: from script for "Mechanism of Tantalum Capacitor of PIN Junction Model". 364, 1955

(3) RADC Note Book. Vol. 2 (1974)

(4) Okuda et al.: NEC Technical Journal, No. 91 (1968)

(5) MIL-HDBK-217A (Dec., 1965)

(6) Y. Hasegawa and Morimoto: "Characteristics and Failure Analysis of Solid Tantalum Capacitors" NEC R&D, No. 50 pp. 79-94 July 1978

8. APPLICATION CIRCUITS

The tantalum capacitor has the following features as compared with the aluminum electrolytic capacitor:

1) Small
2) Low Leakage Current
3) Good Frequency Characteristics
4) Good Temperature Characteristics
5) Low Dissipation Factor (tanδ)
6) Long Life

This section introduces application examples of the tantalum capacitor to demonstrate the above features.

8.1 Example of Using Small, High-Capacitance Capacitor

Many application examples can be cited where the most outstanding features of a solid tantalum capacitor — small size and high capacitance — are fully appreciated. Here are some examples of using NEC's R series and SVS series solid tantalum capacitors that have been developed for application in super small systems:

(1) Car Audio

Figure 34 shows an example of an audio-frequency power amplifier for a car audio system.

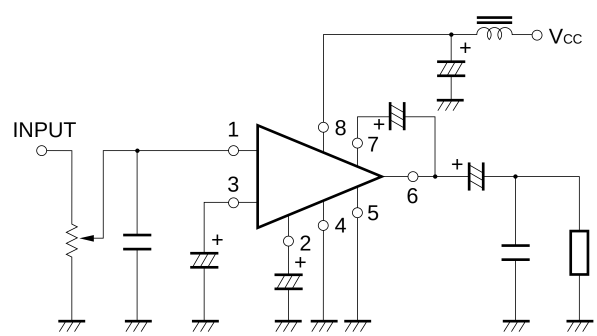


Figure 34 Example of Audio-Frequency Power Amplifier

(2) Headphone Tape Recorder

Figure 35 is an example of a headphone driver, in which five to eight electrolytic capacitors are necessary. If solid tantalum capacitors are used instead of electrolytic capacitors, the volume can be almost halved.

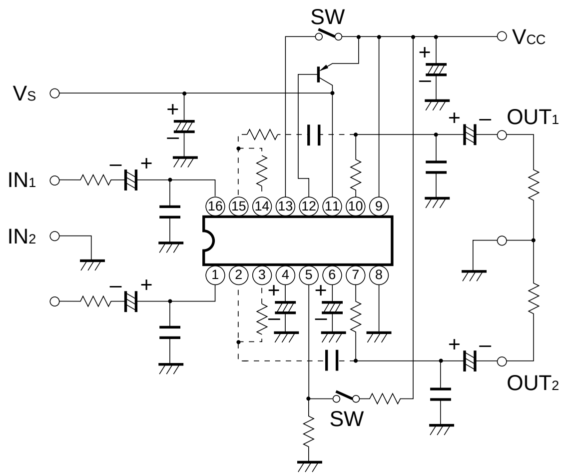


Figure 35 Example of Headphone Driver

(3) Others

The size and the number of capacitors used hold clue to reducing the size of an electronic system.

In addition to the application examples introduced above, small solid tantalum capacltors are employed for many other small electronic systems such as video cameras, cellular telephones, pagers, and hybrid ICs.

8.2 Examples of Using Small, High-Capacitance Capacitors and Leakage Current

(1) Audio Circuit

Capacitors used in an audio circuit such as the one shown in Fig. 36, especially coupling capacitors C_1 and C_0 in operational amplifiers and tone control circuits, may cause noise if they have a high leakage current and if the leakage current fluctuates heavily.

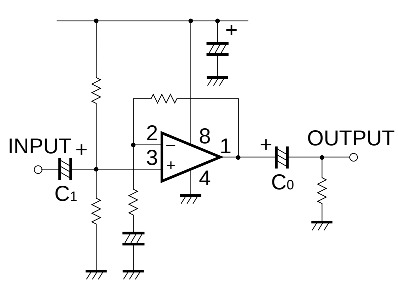


Figure 36 Example of Operational Amplifier

Figure 37 compares the leakage current vs. time characteristics of a solid tantalum capacitor and aluminum electrolytic capacitor.

As shown, the response of the aluminum electrolytic capacitor to fluctuation in leakage current is slower than that of the solid tantalum capacitor. Moreover, the leakage current of the electrolytic capacitor is higher than that of the solid tantalum capacitor. For this reason, the solid tantalum capacitor is often used as a coupling capacitor to provide excellent noise immunity.

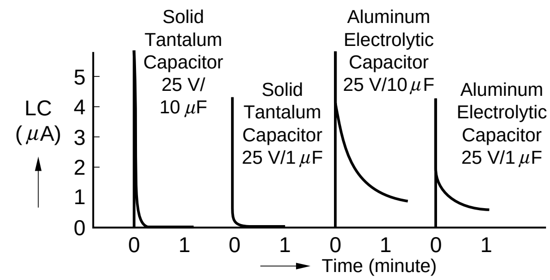


Figure 37 Leakage Current vs. Time Characteristics

(2) Timer Circuit

In the timer circuit shown in figure 38, the leakage current of capacitor C_T must be decreased as much as possible.

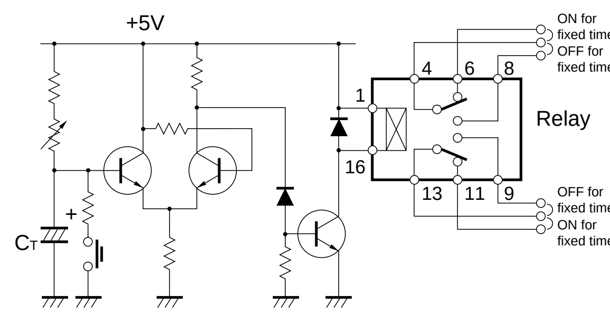


Figure 38 Example of Timer Circuit

As can be seen from Fig. 39, the ideal time constant cannot be realized if the leakage current of the capacitor is too high.

With the aluminum electrolytic capacitor, the leakage current increases if the capacitor is left without load, as shown in Fig. 40; therefore, care must be exercised when using the aluminum electrolytic capacitor in a system where a high accuracy is required, such as an industrial timer.

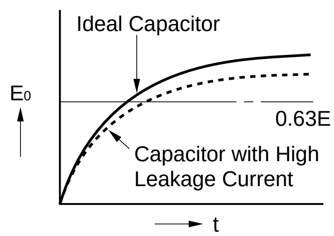


Figure 39 Transient Phenomenon of Capacitor

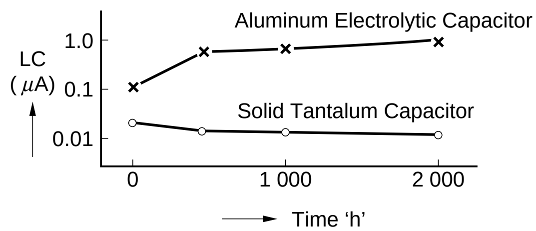


Figure 40 Changes in Leakage Current in No-load Storage Test

If a capacitor is used at a location where the ambient temperature heavily fluctuates, the capacitance fluctuates accordingly. In an application in which a high accuracy must be maintained over a long period (several seconds to minutes}, it is important to use a capacitor with a low leakage current.

8.3 Example of a small, high-capacitance capacitor with stable capacitance against temperature change

The capacitance of the solid tantalum capacitor does not fluctuate with temperature as much as the alumfnum electrolytic capacitor as shown in Fig. 41. This section introduces some application examples of the solid tantalum capacitor using this feature.

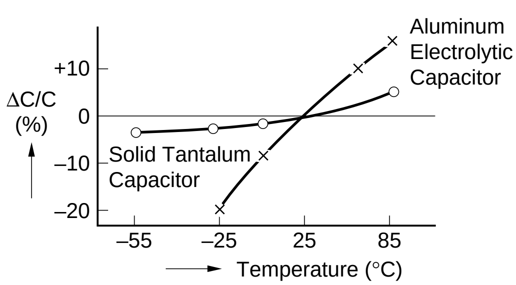


Figure 41 Changes in Capacitance with Temperature

(1) Television

Figure 42 shows an application example of the solid tantalum capacitor in a synchronization circuit.

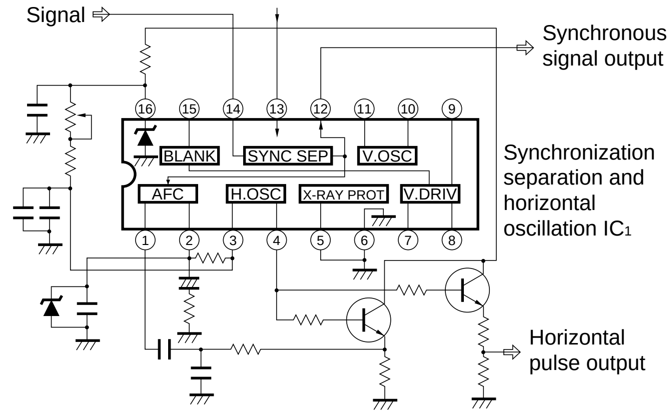


Figure 42 Example of Synchronization Circuit

In this type of circuit, the solid tantalum capacitor, which has good temperature characteristics, is often used because the electrolytic capacitor causes the frequency to change when its capacitance changes with temperature.

8.4 Example of a small, high-capacitance capacitor with good frequency characteristics

(1) Noise Limiter

In logic circuits using high-speed ICs such as TTL and CML, solid tantalum capacitors, aluminum electrolytic capacitors, Mylex capacitors, and ceramic capacitors are used to prevent noise (as noise limiters) and to eliminate malfunction due to noise such as ground noise, crosstalk, reflection, switching noise, and power noise. An ideal noise limiter should provide good high-frequency characteristics (low inductance and equivalent series resistance), be small and high-capacitance, and be free of short mode defect. The biggest demerit when using the solid tantalum capacitor as a noise limiter has been the defect of short mode.

However, recent solid tantalum capacitors have shown substantially improved reliability through various modifications. In addition, the reliability can be further improved by increasing the ratio of the working voltage to the rated voltage (about 50% or less).

Generally, one ceramic capacitor is used with one IC because the ceramic capacitor is not small and high-capacitance. In contrast, only one solid tantalum capacitor is needed per 10 to 20 ICs. NEC offers N Series solid tantalum capacitors with a low inductance and equivalent series res]stance and a pitch interval matching that of ICs, which are ideal for a noise limiter.

Figure 43 shows the pulse response characteristics of NEC's noise limiter capacitors.

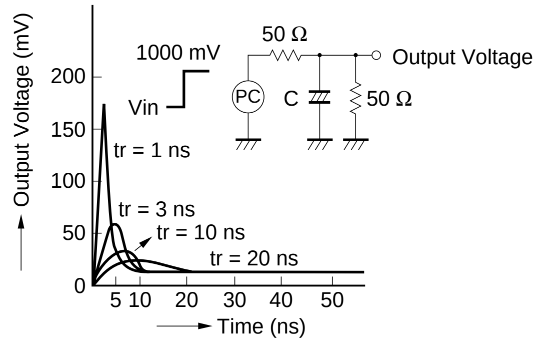
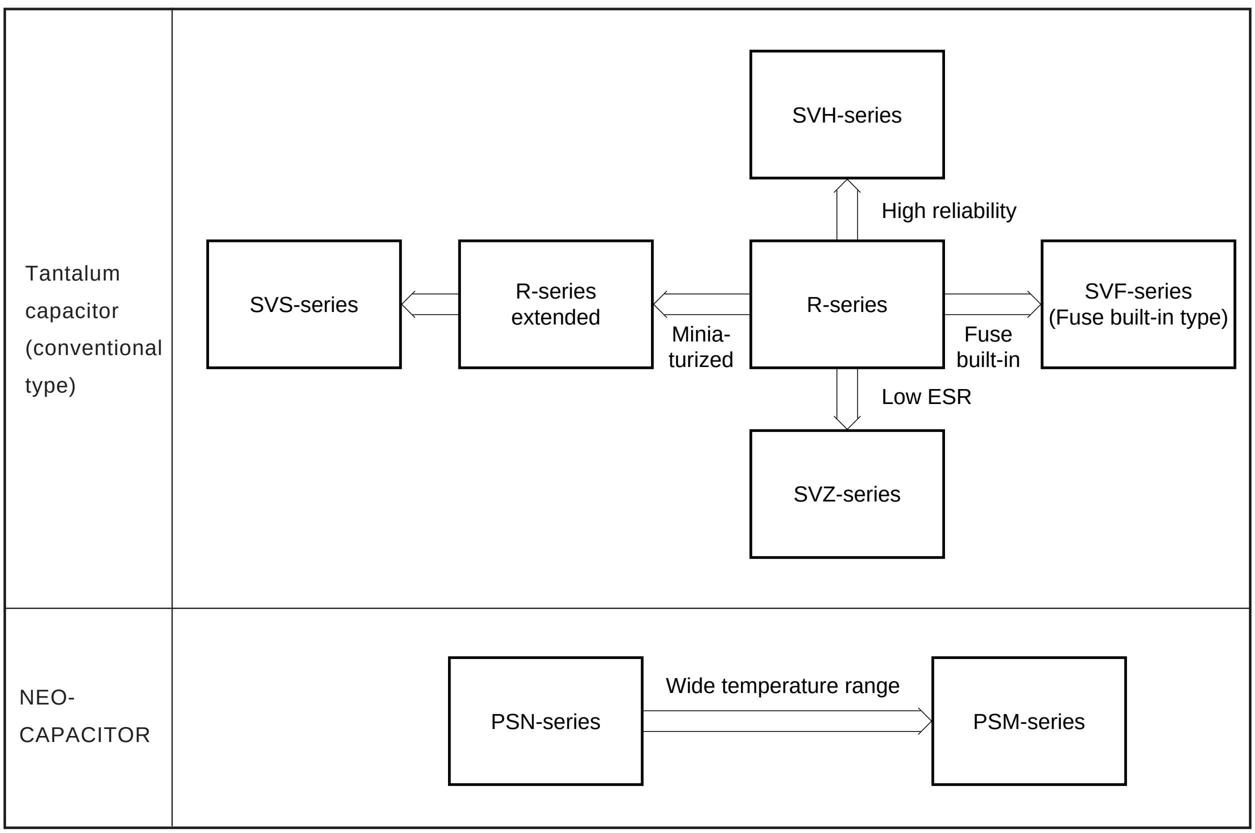


Figure 43 Pulse Response Characteristics

9. OUTLINE OF PRODUCT LINE-UP



[MEMO]

Tantalum Capacitors
(Conventional Type)

R SERIES

FEATURES

- **High Temperature Durability**
  No solder is used in connecting the cathode terminal to the tantalum pellet. Consequently, users can apply direct soldering (wave soldering) and reflow soldering.

- **High Adaptability of Automatic Assembly**
  Tape and reel packaging is available in all product lines.
  Precise dimensions due to transfer molded encapsulation provides excellent adaptability to automatic placement machines. 8 mm width carrier tape packaging, which is used extensively in most machines, is available for capacitors up to 150 μF (B2 Case).
  The A Case has the same dimensions (3.2 mm $\times$ 1.6 mm) as chip resistors and ceramic capacitors.
  The A2 Case has the same dimenslons (3.2 mm $\times$ 1.6 mm $\times$ 1.2 mm MAX.) as mini mold Tr.

- **Wide Operating Temperature Range**
  The R Series operating temperature range is –55˚C to +125˚C.

PERFORMANCE CHARACTERISTICS

<table>
<tr><th colspan="2">Item</th><th colspan="10">Specification</th><th>Test Method</th></tr>
<tr><td colspan="2">Operating Temperature Range</td><td colspan="10">–55 to +125˚C</td><td></td></tr>
<tr><td colspan="2">Rated Voltage</td><td>2.5</td><td>4</td><td>6.3</td><td>10</td><td>16</td><td>20</td><td>25</td><td>35</td><td>50</td><td>Vdc</td><td>Temperature: 85˚C</td></tr>
<tr><td colspan="2">Surge Voltage</td><td>3.3</td><td>5.2</td><td>8</td><td>13</td><td>20</td><td>26</td><td>33</td><td>46</td><td>65</td><td>Vdc</td><td>Temperature: 85˚C</td></tr>
<tr><td colspan="2">Category Voltage</td><td>1.6</td><td>2.5</td><td>4</td><td>6.3</td><td>10</td><td>13</td><td>16</td><td>22</td><td>32</td><td>Vdc</td><td>Temperature: 125˚C (*1)</td></tr>
<tr><td colspan="2">Capacitance Range</td><td colspan="10">0.047 to 470 μF</td><td rowspan="2">Frequency: 120 Hz</td></tr>
<tr><td colspan="2">Capacitance Tolerance</td><td colspan="10">±20% (±10%)</td></tr>
<tr><td colspan="2">Leakage Current (L.C.)</td><td colspan="10">0.01 CV (μA) or 0.5 μA whichever is greater</td><td>5 min, after rated voltage applied</td></tr>
<tr><td rowspan="2">Tangent of Loss Angle (tan δ)</td><td>Standard</td><td colspan="10">0.047 to 4.7 μF : 0.04 max.
6.8 to 68 μF : 0.06 max.</td><td rowspan="2">Frequency: 120 Hz</td></tr>
<tr><td>Extended</td><td colspan="10">2.5 to 10 V : 0.08 max.
16 to 35 V : 0.06 max. (*2)</td></tr>
<tr><td colspan="2">Equivalent Series Resistance (ESR)</td><td colspan="10">Refer to standard ratings</td><td>Frequency: 100 kHz</td></tr>
<tr><td colspan="2">Surge Voltage Rest</td><td colspan="10">ΔC/C : ±5% (*3)
tan δ : Initial Requirement
L.C. : Initial Requirement</td><td>Temperature: 85˚C
Surge Voltage for 30 sec.
Series Resistance: 1 kΩ
Discharging Voltage for 5 min. 30 sec.
1000 cycles</td></tr>
<tr><td rowspan="4">Characteristics at High and Low Temperature</td><td>Temp.</td><td colspan="3">–55˚C</td><td colspan="3">+85˚C</td><td colspan="4">+125˚C</td><td rowspan="4">Step 1: 20˚C
Step 2: –55˚C
Step 3: 20˚C
Step 4: 85˚C
Step 5: 125˚C
Step 6: 20 ˚C</td></tr>
<tr><td>ΔC/C</td><td colspan="3">0, –12%</td><td colspan="3">+12, 0%</td><td colspan="4">+15, 0%</td></tr>
<tr><td>tan δ</td><td colspan="3">[Standard] (*4)
0.47 to 4.7 μF:
0.08 max.
6.8 to 68 μF:
0.1 max.
[Extended] (*5)
2.5 to 10 V:
0.12 max.
16 to 35 V:
0.1 max.</td><td colspan="3">Initial Requirement</td><td colspan="4">[Standard]
0.47 to 4.7 μF:
0.06 max.
6.8 to 68 μF:
0.08 max.
[Extended] (*6)
2.5 to 10 V:
0.1 max.
16 to 35 V:
0.08 max.</td></tr>
<tr><td>L.C.</td><td colspan="3">–</td><td colspan="3">0.1CV or 5μA whichever is greater</td><td colspan="4">0.125CV or 6.25 μA whichever is greater</td></tr>
<tr><td colspan="2">Rapid Change of Temperature</td><td colspan="10">ΔC/C : ±5% (*3)
tan δ : Initial Requirement
L.C. : Initial Requirement</td><td>–55 to +125˚C
5 cycles</td></tr>
<tr><td colspan="2">Resistance to Soldering Heat</td><td colspan="10">ΔC/C : ±5% (*3)
tan δ : Initial Requirement
L.C. : Initial Requirement</td><td>Fully immersion to solder, 260˚C, 5 sec.</td></tr>
<tr><td colspan="2">Damp Heat, Steady State</td><td colspan="10">ΔC/C : ±5% (*3)
tan δ : Initial Requirement × 1.5
L.C. : Initial Requirement</td><td>Temperature: 40˚C
90 to 95% RH
500 hours</td></tr>
<tr><td colspan="2">Endurance</td><td colspan="10">ΔC/C : ±10% (*3)
tan δ : Initial Requirement
L.C. : Initial Requirement × 1.25</td><td>Temperature: 85˚C
Rated voltage applied
Temperature: 125˚C
Category voltage applied for 2000 hours</td></tr>
<tr><td colspan="2">Failure Rate</td><td colspan="10">λ_0 = 1%/1000H</td><td></td></tr>
</table>

LEGEND

CV : Product of capacitance in μF and voltage in V

ΔC/C : Capacitance change ratio

*1: Category voltage at 85˚C or more is calculated by following expression.

$$U_T = U_R - \frac{U_R - U_C}{40} (T - 85)$$

U_R : rated voltage

U_C : category voltage at 125˚C

*2: tan δ of the specific products of R Series Extended is shown in the following table.

Product	tan δ
A case : 4 V/33 μF, 6.3 V/22 μF C case : 4 V/150 μF, 6.3 V/100 μF D2 case : 6.3 V/150 μF, 10 V/100 μF D case : 10 V/150 μF, 16 V/100 μF	0.10 max.
A2 case : 2.5 V/15 μF, 22 μF, 4 V/10 μF, 15 μF A case : 2.5 V/47 μF B3 case : 2.5 V/47 μF, 4 V/33 μF, 6.3 V/22 μF C case : 2.5 V/220 μF D2 case : 4 V/220 μF D case : 6.3 V/220 μF	0.12 max.
D2 case : 2.5 V/330 μF D case : 2.5 V/470 μF, 4 V/330 μF	0.14 max.

*3: The specific products of R series Extended in the following table are applied to capacitance change of ±12% or ±15% .

ΔC/C	Case Code	Product
±12%	A2	2.5 V/4.7 μF to 22 μF, 4 V/4.7 μF, 6.3 V/3.3 μF to 10 μF, 10 V/2.2 μF to 4.7 μF, 16 V/1.5 μF, 2.2 μF, 20 V/1 μF, 1.5 μF
	A	2.5 V/15 μF to 47 μF, 4 V/10 μF to 33 μF, 6.3 V/6.8 μF to 22 μF, 10 V/4.7 μF to 10 μF, 16 V/3.3 μF to 6.8 μF, 20 V/2.2 μF to 4.7μF, 25 V/1.5 μF, 2.2μF, 35 V/1 μF, 1.5 μF
	B2	2.5 V/33 μF to 100 μF
	C	2.5 V/220 μF, 4 V/150 μF, 6.3 V//100 μF, 10 V/68 μF, 16 V/47 μF
	D2	2.5 V/330 μF, 4 V/220 μF, 6.3 V/150 μF, 10 V/100 μF
	D	2.5 V/470 μF, 4 V/330 μF, 6.3 V/220 μF, 10 V/150 μF, 16 V/100 μF
±15%	B3	All Items

*4: The following products of R-series Standard are applied to tan δ of 0.12

4 V3.3 μF, 4.7 μF, 10 μF, 22 μF, 33 μF, 68 μF, 6.3 V/3.3 μF, 10 V/2.2 μF

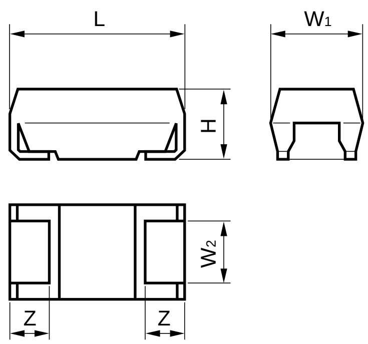
*5 : tan δ of the specific products of R-series Extended is shown in the following table

Product	tan δ
A case : 4 V/33 μF, 6.3 V/22 μF, 10 V/15 μF B2 case : 2.5 V/100 μF C case : 4 V/150 μF, 6.3 V/100 μF D2 case : 6.3 V/150 μF, 10 V/100 μF	0.14 max.
A2 case : 2.5 V/15 μF, 4 V/10 μF C case : 2.5 V/ 220 μF	0.16 max.
B3 case : 2.5 V/47 μF, 4 V/33 μF, 6.3 V/22 μF D2 case : 2.5 V/330 μF, 4 V/220 μF D case : 2.5 V/470 μF, 4 V/330 μF, 6.3 V/220 μF, 10 V/150 μF, 16 V/100 μF	0.18 max.
A2 case : 4 v/15 μF	0.20 max.
A2 case : 2.5 V/22 μF A case : 2.5 V/47 μF	0.22 max.

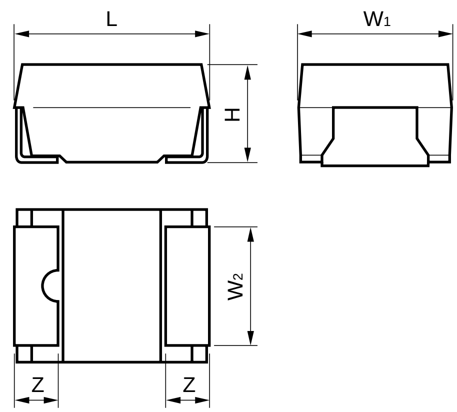
*6 : tan δ of the specific products of R Series Extended is shown in the following table

Product	tan δ
A case : 4 V/33 μF, 6.3 V/22 μF C case : 4 V/150 μF, 6.3 V/100 μF D2 case : 6.3 V/150 μF, 10 V/100 μF D case : 10 V/150 μF, 16 V/100 μF	0.12 max.
A2 case : 2.5V/15 μF, 4 V/10 μF, 4 V/15 μF C case : 2.5 V/220 μF D2 case : 4 V/220 μF D case : 6.3 V/220 μF	0.14 max.
B3 case : 2.5 V/47 μF, 4 V/33 μF, 6.3 V/22 μF	0.15 max.
A case : 2.5 V/22 μF A case : 2.5 V/47 μF D2 case : 2.5 V/330 μF D case : 2.5 V/470 μF, 4 V/330 μF	0.16 max.

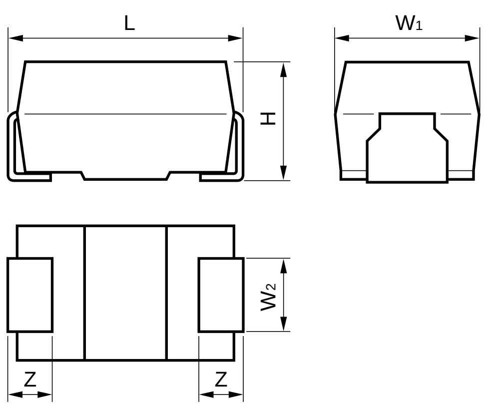
OUTLINE DRAWINGS AND DIMENSIONS



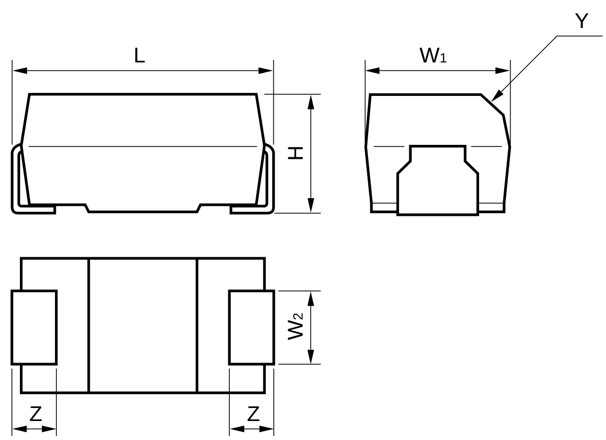
[A2, A & B3 cases]



[B2 case]



[D2 case]



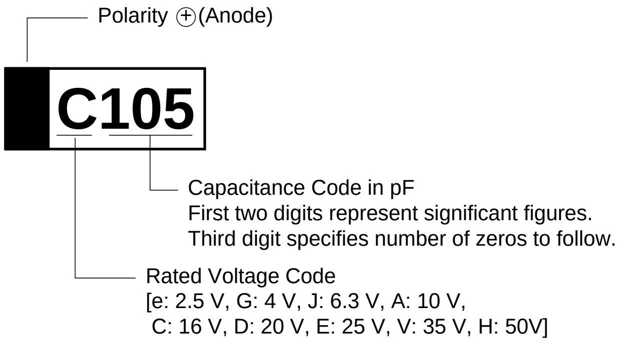
[B, C & D cases]

Unit : mm (inch)

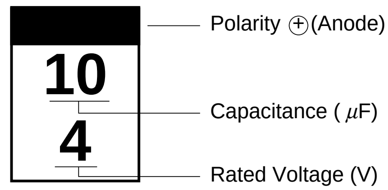
Case Size (Case Code)	EIA Code	L	W_1	W_2	H	Z	Y
A2 (U)	3216L	3.2±0.2 (0.126±0.008)	1.6±0.2 (0.063±0.008)	1.2±0.1 (0.047±0.004)	1.2 MAX. (0.047 MAX.)	0.8±0.3 (0.031±0.012)	—
A	3216	3.2±0.2 (0.126±0.008)	1.6±0.2 (0.063±0.008)	1.2±0.1 (0.047±0.004)	1.6±0.2 (0.063±0.008)	0.8±0.3 (0.031±0.012)	—
B3 (W)	3528L	3.5±0.2 (0.138±0.008)	2.8±0.2 (0.110±0.008)	2.2±0.1 (0.087±0.004)	1.2 MAX. (0.047 MAX.)	0.8±0.3 (0.031±0.012)	—
B2 (S)	3528	3.5±0.2 (0.138±0.008)	2.8±0.2 (0.110±0.008)	2.3±0.1 (0.091±0.004)	1.9±0.2 (0.075±0.008)	0.8±0.3 (0.031±0.012)	—
B	—	4.7±0.3 (0.185±0.012)	2.6±0.3 (0.102±0.012)	1.4±0.1 (0.055±0.004)	2.1±0.3 (0.083±0.012)	0.8±0.3 (0.031±0.012)	C0.4 (0.016)
C	6032	6.0±0.3 (0.236±0.012)	3.2±0.3 (0.126±0.012)	2.2±0.1 (0.087±0.004)	2.5±0.3 (0.098±0.012)	1.3±0.3 (0.051±0.012)	C0.4 (0.016)
D2 (T)	—	5.8±0.3 (0.228±0.012)	4.6±0.2 (0.181±0.012)	2.4±0.1 (0.094±0.004)	3.2±0.3 (0.126±0.012)	1.3±0.3 (0.051±0.012)	—
D	7343	7.3±0.2 (0.287±0.012)	4.3±0.2 (0.169±0.008)	2.4±0.1 (0.094±0.004)	2.8±0.3. (0.110±0.012)	1.3±0.3 (0.051±0.012)	C0.5 (0.020)

MARKING

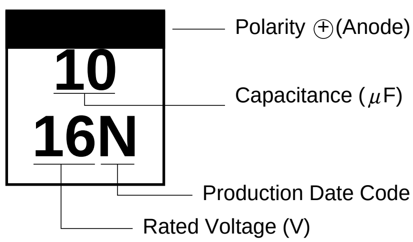
[A2 & A Case]



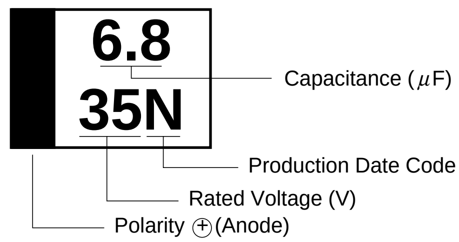
[B Case]



[C & D Case]



[B3, B2 & D2 Case]



[Marking of Production Date Code]

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1998	N	P	Q	R	S	T	U	V	W	X	Y	Z
1999	a	b	c	d	e	f	g	h	j	k	l	m
2000	n	p	q	r	s	t	u	v	w	x	y	z
2001	A	B	C	D	E	F	G	H	J	K	L	M

Date code will resume beginning in 2002.

PRODUCT LINE-UP AND CASE SIZE

R SERIES STANDARD

Capacitance (μF) \ Rated Voltage (Vdc)	4	6.3	10	16	20	25	35	50
0.010								
0.015								
0.022								
0.033								
0.047							A	
0.068							A	
0.10							A	A
0.15							A	A
0.22							A	B2
0.33							A	B2
0.47						A	B2 B	B2
0.68					A		B2 B	C
1.0				A			B2 B	C
1.5			A	A		B2 B	C	C
2.2		A	A		B2 B		C	D
3.3	A	A		B2 B		C	C D	D2 D
4.7	A		B2 B		C	C	D2 D	D
6.8		B2 B		C	C	D2 D	D2 D	
10	B2 B		C	C	D2 D	D2 D		
15		C	C	D2 D	D2 D			
22	C	C	D2 D	D2 D				
33	C	D2 D	D2 D					
47	D2 D	D2 D						
68	D2 D							

R SERIES EXTENDED

Capacitance (µF) \ Rated Voltage (Vdc)	2.5	4	6.3	10	16	20	25	35
0.1						A2		
0.15						A2		
0.22						A2		
0.33						A2		
0.47						A2		A
0.68					A2	A2	A	A
1				A2	A2	A2 A	A	A
1.5			A2	A2	A2	A2 A	A	A B2 B
2.2		A2	A2	A2	A2 A	A	A B2	B2 B
3.3		A2	A2	A2 A	A	A B2	B2 B	B2
4.7	A2	A2	A2 A	A2 A	A B2	A B2 B	B2	C
6.8	A2	A2 A	A2 A	A B2	A B3 B2 B	B2	C	C
10	A2	A2 A	A2 A B2	A B3 B2 B	B2	B2 C	C	D2 D
15	A2 A	A2 A B2	A B3 B2 B	B2	B2 C	C	D2 D	D
22	A2 A	A B3 B2 B	A B3 B2	B2 C	B2 C	C D2 D	D	
33	A B3 B2	A B3 B2	B2 C	B2 C	C D2 D	D2 D		
47	A B3 B2	B2 C	B2 C	C D2 D	C D2 D	D		
68	B2	B2 C	B2 C D2 D	C D2 D	D			
100	B2	B2 C D2 D	C D2 D	D2 D	D			
150	B2	C D2 D	D2 D	D				
220	C	D2 D	D					
330	D2	D						
470	D							

PART NUMBERING SYSTEM

— Bulk —

NR A 475 M 04

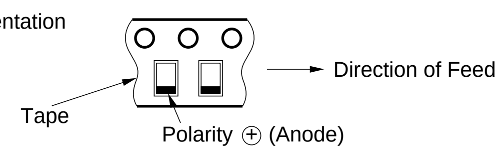
- **04** — DC Rated Voltage in Volts
- **M** — Capacitance Tolerance
  - M: ±20%
  - K: ±10%
- **475** — Capacitance Code in pF
  - First two digits represent significant figures. Third digit specifies number of zeros to follow.
- **A** — Case Code
  - U : A2 Case
  - A : A Case
  - W: B3 Case
  - S : B2 Case
  - B : B Case
  - C : C Case
  - T : D2 Case
  - D : D Case
- **NR** — NEC R Series

– Tape and Reel –

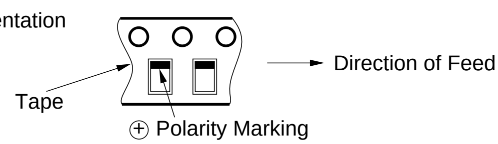
NR A 475 M 04R 8

- **8** — Tape Width (8 mm for U, A, W and S Case Codes, 12 mm for B, C, T and D Case Codes)
- **R** — Packaging

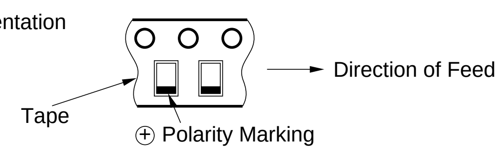
R: Reel Diameter 178 mm (7 inch) Orientation



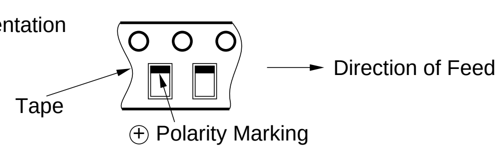
L: Reel Diameter 178 mm (7 inch) Orientation



P: Reel Diameter 330 mm (13 inch) Orientation



N: Reel Diameter 330 mm (13 inch) Orientation



RATINGS

STANDARD

DC Rated Voltage @85˚C (125˚C) V	Capacitance @20˚C, 120 Hz μF	Case Size (Case Code)	Part Number	Leakage Current @20˚C μA Max.	tan δ @20˚C, 120 Hz % Max.	ESR @20˚C, 100 kHz Ω Max.
4	3.3	A	NRA335M04	0.5	4	8.0
(2.5)	4.7	A	NRA475M04	0.5	4	7.5
	10	B2(S)	NRS106M04	0.5	6	3.5
	10	B	NRB106M04	0.5	6	3.5
	22	C	NRC226M04	0.8	6	1.8
	33	C	NRC336M04	1.3	6	1.8
	47	D2(T)	NRT476M04	1.9	6	1.2
	47	D	NRD476M04	1.9	6	1.2
	68	D2(T)	NRT686M04	2.7	6	0.8
	68	D	NRD686M04	2.7	6	0.8
6.3	2.2	A	NRA225M06	0.5	4	8.0
(4)	3.3	A	NRA335M06	0.5	4	7.0
	6.8	B2(S)	NRS685M06	0.5	6	3.5
	6.8	B	NRB685M06	0.5	6	3.5
	15	C	NRC156M06	0.9	6	1.8
	22	C	NRC226M06	1.4	6	1.8
	33	D2(T)	NRT336M06	2.0	6	1.5
	33	D	NRD336M06	2.0	6	1.5
	47	D2(T)	NRT476M06	3.0	6	1.1
	47	D	NRD476M06	3.0	6	0.8
10	1.5	A	NRA155M10	0.5	4	8.0
(6.3)	2.2	A	NRA225M10	0.5	4	7.0
	4.7	B2(S)	NRS475M10	0.5	4	3.5
	4.7	B	NRB475M10	0.5	4	3.5
	10	C	NRC106M10	1.0	6	1.8
	15	C	NRC156M10	1.5	6	1.8
	22	D2(T)	NRT226M10	2.2	6	1.5
	22	D	NRD226M10	2.2	6	1.5
	33	D2(T)	NRT336M10	3.3	6	1.1
	33	D	NRD336M10	3.3	6	0.8
16	1	A	NRA105M16	0.5	4	10
(10)	1.5	A	NRA155M16	0.5	4	8.0
	3.3	B2(S)	NRS335M16	0.5	4	3.5
	3.3	B	NRB335M16	0.5	4	4.5
	6.8	C	NRC685M16	1.0	6	1.9
	10	C	NRC106M16	1.6	6	1.8
	15	D2(T)	NRT156M16	2.4	6	1.5
	15	D	NRD156M16	2.4	6	1.5
	22	D2(T)	NRT226M16	3.5	6	1.1
	22	D	NRD226M16	3.5	6	0.8

Note Part numbers in the tables above are for products with a capacitance tolerance of ±20%. For products with a capacitance tolerance of ±10%, change the letter “M” to “K”.
Use the letters “S” and “T” in part numbers for the case code “B2” and “D2”.
Please refer to page 41 for the detail of part numbering system.

DC Rated Voltage @85˚C (125˚C) V	Capacitance @20˚C, 120 Hz μF	Case Size (Case Code)	Part Number	Leakage Current @20˚C μA Max.	tan δ @20˚C, 120 Hz % Max.	ESR @20˚C, 100 kHz Ω Max.
20 (13)	0.68	A	NRA684M20	0.5	4	12
	2.2	B2(S)	NRS225M20	0.5	4	3.5
	2.2	B	NRB225M20	0.5	4	5
	4.7	C	NRC475M20	0.9	4	2.4
	6.8	C	NRC685M20	1.4	6	1.9
	10	D2(T)	NRT106M20	2.0	6	1.5
	10	D	NRD106M20	2.0	6	1.3
	15	D2(T)	NRT156M20	3.0	6	1.1
	15	D	NRD156M20	3.0	6	1.0
25 (16)	0.47	A	NRA474M25	0.5	4	14
	1.5	B2(S)	NRS155M25	0.5	4	4.6
	1.5	B	NRB155M25	0.5	4	10
	3.3	C	NRC335M25	0.8	4	2.5
	4.7	C	NRC475M25	1.1	4	2.4
	6.8	D2(T)	NRT685M25	1.7	6	1.5
	6.8	D	NRD685M25	1.7	6	1.4
	10	D2(T)	NRT106M25	2.5	6	1.2
	10	D	NRD106M25	2.5	6	1.2
35 (22)	0.047	A	NRA473M35	0.5	4	40
	0.068	A	NRA683M35	0.5	4	40
	0.1	A	NRA104M35	0.5	4	18
	0.15	A	NRA154M35	0.5	4	18
	0.22	A	NRA224M35	0.5	4	18
	0.33	A	NRA334M35	0.5	4	15
	0.47	B2(S)	NRS474M35	0.5	4	8.0
	0.47	B	NRB474M35	0.5	4	12
	0.68	B2(S)	NRS684M35	0.5	4	5.4
	0.68	B	NRB684M35	0.5	4	10
	1	B2(S)	NRS105M35	0.5	4	4.8
	1	B	NRB105M35	0.5	4	10
	1.5	C	NRC155M35	0.5	4	3.0
	2.2	C	NRC225M35	0.7	4	3.0
	3.3	C	NRC335M35	1.2	4	2.5
	3.3	D	NRD335M35	1.2	4	2.0
	4.7	D2(T)	NRT475M35	1.6	4	1.5
	4.7	D	NRD475M35	1.6	4	1.5
	6.8	D2(T)	NRT685M35	2.3	6	1.3
	6.8	D	NRD684M35	2.3	6	1.3
50 (32)	0.1	A	NRA104M50	0.5	4	20
	0.15	A	NRA154M50	0.5	4	19
	0.22	B2(S)	NRS224M50	0.5	4	14
	0.33	B2(S)	NRS334M50	0.5	4	10
	0.47	B2(S)	NRS474M50	0.5	4	9.0
	0.68	C	NRC684M50	0.5	4	7.0
	1	C	NRC105M50	0.5	4	5.5
	1.5	C	NRC155M50	0.7	4	4.0
	2.2	D	NRD225M50	1.1	4	2.0
	3.3	D2(T)	NRT335M50	1.6	4	2.0
	3.3	D	NRD335M50	1.6	4	1.8
	4.7	D	NRD475M50	2.3	4	1.4

Note Part numbers in the tables above are for products with a capacitance tolerance of ±20%. For products with a capacitance tolerance of ±10%, change the letter “M” to “K”.
Use the letters “S” and “T” in part numbers for the case code “B2” and “D2”.
Please refer to page 41 for the detail of part numbering system.

EXTENDED

DC Rated Voltage @85˚C (125˚C) V	Capacitance @20˚C, 120 Hz μF	Case Size (Case Code)	Part Number	Leakage Current @20˚C μA Max.	tan δ @20˚C, 120 Hz % Max.	ESR @20˚C, 100 kHz Ω Max.
2.5 (1.6)	4.7	A2(U)	NRU475M02	0.5	8	18
	6.8	A2(U)	NRU685M02	0.5	8	16
	10	A2(U)	NRU106M02	0.5	8	15
	15	A2(U)	NRU156M02	0.5	12	10
	15	A	NRA156M02	0.5	8	5.0
	22	A2(U)	NRU226M02	0.5	12	10
	22	A	NRA226M02	0.5	8	4
	33	A	NRA336M02	0.8	8	3.5
	33	B3(W)	NRW336M02	0.8	8	—
	33	B2(S)	NRS336M02	0.8	8	3.0
	47	A	NRA476M02	1.1	12	4.5
	47	B3(W)	NRW476M02	1.1	12	—
	47	B2(S)	NRS476M02	1.1	8	2.4
	68	B2(S)	NRS686M02	1.7	8	2.0
	100	B2(S)	NRS107M02	2.5	8	2.0
	150	B2(S)	NRS157M02	3.7	16	—
	220	C	NRC227M02	5.5	12	1.0
	330	D2(T)	NRT337M02	8.2	14	0.7
	470	D	NRD477M02	11.7	14	0.7
4 (2.5)	2.2	A2(U)	NRU225M04	0.5	8	25
	3.3	A2(U)	NRA335M04	0.5	8	18
	4.7	A2(U)	NRU475M04	0.5	8	10
	6.8	A2(U)	NRU685M04	0.5	8	8.0
	6.8	A	NRA685M04	0.5	8	6.0
	10	A2(U)	NRU106M04	0.5	12	8.0
	10	A	NRA106M04	0.5	8	5.0
	15	A2(U)	NRU156M04	0.6	12	8.0
	15	A	NRA156M04	0.6	8	4.0
	15	B2(S)	NRS156M04	0.6	8	3.0
	22	A	NRA226M04	0.8	8	3.5
	22	B3(W)	NRW226M04	0.8	8	—
	22	B2(S)	NRS226M04	0.8	8	2.8
	22	B	NRB226M04	0.8	8	3.0
	33	A	NRA336M04	1.3	10	4.5
	33	B3(W)	NRW336M04	1.3	12	—
	33	B2(S)	NRS336M04	1.3	8	2.4
	47	B2(S)	NRS476M04	1.8	8	2.0
	47	C	NRC476M04	1.8	8	1.8
	68	B2(S)	NRS686M04	2.7	8	2.0
	68	C	NRC686M04	2.7	8	1.6
	100	B2(S)	NRS107M04	4.0	12	—
	100	C	NRC107M04	4.0	8	1.2
	100	D2(T)	NRT107M04	4.0	8	0.9
	100	D	NRD107M04	4.0	8	0.8
	150	C	NRC157M04	6.0	10	1.0
	150	D2(T)	NRT157M04	6.0	8	0.7
	150	D	NRD157M04	6.0	8	0.7
	220	D2(T)	NRT227M04	8.8	12	0.7
	220	D	NRD227M04	8.8	8	0.7
	330	D	NRD337M04	13.2	14	0.7

Note Part numbers in the tables above are for products with a capacitance tolerance of ±20%. For products with a capacitance tolerance of ±10%, change the letter “M” to “K”.
Use the letters “U”, “W”, “S” and “T” in part numbers for the case code “A2”, “B3”, “B2” and “D2”.
Please refer to page 41 for the detail of part numbering system.

DC Rated Voltage @85˚C (125˚C) V	Capacitance @20˚C, 120 Hz μF	Case Size (Case Code)	Part Number	Leakage Current @20˚C μA Max.	tan δ @20˚C, 120 Hz % Max.	ESR @20˚C, 100 kHz Ω Max.
6.3	1.5	A2(U)	NRU155M06	0.5	8	25
(4)	2.2	A2(U)	NRU225M06	0.5	8	18
	3.3	A2(U)	NRU335M06	0.5	8	9.0
	4.7	A2(U)	NRU475M06	0.5	8	7.5
	4.7	A	NRA475M06	0.5	8	6.0
	6.8	A2(U)	NRU685M06	0.5	8	7.5
	6.8	A	NRA685M06	0.5	8	5.0
	10	A2(U)	NRU106M06	0.6	8	10
	10	A	NRA106M06	0.6	8	4.0
	10	B2(S)	NRS106M06	0.6	8	3.0
	15	A	NRA156M06	0.9	8	3.5
	15	B3(W)	NRW156M06	0.9	8	—
	15	B2(S)	NRS156M06	0.9	8	2.5
	15	B	NRB156M06	0.9	8	3.0
	22	A	NRA226M06	1.4	10	4.5
	22	B3(W)	NRW226M06	1.4	12	—
	22	B2(S)	NRS226M06	1.4	8	2.3
	33	B2(S)	NRS336M06	2.0	8	2.0
	33	C	NRC336M06	2.0	8	1.8
	47	B2(S)	NRS476M06	3.0	8	2.0
	47	C	NRC476M06	3.0	8	1.6
	68	B2(S)	NRS686M06	4.2	10	—
	68	C	NRC686M06	4.2	8	1.2
	68	D2(T)	NRT686M06	4.2	8	0.9
	68	D	NRD686M06	4.2	8	0.8
	100	C	NRC107M06	6.3	10	0.9
	100	D2(T)	NRT107M06	6.3	8	0.8
	100	D	NRD107M06	6.3	8	0.8
	150	D2(T)	NRT157M06	9.4	10	0.8
	150	D	NRD157M06	9.4	8	0.8
	220	D	NRD227M06	13.8	12	0.8
10	1	A2(U)	NRU105M10	0.5	8	25
(6.3)	1.5	A2(U)	NRU155M10	0.5	8	20
	2.2	A2(U)	NRU225M10	0.5	8	12
	3.3	A2(U)	NRU335M10	0.5	8	12
	3.3	A	NRA335M10	0.5	8	5.5
	4.7	A2(U)	NRU475M10	0.5	8	8.0
	4.7	A	NRA475M10	0.5	8	5.0
	6.8	A	NRA685M10	0.6	8	4.5
	6.8	B2(S)	NRS685M10	0.6	8	3.0
	10	A	NRA106M10	1.0	8	3.2
	10	B3(W)	NRW106M10	1.0	8	—
	10	B2(S)	NRS106M10	1.0	8	2.5
	10	B	NRB106M10	1.0	8	3.0
	15	B2(S)	NRS156M10	1.5	8	2.5
	22	B2(S)	NRS226M10	2.2	8	2.4
	22	C	NRC226M10	2.2	8	1.8
	33	B2(S)	NRS336M10	3.3	8	2.0
	33	C	NRC336M10	3.3	8	1.6

Note Part numbers in the tables above are for products with a capacitance tolerance of ±20%. For products with a capacitance tolerance of ±10%, change the letter "M" to "K".
Use the letters "U", "W", "S" and "T" in part numgers for the case code "A2", "B3", "B2" and "D2".
Please refer to page 41 for the detail of part numbering system.

DC Rated Voltage @85˚C (125˚C) V	Capacitance @20˚C, 120 Hz μF	Case Size (Case Code)	Part Number	Leakage Current @20˚C μA Max.	tan δ @20˚C, 120 Hz % Max.	ESR @20˚C, 100 kHz Ω Max.
10	47	C	NRC476M10	4.7	8	1.6
(6.3)	47	D2(T)	NRT476M10	4.7	8	0.9
	47	D	NRD476M10	4.7	8	0.8
	68	C	NRC686M10	6.8	8	1.2
	68	D2(T)	NRT686M10	6.8	8	0.8
	68	D	NRD686M10	6.8	8	0.8
	100	D2(T)	NRT107M10	10	10	0.8
	100	D	NRD107M10	10	8	0.7
	150	D	NRD157M10	15	10	0.7
16	0.68	A2(U)	NRU684M16	0.5	6	25
(10)	1	A2(U)	NRU105M16	0.5	6	16
	1.5	A2(U)	NRU155M16	0.5	6	13
	2.2	A2(U)	NRU225M16	0.5	6	13
	2.2	A	NRA225M16	0.5	6	6.0
	3.3	A	NRA335M16	0.5	6	5.0
	4.7	A	NRA475M16	0.7	6	5.0
	4.7	B2(S)	NRS475M16	0.7	6	3.0
	6.8	A	NRA685M16	1.0	6	5.0
	6.8	B3(W)	NRW685M16	1.0	6	—
	6.8	B2(S)	NRS685M16	1.0	6	2.5
	6.8	B	NRB685M16	1.0	6	3.5
	10	B2(S)	NRS106M16	1.6	6	2.4
	15	B2(S)	NRS156M16	2.4	6	2.5
	15	C	NRC156M16	2.4	6	1.8
	22	B2(S)	NRS226M16	3.5	6	2.5
	22	C	NRC226M16	3.5	6	1.6
	33	C	NRC336M16	5.2	6	1.2
	33	D2(T)	NRT336M16	5.2	6	0.9
	33	D	NRD336M16	5.2	6	0.8
	47	C	NRC476M16	7.5	6	1.2
	47	D2(T)	NRT476M16	7.5	6	0.8
	47	D	NRD476M16	7.5	6	0.8
	68	D	NRD686M16	10.8	6	0.7
	100	D	NRD107M16	16	10	—
20	0.1	A2(U)	NRU104M20	0.5	6	40
(13)	0.15	A2(U)	NRU154M20	0.5	6	35
	0.22	A2(U)	NRU224M20	0.5	6	35
	0.33	A2(U)	NRU334M20	0.5	6	30
	0.47	A2(U)	NRU474M20	0.5	6	27
	0.68	A2(U)	NRU684M20	0.5	6	15
	1	A2(U)	NRU105M20	0.5	6	13
	1	A	NRA105M20	0.5	6	9.0
	1.5	A2(U)	NRU155M20	0.5	6	13
	1.5	A	NRA155M20	0.5	6	6.5
	2.2	A	NRA225M20	0.5	6	6.0
	3.3	A	NRA335M20	0.6	6	5.0
	3.3	B2(S)	NRS335M20	0.6	6	3.0
	4.7	A	NRA475M20	0.9	6	5.0
	4.7	B2(S)	NRS475M20	0.9	6	3.0

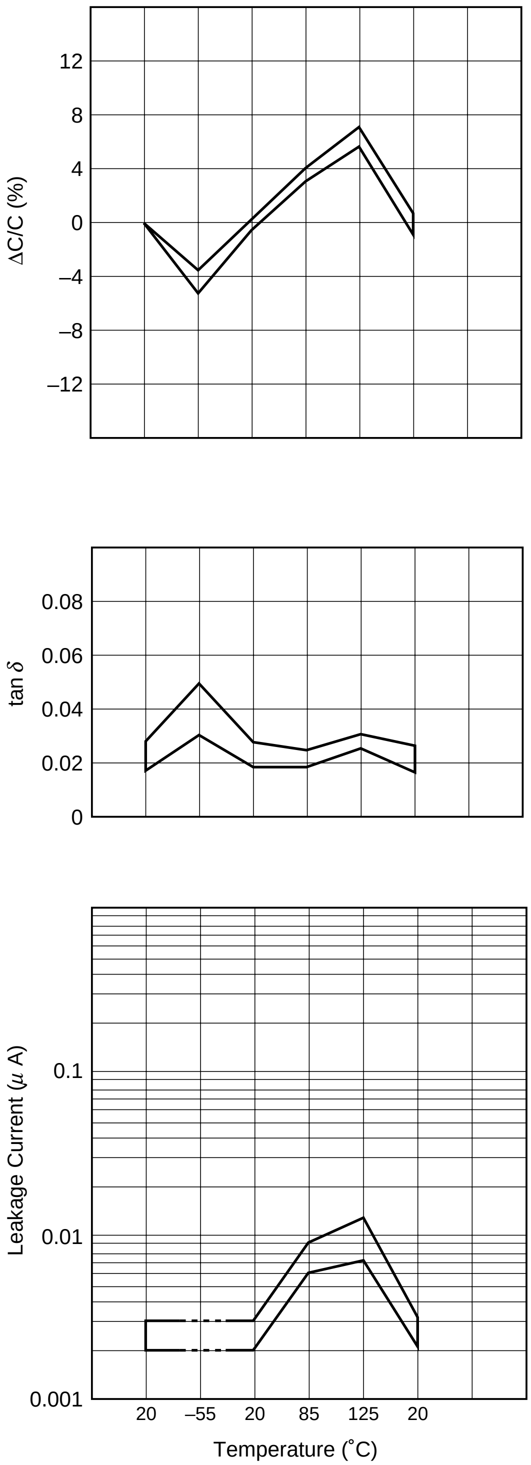
Note Part numbers in the tables above are for products with a capacitance tolerance of ±20%. For products with a capacitance tolerance of ±10%, change the letter “M” to “K”.
Use the letters “U”, “W”, “S” and “T” in part numbers for the case code “A2”, “B3”, “B2” and “D2”.
Please refer to page 41 for the detail of part numbering system.

DC Rated Voltage @85˚C (125˚C) V	Capacitance @20˚C, 120 Hz μF	Case Size (Case Code)	Part Number	Leakage Current @20˚C μA Max.	tan δ @20˚C, 120 Hz % Max.	ESR @20˚C, 100 kHz Ω Max.
20	4.7	B	NRB475M20	0.9	6	4.0
(13)	6.8	B2(S)	NRS685M20	1.4	6	2.8
	10	B2(S)	NRS106M20	2.0	6	2.5
	10	C	NRC106M20	2.0	6	1.8
	15	C	NRC156M20	3.0	6	1.7
	22	C	NRC226M20	4.4	6	1.5
	22	D2(T)	NRT226M20	4.4	6	0.9
	22	D	NRD226M20	4.4	6	0.8
	33	D2(T)	NRT336M20	6.6	6	0.8
	33	D	NRD336M20	6.6	6	0.8
	47	D	NRD476M20	9.4	6	0.8
25	0.68	A	NRA684M25	0.5	6	10
(16)	1	A	NRA105M25	0.5	6	8.0
	1.5	A	NRA155M25	0.5	6	8.0
	2.2	A	NRS225M25	0.5	6	8.0
	2.2	B2(S)	NRS225M25	0.5	6	4.0
	3.3	B2(S)	NRS335M25	0.8	6	3.5
	3.3	B	NRB335M25	0.8	6	4.5
	4.7	B2(S)	NRS475M25	1.1	6	3.0
	6.8	C	NRC685M25	1.7	6	1.9
	10	C	NRC106M25	2.5	6	1.8
	15	D2(T)	NRT156M25	3.7	6	1.2
	15	D	NRD156M25	3.7	6	1.0
	22	D	NRD226M25	5.5	6	0.8
35	0.47	A	NRA474M35	0.5	6	12
(22)	0.68	A	NRA684M35	0.5	6	9.0
	1	A	NRA105M35	0.5	6	8.0
	1.5	A	NRA155M35	0.5	6	8.0
	1.5	B2(S)	NRS155M35	0.5	6	4.8
	1.5	B	NRB155M35	0.5	6	5.0
	2.2	B2(S)	NRS225M35	0.7	6	4.2
	2.2	B	NRB225M35	0.7	6	5.0
	3.3	B2(S)	NRS335M35	1.1	6	4.0
	4.7	C	NRC475M35	1.6	6	2.2
	6.8	C	NRC685M35	2.3	6	1.9
	10	D2(T)	NRT106M35	3.5	6	1.2
	10	D	NRD106M35	3.5	6	1.0
	15	D	NRD156M35	5.2	6	0.9

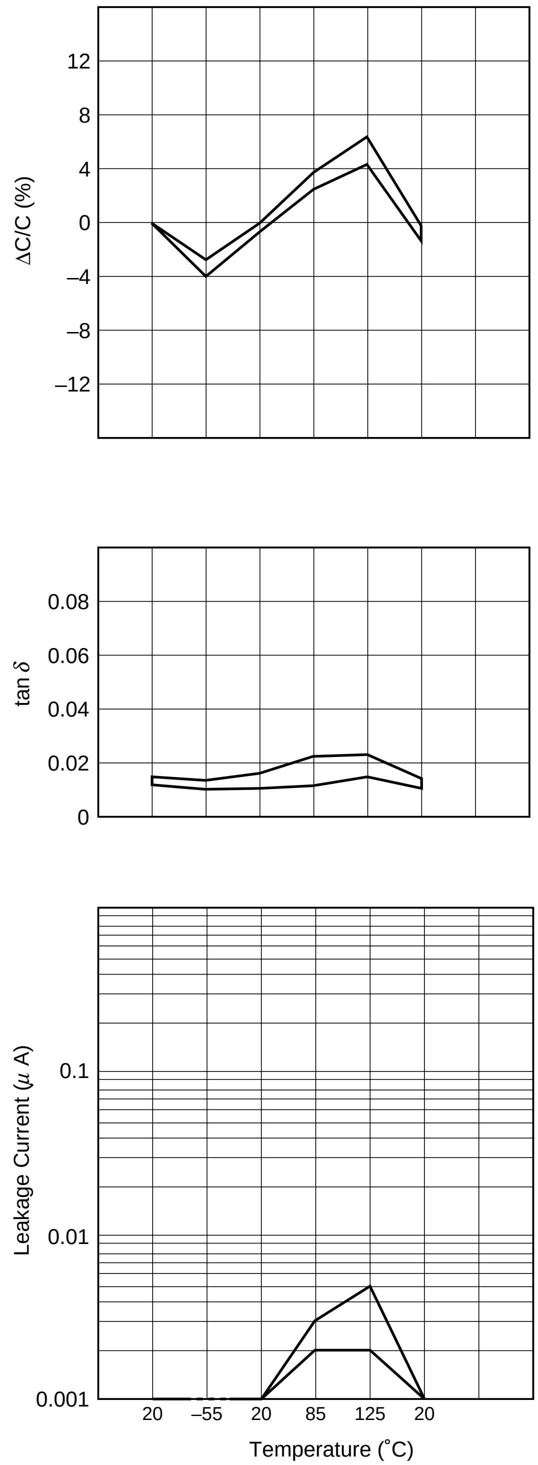
Note Part numbers in the tables above are for products with a capacitance tolerance of ±20%. For products with a capacitance tolerance of ±10%, change the letter “M” to “K”.
Use the letters “U”, “W”, “S” and “T” in part numbers for the case code “A2”, “B3”, “B2” and “D2”.
Please refer to page 41 for the detail of part numbering system.

- R Series (Standard)

Characteristics at High and Low Temperature



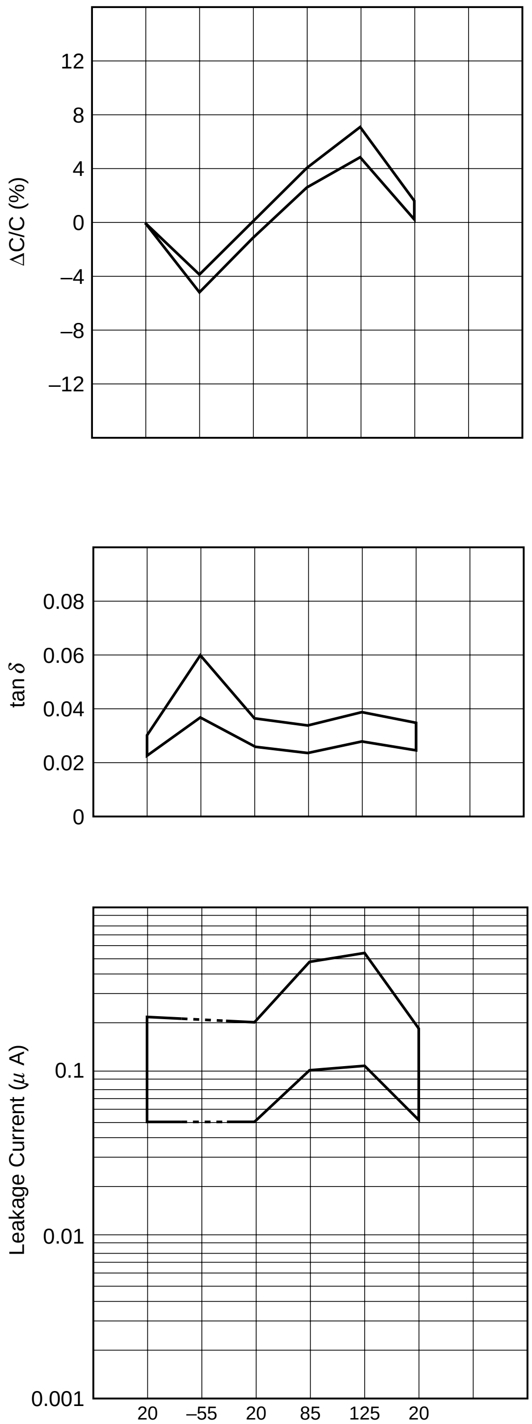
3.3 μF/4 V A Case



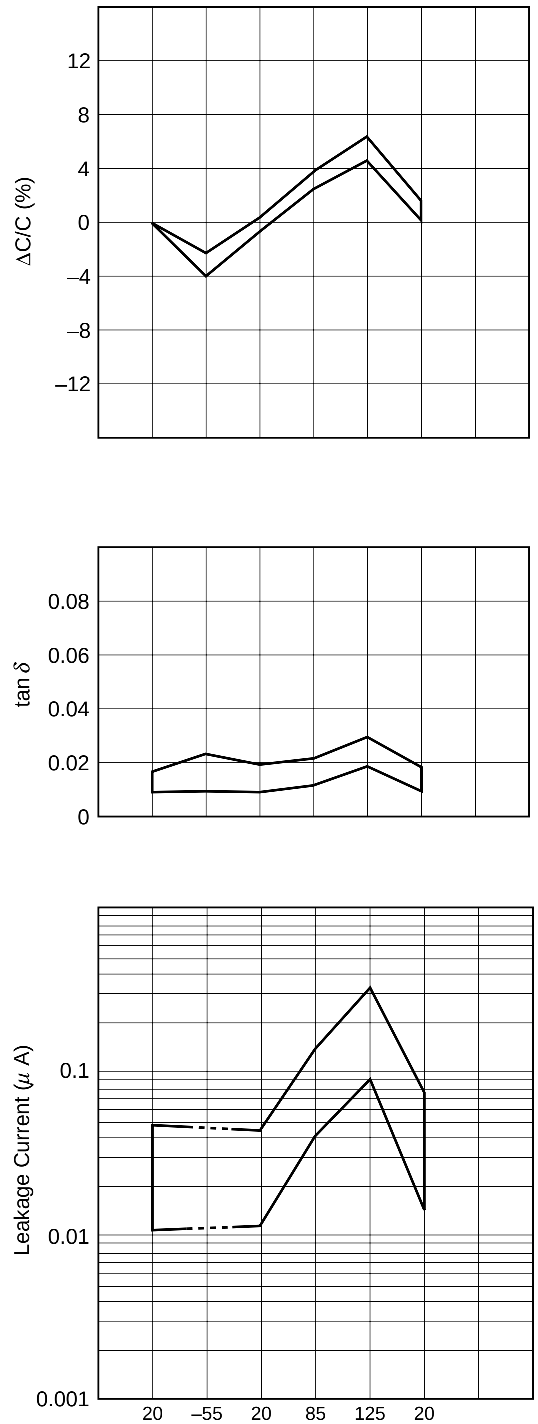
0.33 μF/35 V A Case

- R Series (Standard)

Characteristics at High and Low Temperature



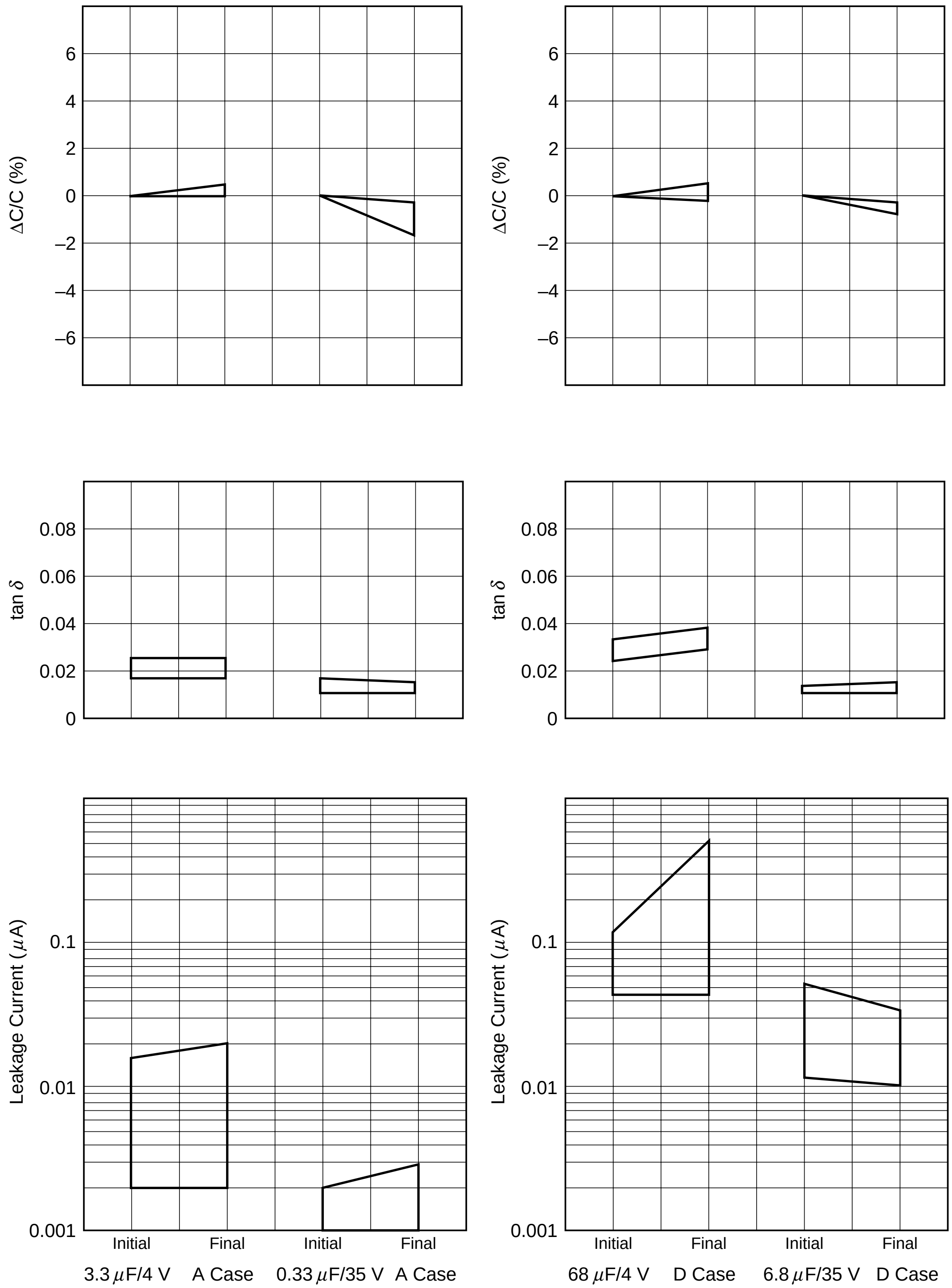
68 μF/4 V D Case



6.8 μF/35 V D Case

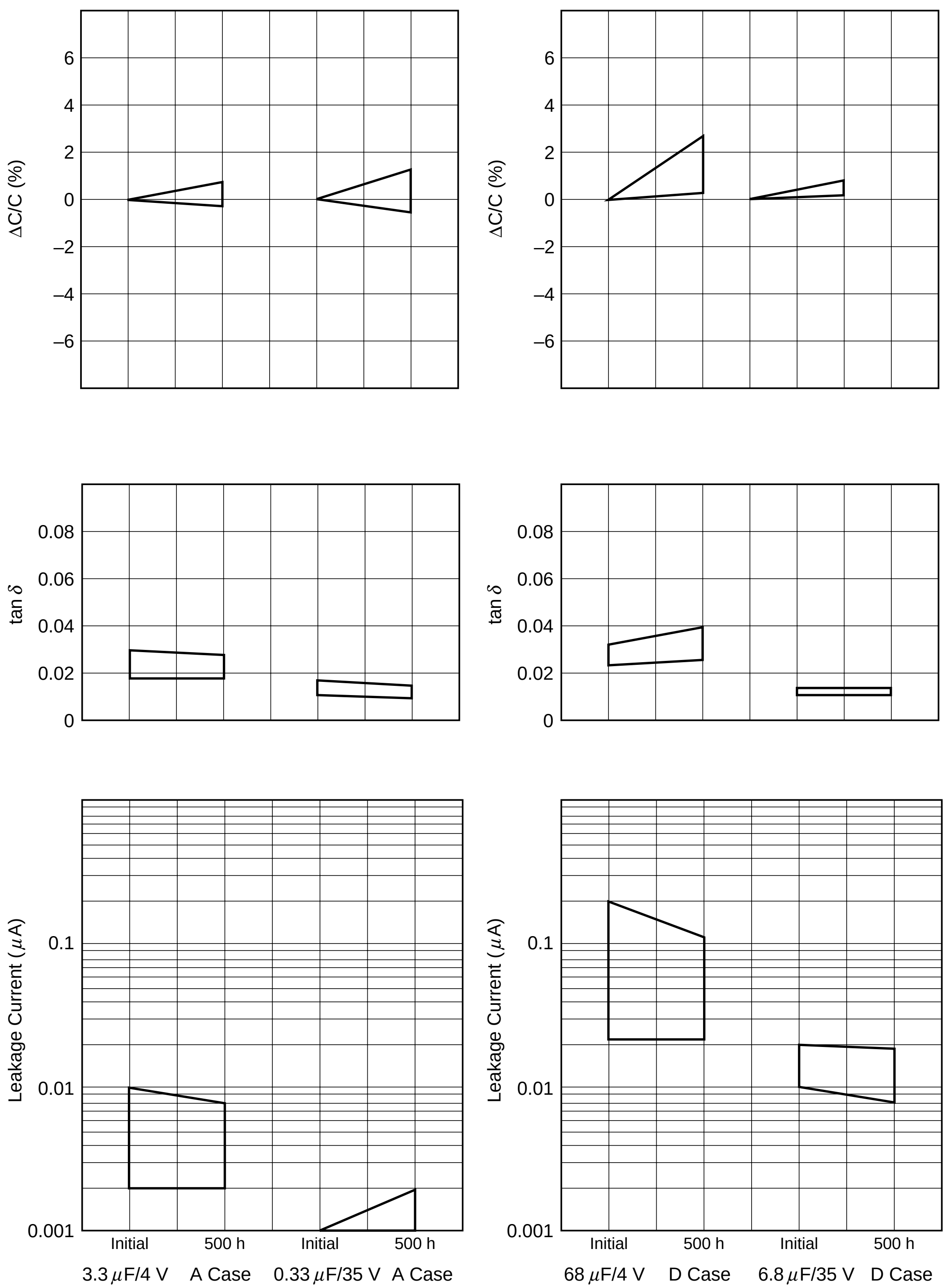
• R Series (Standard)

Resistance to Soldering Heat (Immersing for 10 sec. at 260 ˚C)



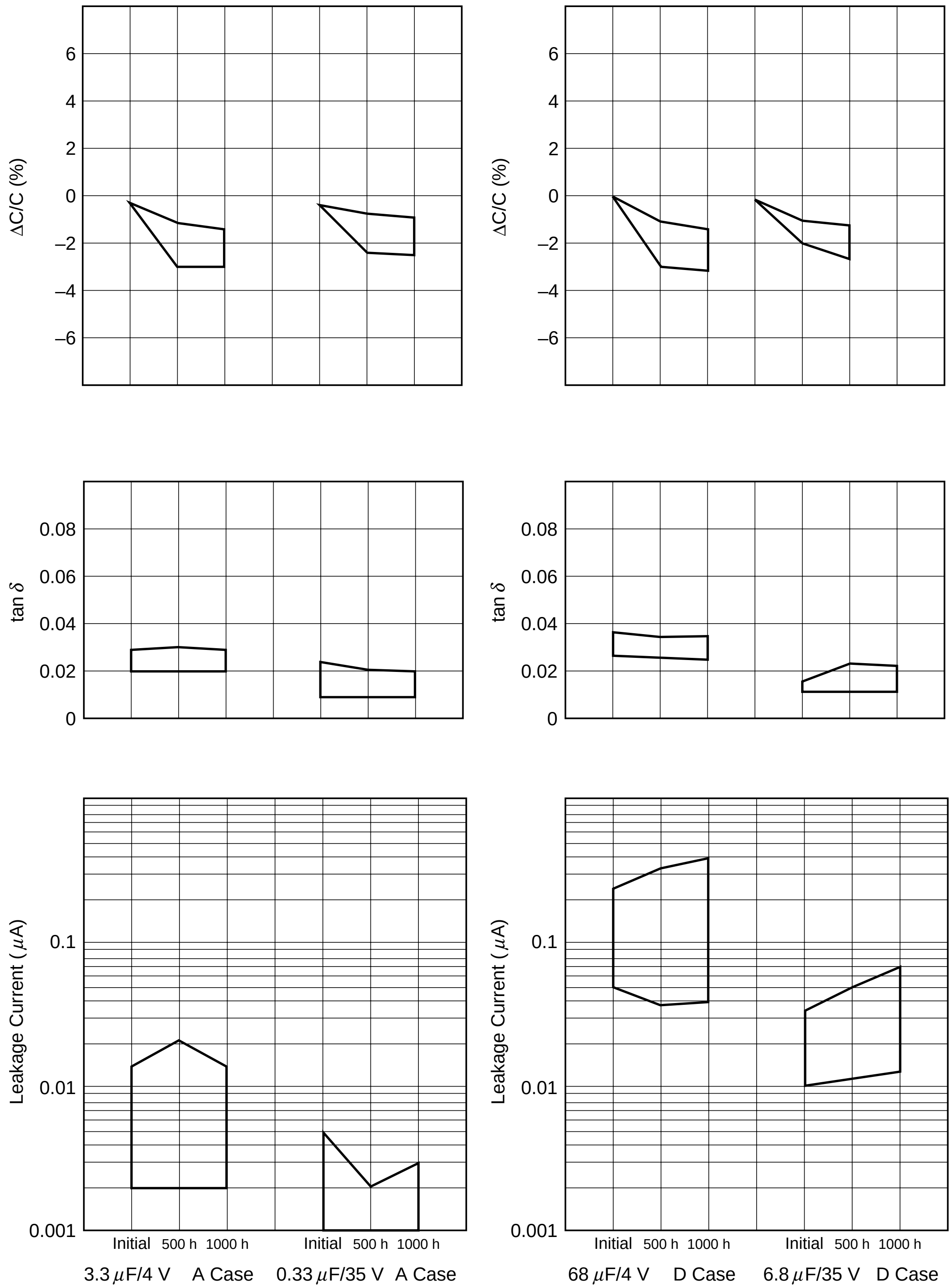
• R Series (Standard)

Damp Heat, Steady State (40˚C, 90 to 95%RH)



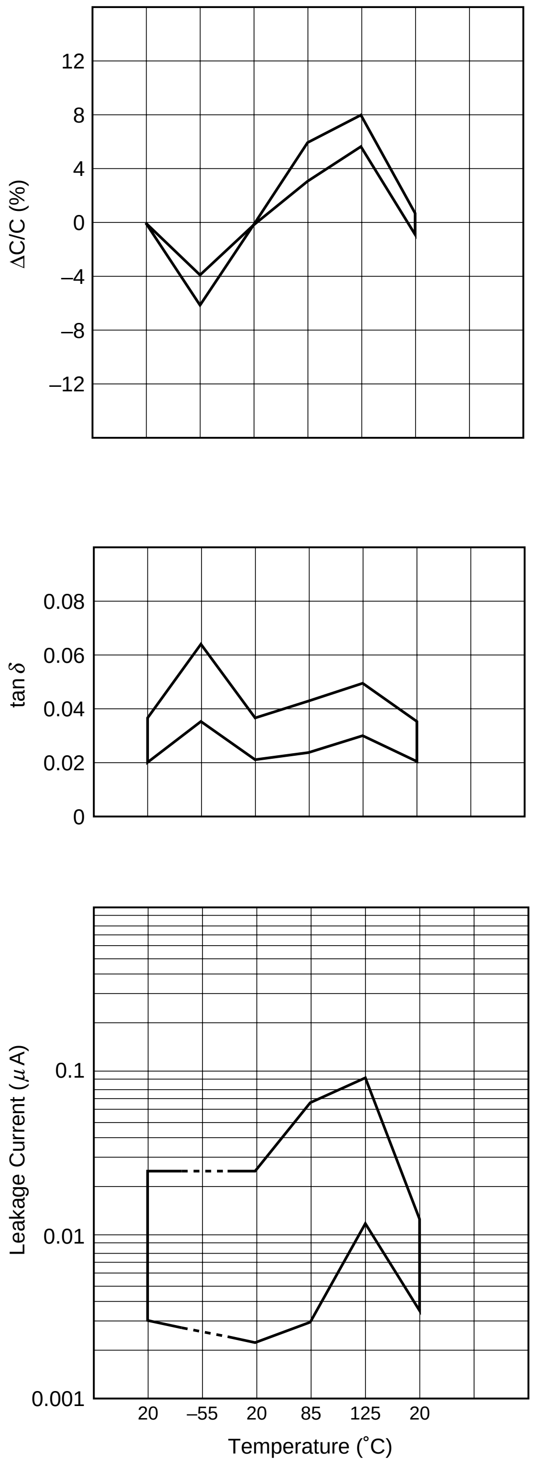
• R Series (Standard)

Endurance (85˚C, Rated Voltage Applied)

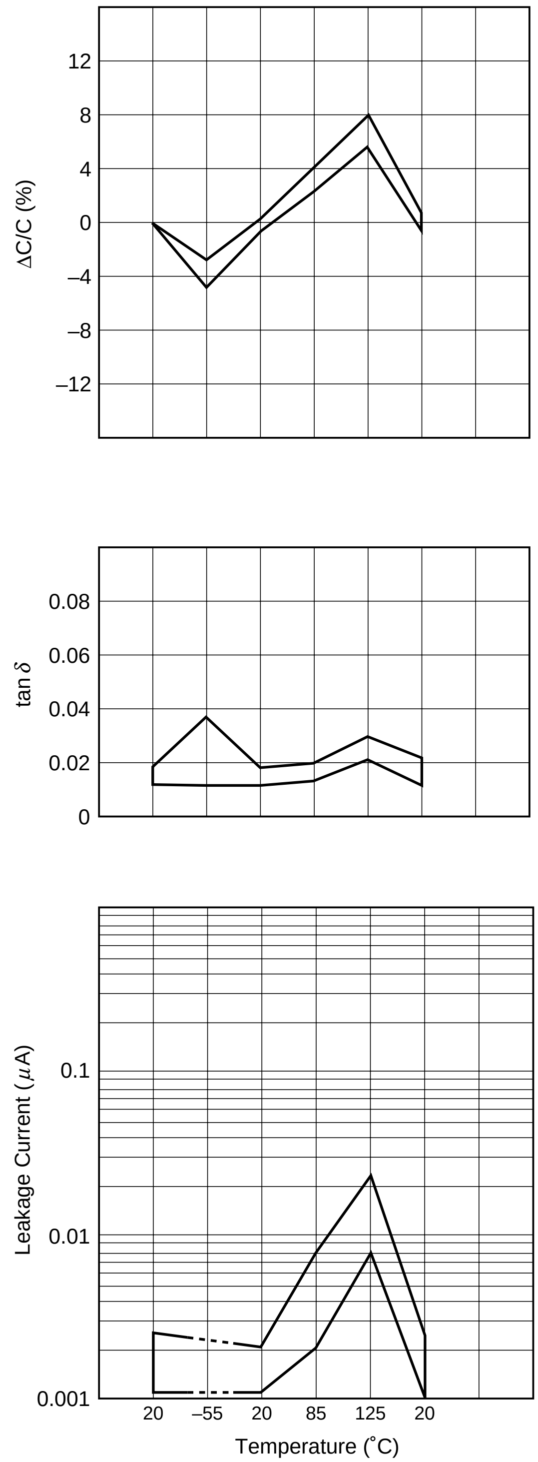


- R Series (Extended)

Characteristics at High and Low Temperature



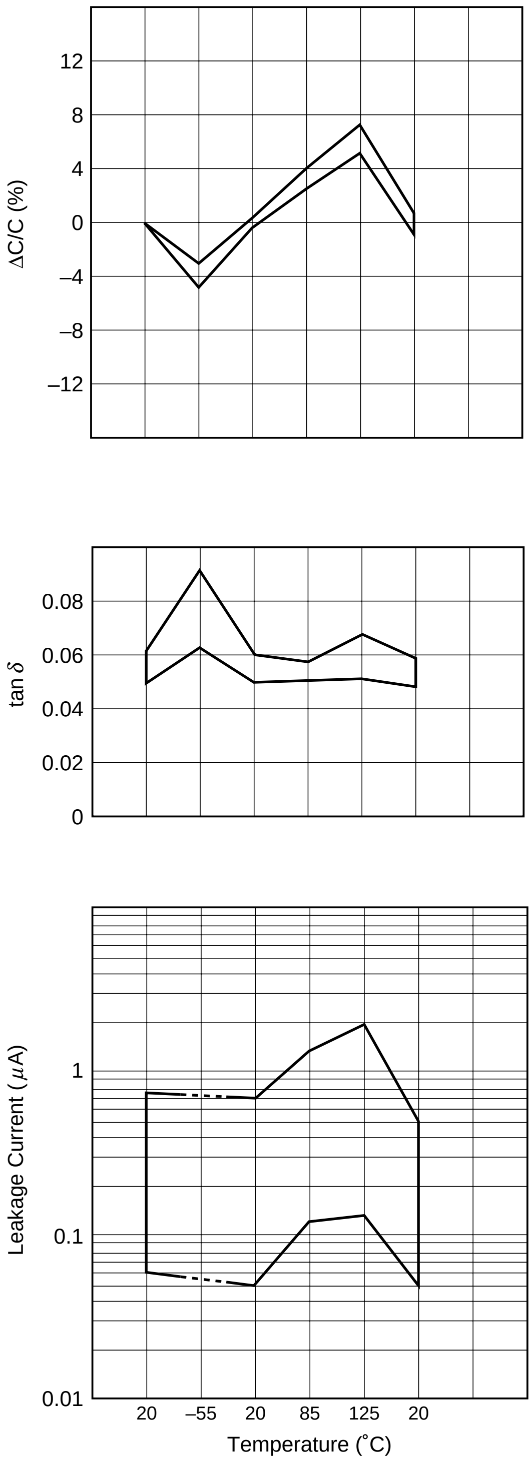
6.8 μF/4 V A Case



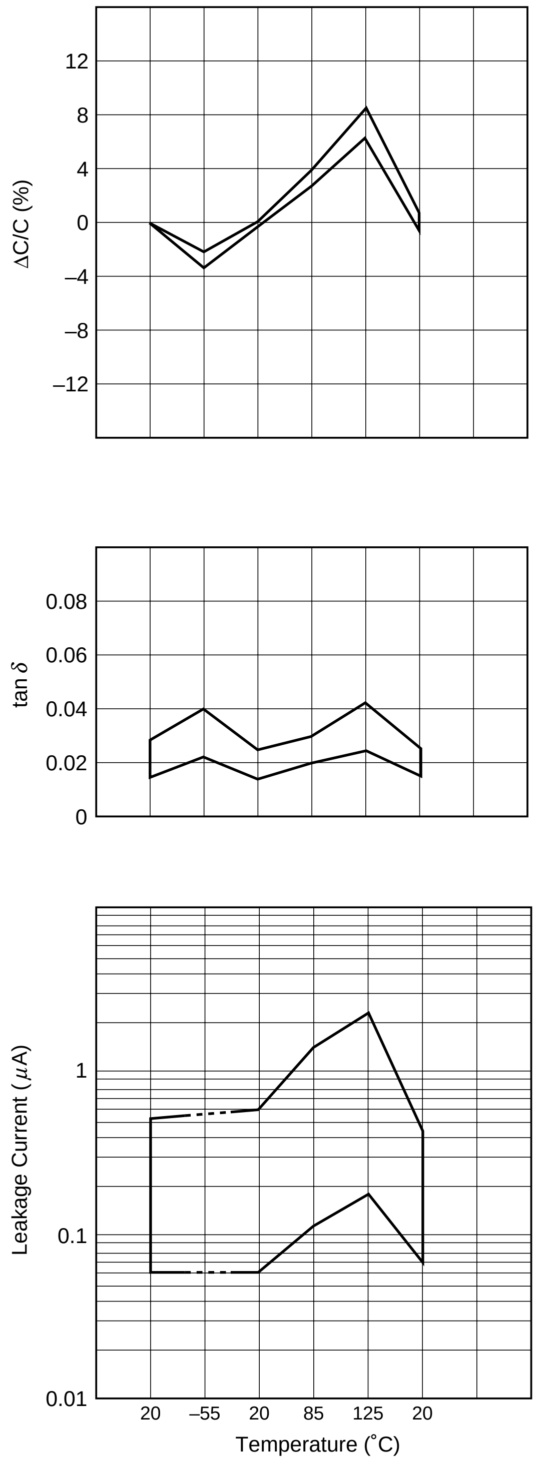
0.68 μF/35 V A Case

• R Series (Extended)

Characteristics at High and Low Temperature



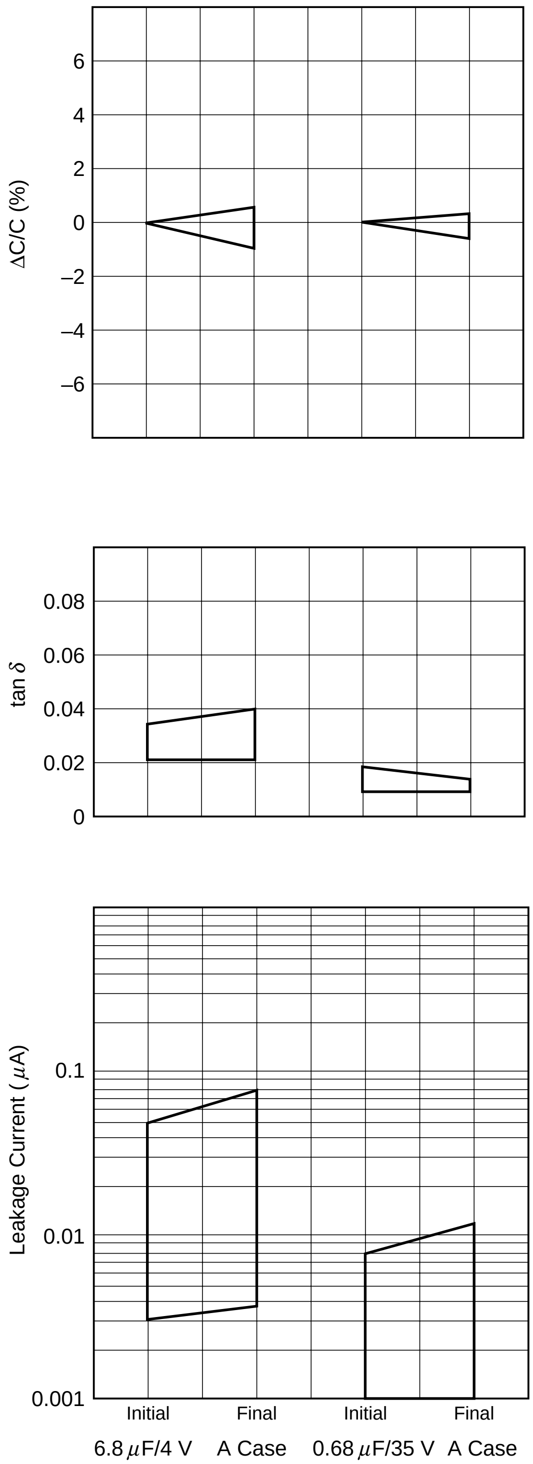
100 μF/4 V D Case

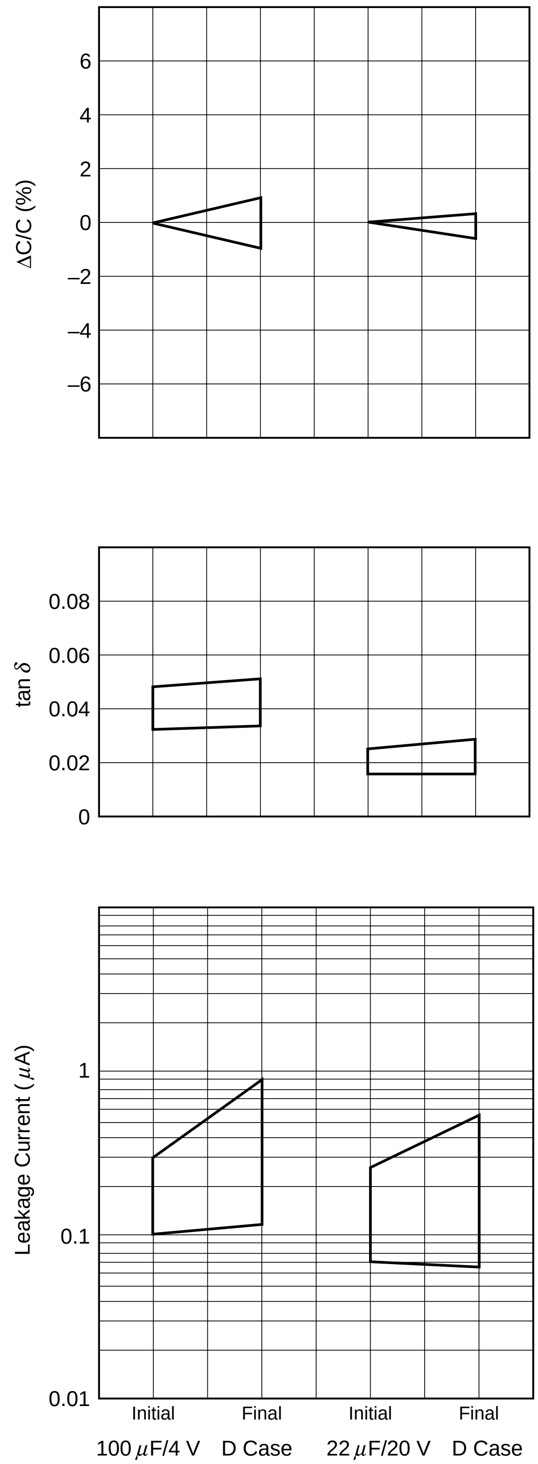


22 μF/20 V D Case

- R Series (Extended)

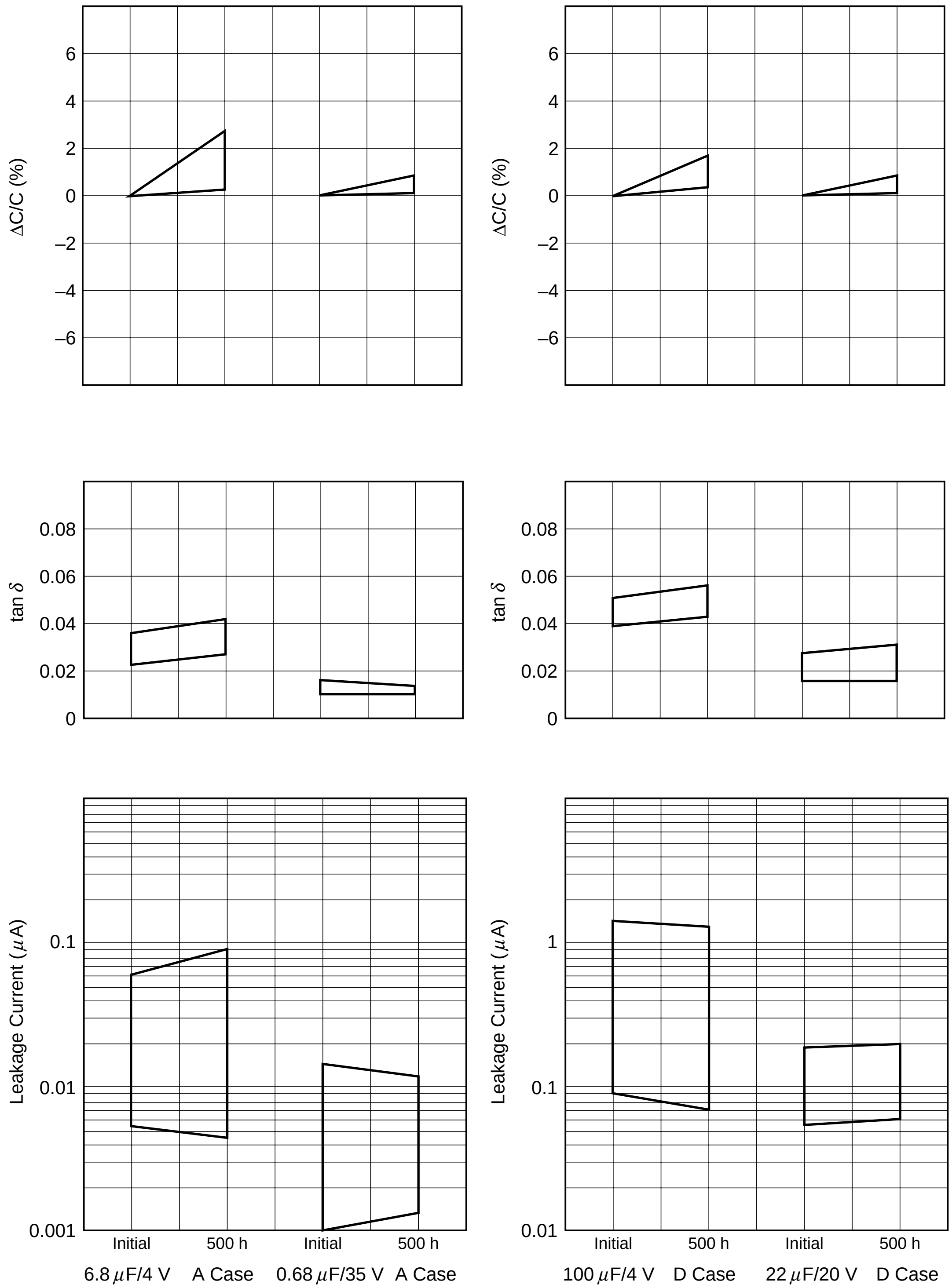
Resistance to Soldering Heat (Immersing for 10 sec. at 260˚C)





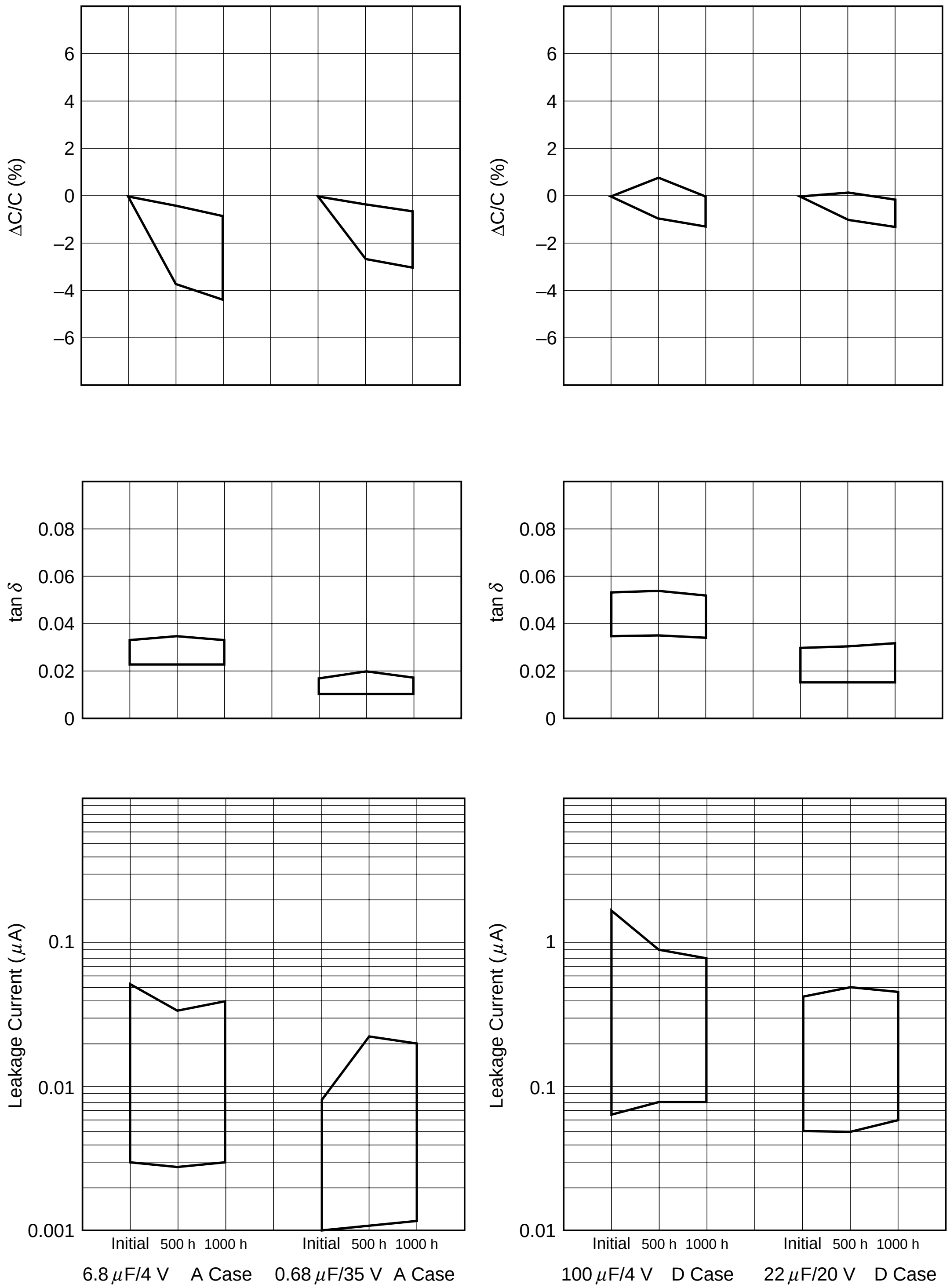
- R Series (Extended)

Damp Heat, Steady State (40˚C, 90 to 95% RH)



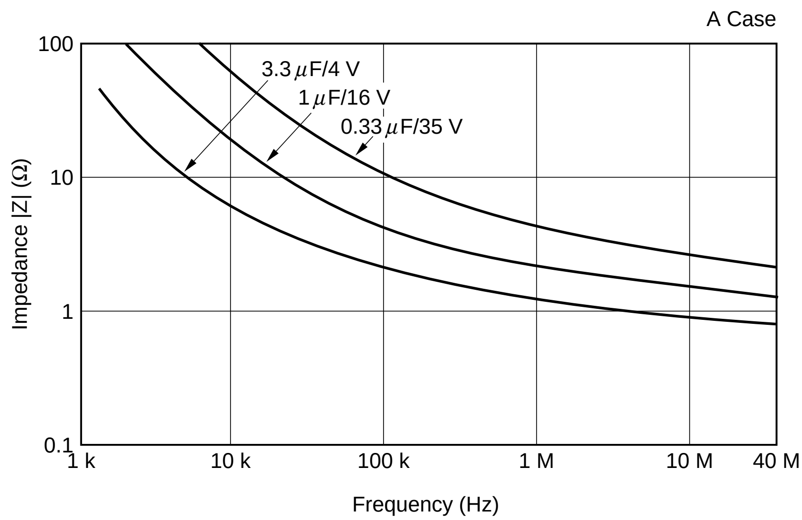
• R Series (Extended)

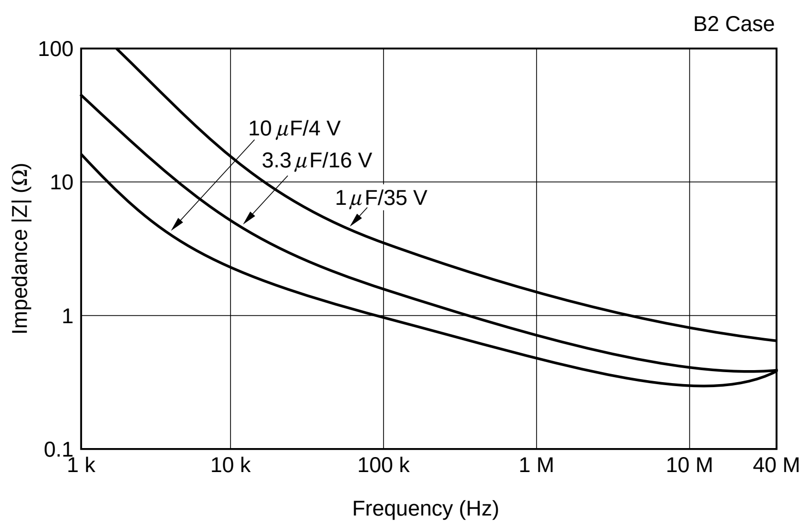
Endurance (85˚C, Rated Voltage Applied)

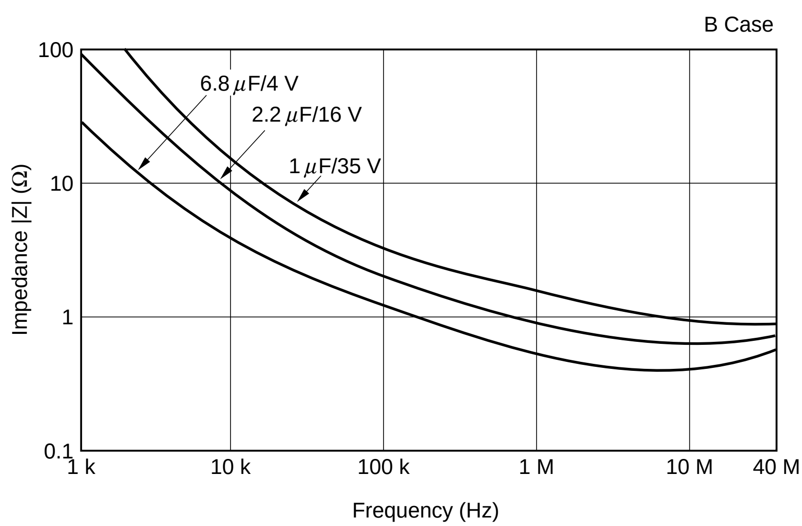


R Series (Standard)

Impedance – Frequency Characteristics

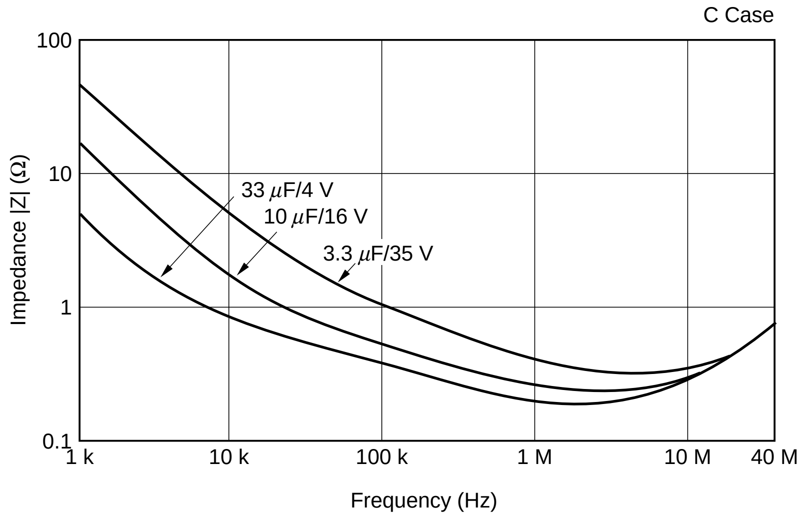


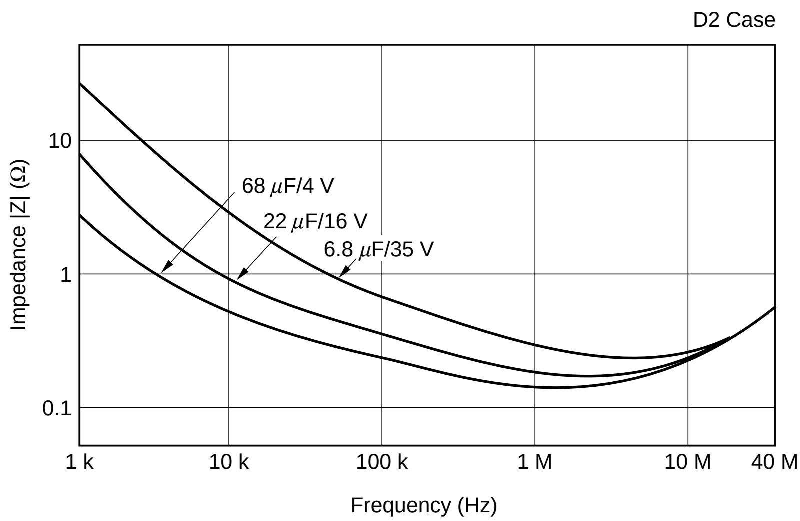


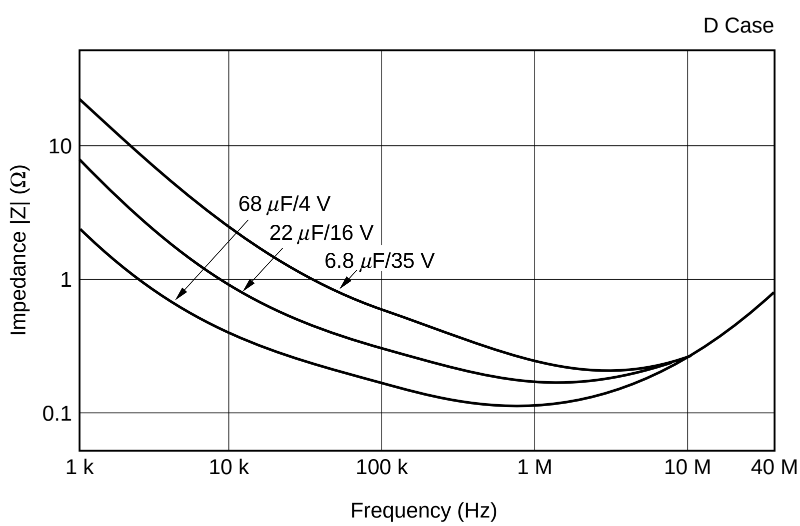


R Series (Standard)

Impedance – Frequency Characteristics

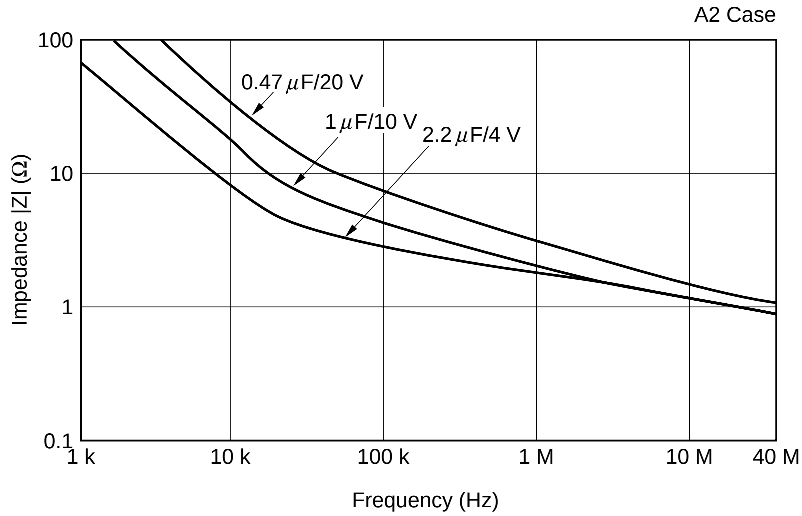


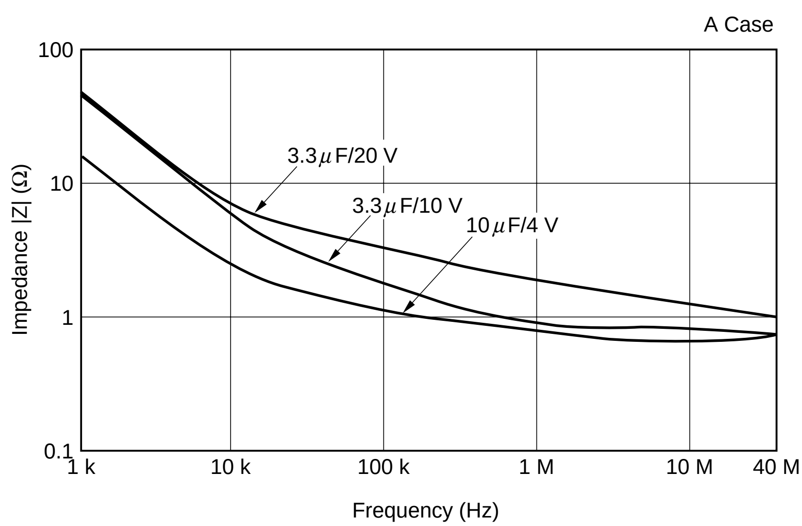


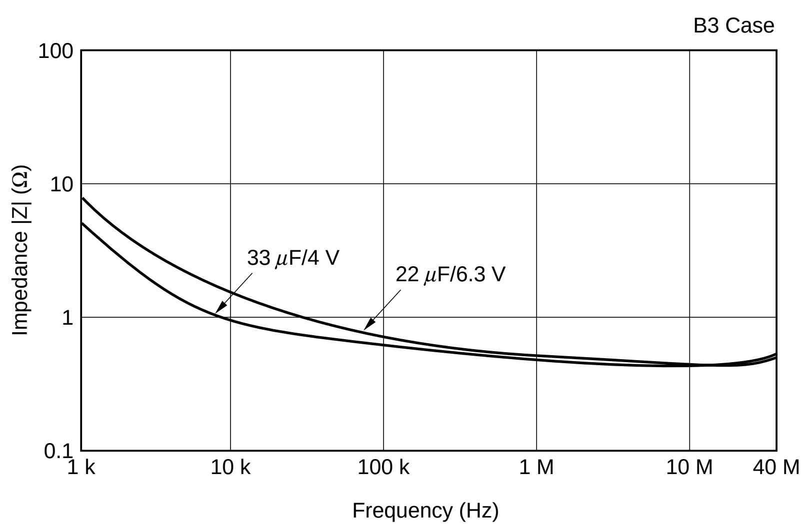


R Series (Extended)

Impedance – Frequency Characteristics

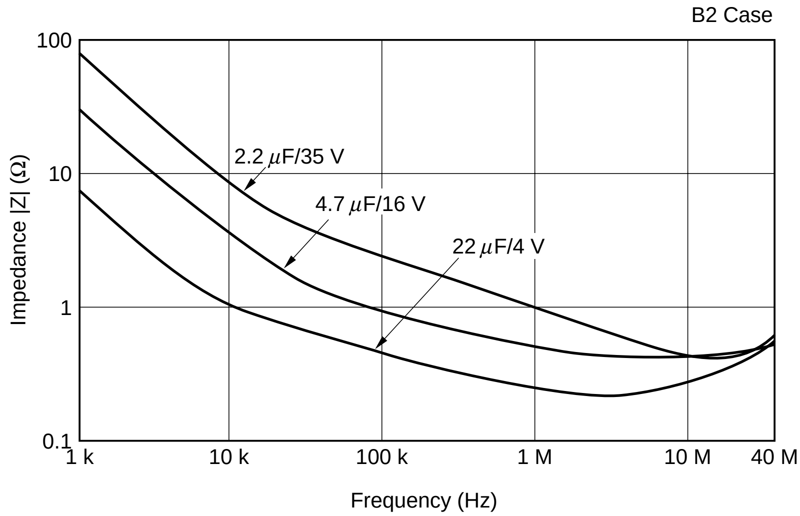


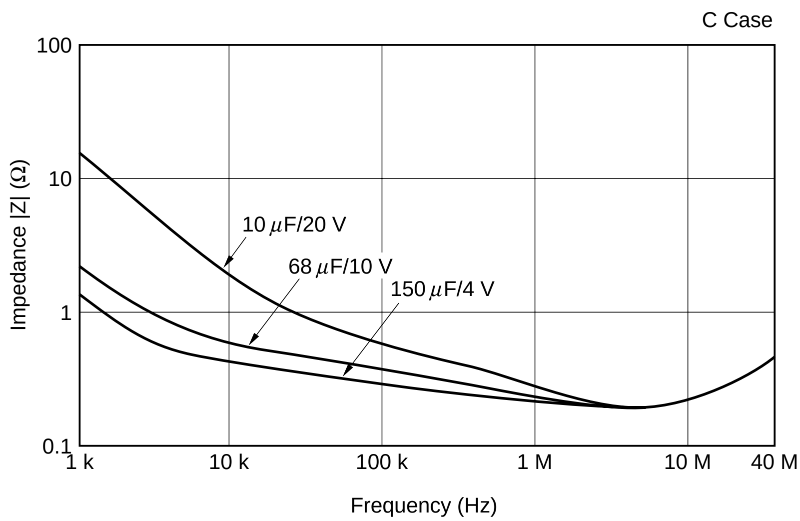


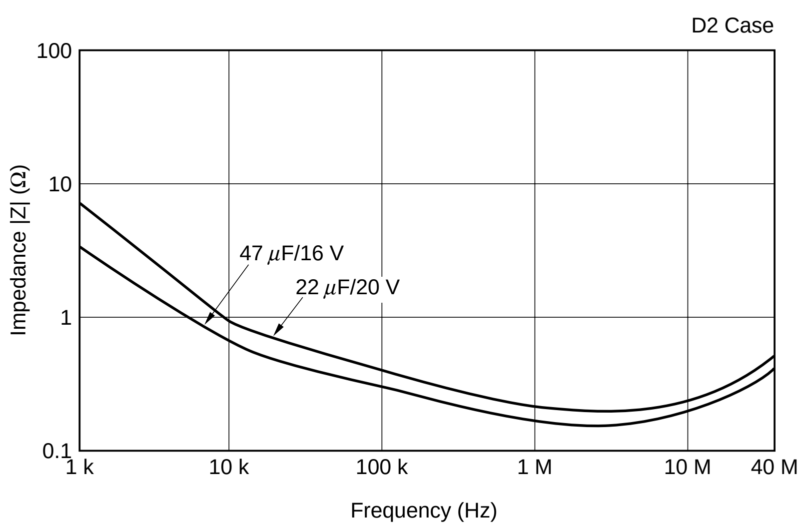


R Series (Extended)

Impedance – Frequency Characteristics

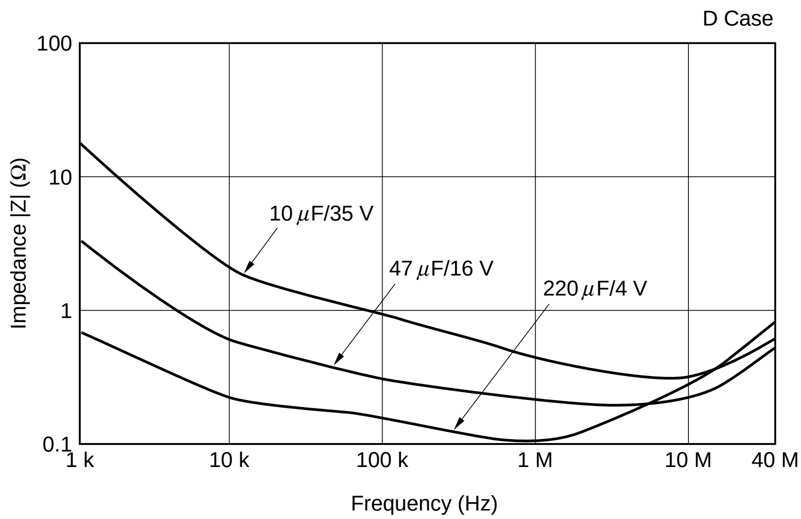






R Series (Extended)

Impedance – Frequency Characteristics



SVS SERIES

The SVS series is a line-up of high performance ultra-miniaturized tantalum chip capacitors.
The case dimensions are 2.0 mm × 1.25 mm × 1.2 mm as shown below.

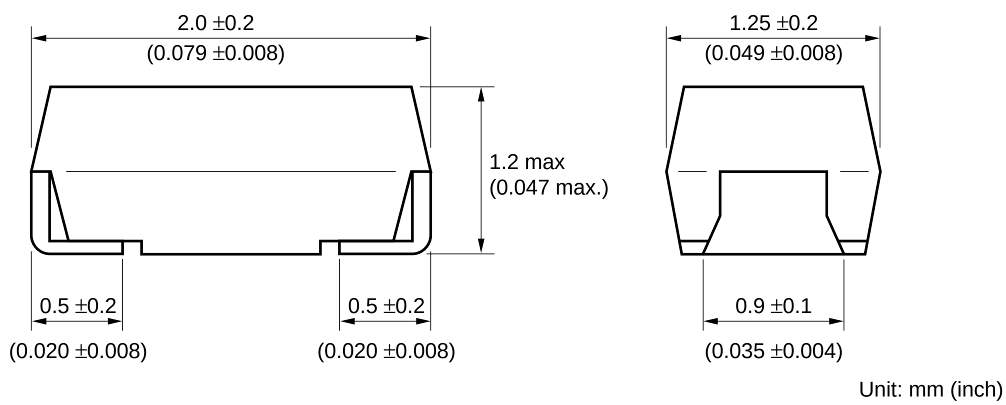
FEATURES

- The smallest molded chip tantalum capacitor
- Available up to 10 μF with case dimension of 2.0 mm × 1.25 mm × 1.2 mm (Case Code P)
- Case size of half as small as the EIA standard A case (EIA Case Code: 3216)

APPLICATIONS

- Portable Stereos
- VCR
- Hearing Aids

OUTLINE DRAWINGS AND DIMENSIONS

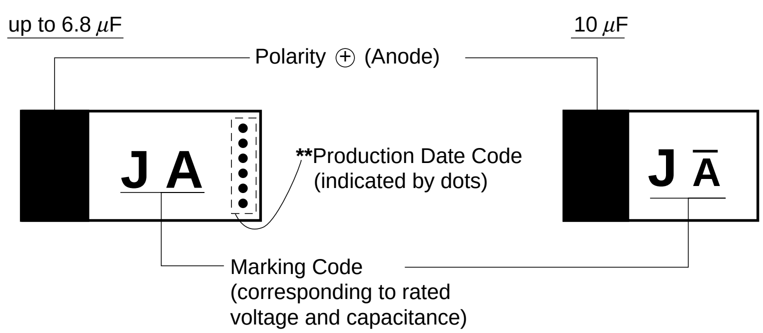


Case Code: P (EIA Case Code: 2012)

PRODUCT LINE-UP AND MARKING CODE

Capacitance (μF) \ Rated Voltage (V dc)	2.5	4	6.3	10	16
0.33					CN
0.47					CS
0.68				AW	CW
1			JA	AA	
1.5		GE	JE	AE	
2.2	eJ	GJ	JJ	AJ	
3.3	eN	GN	JN	AN	
4.7	eS	GS	JS		
6.8	eW	GW	JW		
10	e$\overline{\text{A}}$	G$\overline{\text{A}}$	J$\overline{\text{A}}$		

MARKING



**Implement date code on trial.

PART NUMBERING SYSTEM

– Bulk –

SVS P 0J 105 M

- M — Capacitance Tolerance ±20%
- 105 — Capacitance Code in pF
  First two digits represent significant figures.
  Third dight specifies number of zeros to follow.
- 0J — DC Rated Voltage
  0E: 2.5 V, 0G: 4 V, 0J: 6.3 V
  1A: 10 V, 1C: 16 V
- P — Case Size
- SVS — SVS Series

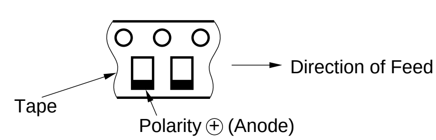
– Tap and Reel –

TE SVSP0J105M 8 R

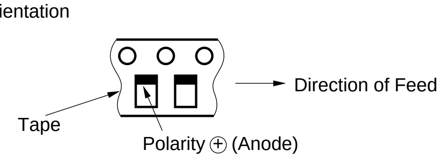
- SVSP0J105M — Same as Bulk Part
- R — Packing Orientation (See below)
- 8 — Tape Width 8 mm for P Case
- TE — Tape and Reel
  TE: Reel Diameter 178 mm (7 inch)

– Packing Orientaion –

R : Orientation



L : Orientation



PERFORMANCE CHARACTERISTICS

Item	Specification						Test Method
Operating Temperature Range	–55 to +125˚C						
Rated Voltage	2.5	4	6.3	10	16	Vdc	Temperature: 85˚C
Surge Voltage	3.3	5.2	8	13	20	Vdc	Temperature: 85˚C
Category Voltage	1.6	2.5	4	6.3	10	Vdc	Temperature: 125˚C (*1)
Capacitance Range	0.33 to 10 μF						Frequency: 120 Hz
Capacitance Tolerance	±20%						
Leakage Current (L.C.)	0.01 CV (μA) or 0.5 μA whichever is greater						5 min, after rated voltage applied
Tangent of Loss Angle (tan δ)	Refer to Standard Ratings						Frequency: 120 Hz
Equivalent Series Resistance (ESR)	Refer to standard ratings						Frequency: 100 kHz
Surge Voltage Test	ΔC/C : ±20% tan δ : Initial requirement L.C. : Initiail requirement						Temperature: 8.5˚C Surge Voltage for 30 sec. Series Resistance: 1 kΩ Discharging Voltage for 5 min. 30 sec. 1000 cycles
Characteristics at High and Low Temperature	Temp.	–55˚C	+85˚C	+125˚C			Step 1: 20˚C Step 1: –55˚C Step 2: –55˚C Step 3: 20˚C Step 4: 85˚C Step 5: 125˚C Step 6: 20˚C
	ΔC/C	0, –20%	+20, 0%	+20, 0%			
	tan δ	Initial Requirement × 1.5	Initial Requirement	Initial Requirement × 1.5			
	L.C.	–	0.1 CV or 5 μA whichever is greater	0.125 CV or 6.25 μA whichever is greater			
Rapid Change of Temperature	ΔC/C : ±20% tan δ : Initial Requirement L.C. : Initial Requirement						–55 to +125˚C 5 cycles
Resistance to Soldering Heat	ΔC/C : ±20% tan δ : Initial Requirement L.C. : Initial Requirement						Fully immersion to solder, 260˚C, 5 sec.
Damp Heat, Steady State	ΔC/C : ±20% tan δ : Initial Requirement × 1.5 L.C. : Initial Requirement 500 hour						Temperature: 40˚C 90 to 95% RH 500 hours
Endurance	ΔC/C : ±20% tan δ : Initial Requirement L.C. : Initial Requirement × 2						Temperature: 85˚C Rated Voltage Applied Temperature: 125˚C Category Voltage Applied 2000 hours
Failure Rate	λ_0 = 1%/1000H						

LEGEND
CV : Product of Capacitance in μF and Voltage in V
ΔC/C : Capacitance Change Ratio

*1: Category voltage at 85˚C or more is calculated by following expression.

$$U_T = U_R - \frac{U_R - U_C}{40}(T - 85)$$

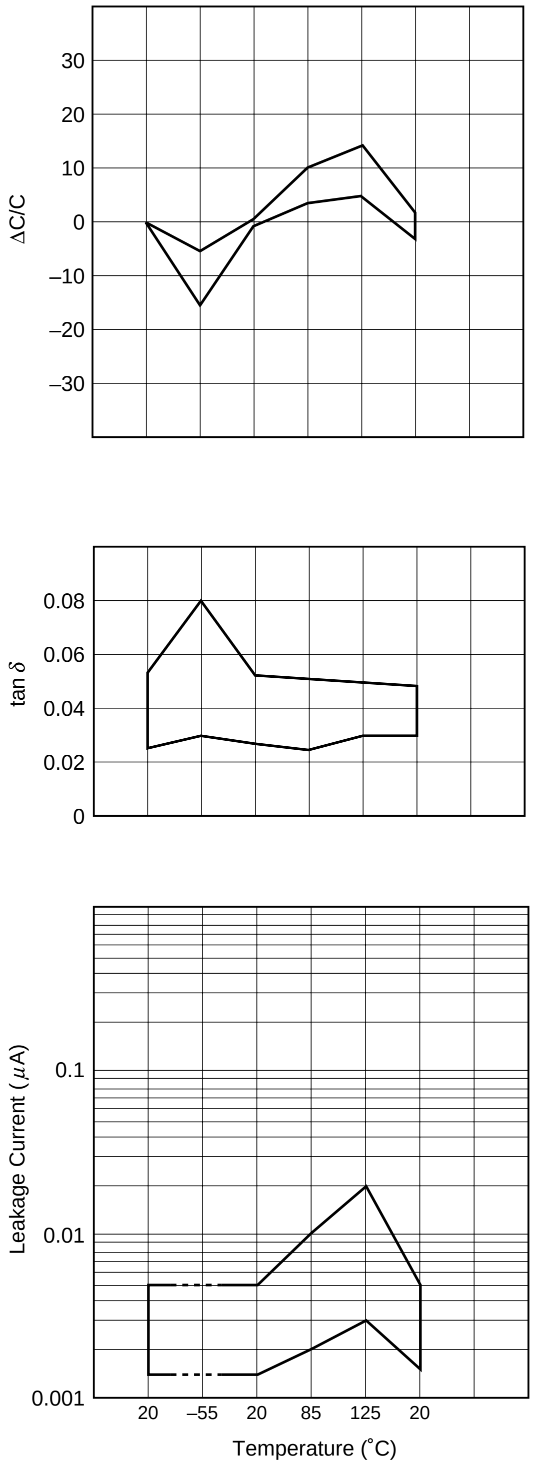
U_R : Rated Voltage
U_C : Category Voltage at 125˚C

RATINGS

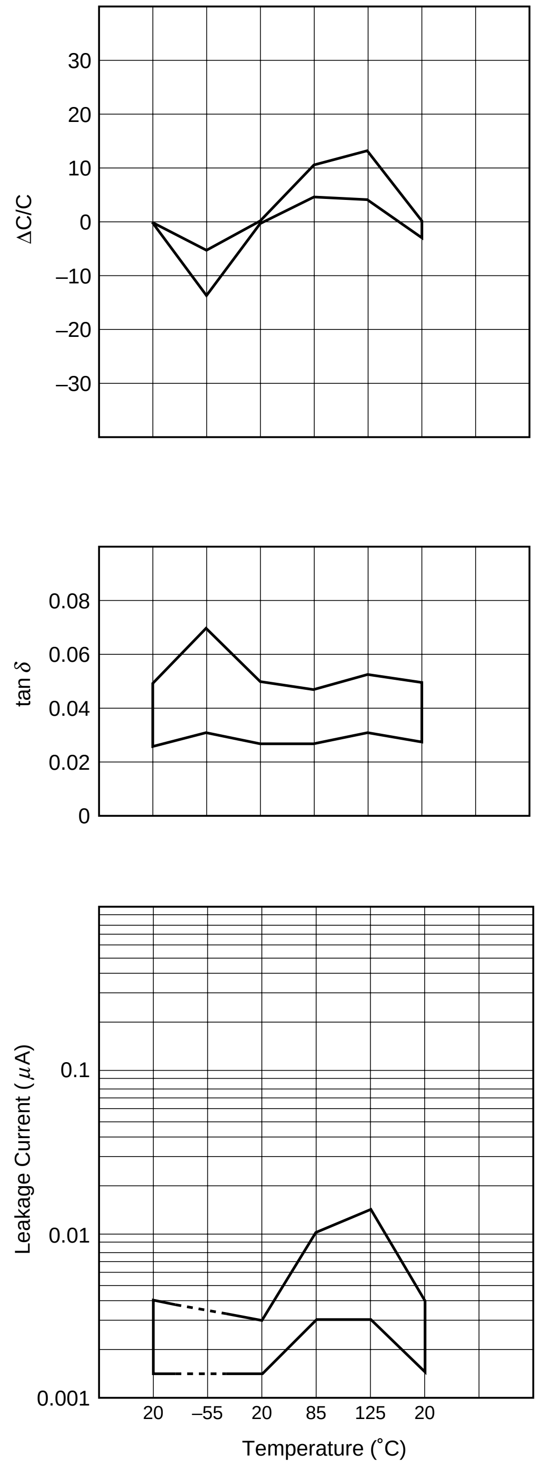
DC Rated Voltage @85°C (125°C) Vdc	Capacitance @20°C, 120 Hz μF	Case Size	Part Number	Leakage Current @20°C μA Max.	tan δ @20°C, 120 Hz % Max	ESR @20°C, 100 kHz Ω Max
2.5 (1.6)	2.2	P	SVSP0E225M	0.5	10	25
	3.3	P	SVSP0E335M	0.5	10	25
	4.7	P	SVSP0E475M	0.5	20	20
	6.8	P	SVSP0E685M	0.5	20	20
	10	P	SVSP0E106M	0.5	20	12
4 (2.5)	1.5	P	SVSP0G155M	0.5	10	25
	2.2	P	SVSP0G225M	0.5	10	25
	3.3	P	SVSP0G335M	0.5	20	20
	4.7	P	SVSP0G475M	0.5	20	12
	6.8	P	SVSP0G685M	0.5	20	12
	10	P	SVSP0G106M	0.5	20	12
6.3 (4)	1	P	SVSP0J105M	0.5	10	25
	1.5	P	SVSP0J155M	0.5	10	25
	2.2	P	SVSP0J225M	0.5	20	20
	3.3	P	SVSP0J335M	0.5	20	13
	4.7	P	SVSP0J475M	0.5	20	12
	6.8	P	SVSP0J685M	0.5	20	12
	10	P	SVSP0J106M	0.6	20	12
10 (6.3)	0.68	P	SVSP1A684M	0.5	10	25
	1	P	SVSP1A105M	0.5	10	25
	1.5	P	SVSP1A155M	0.5	20	25
	2.2	P	SVSP1A225M	0.5	20	20
	3.3	P	SVSP1A335M	0.5	20	20
16 (10)	0.33	P	SVSP1C334M	0.5	10	40
	0.47	P	SVSP1C474M	0.5	10	35
	0.68	P	SVSP1C684M	0.5	10	25
	1	P	SVSP1C105M	0.5	20	25

CHARACTERISTICS DATA

Characteristics at High and Low Temperature

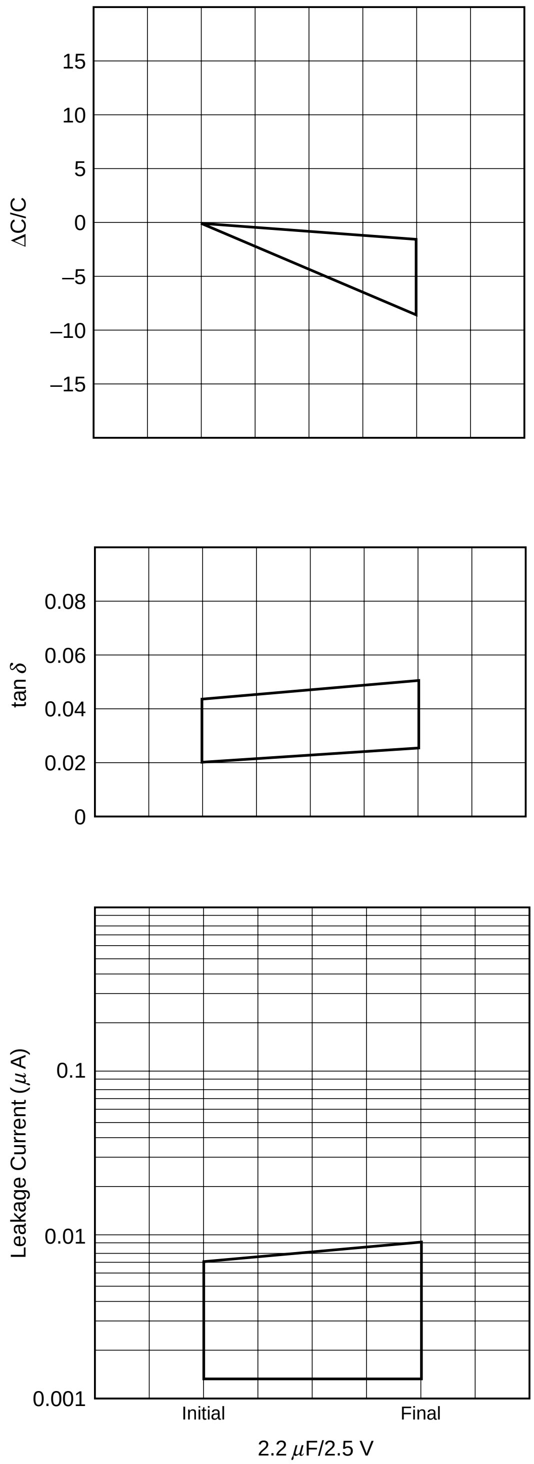


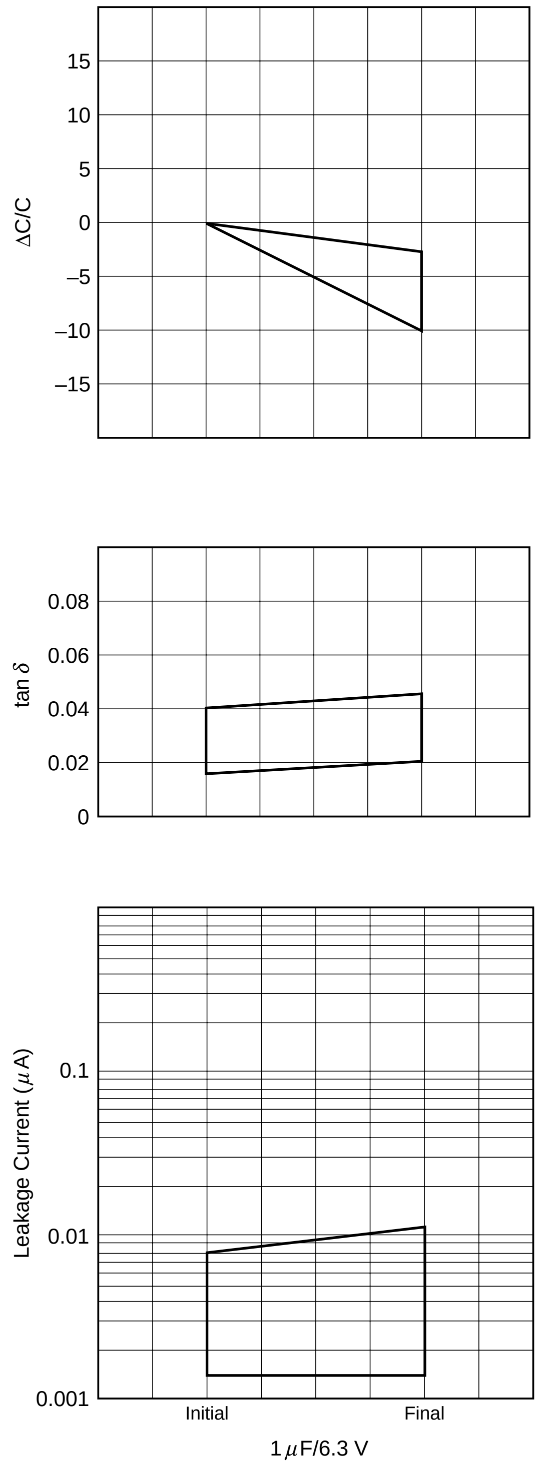
2.2 μF/2.5 V



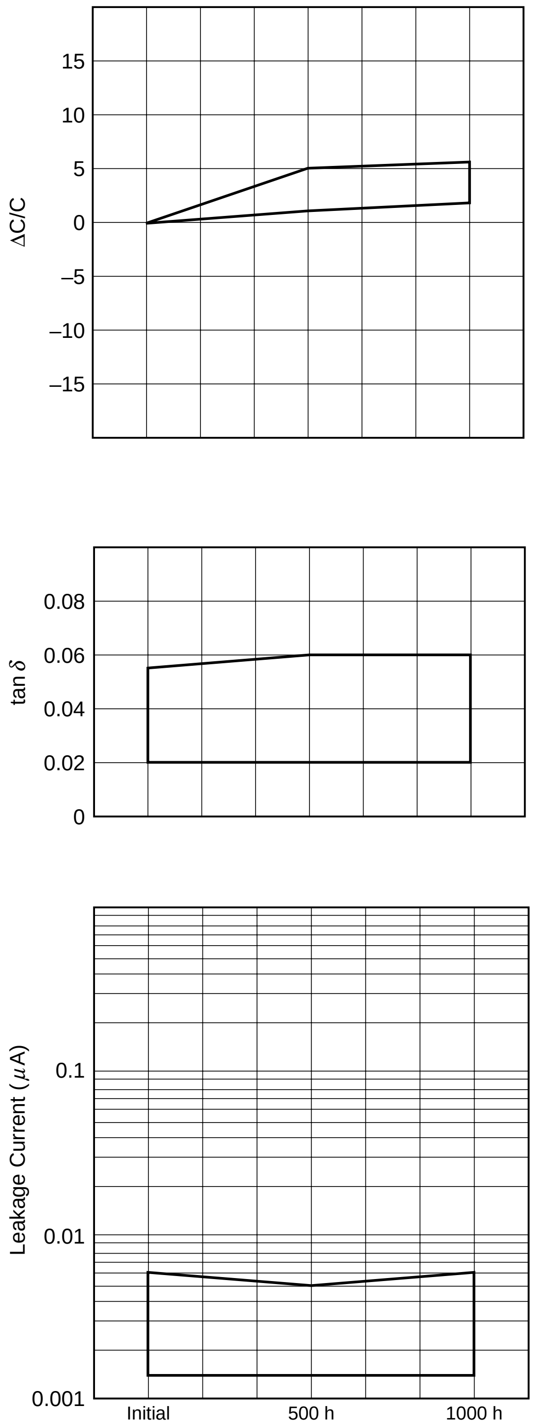
1 μF/6.3 V

Resistance to Soldering Heat (immersing for 10 sec. at 260˚C)

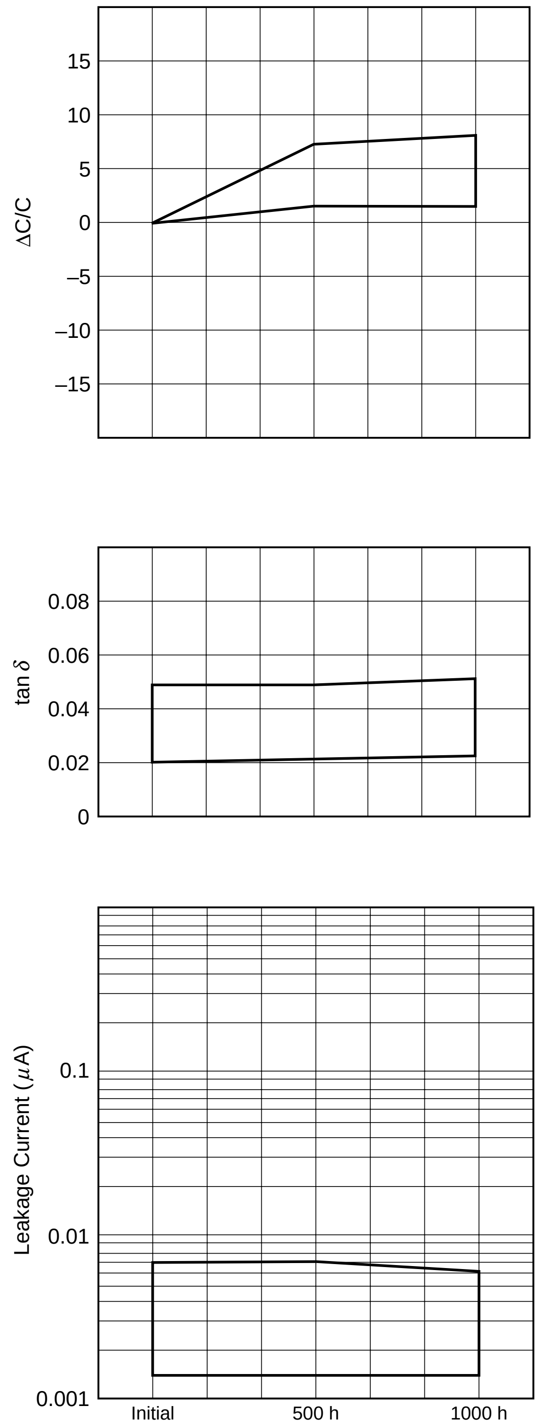




Damp Heat, Steady State (65˚C, 90 to 95% RH)

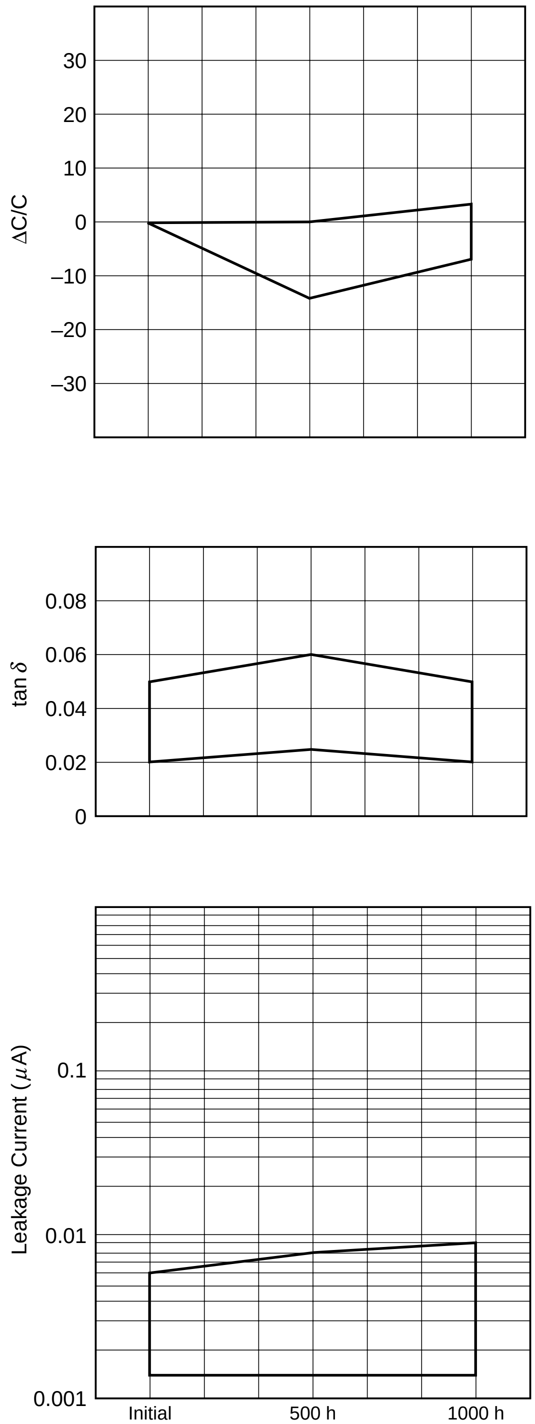


2.2 μF/2.5 V

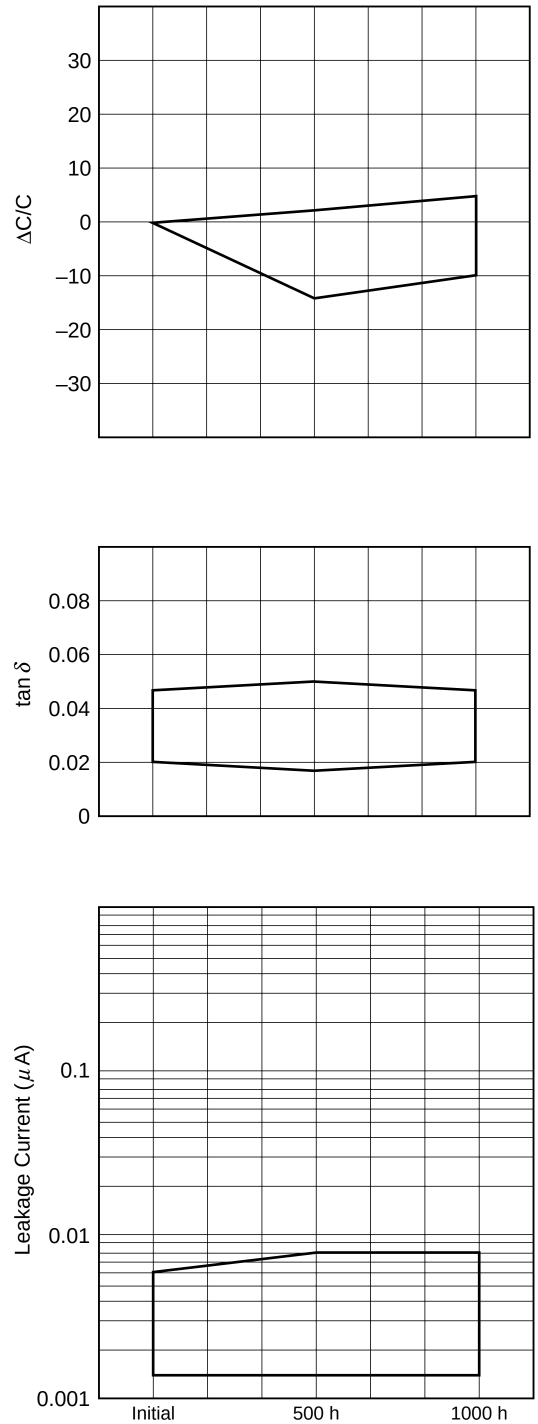


1 μF/6.3 V

Endurance (85˚C Rated Voltage × 1.3 Applied)

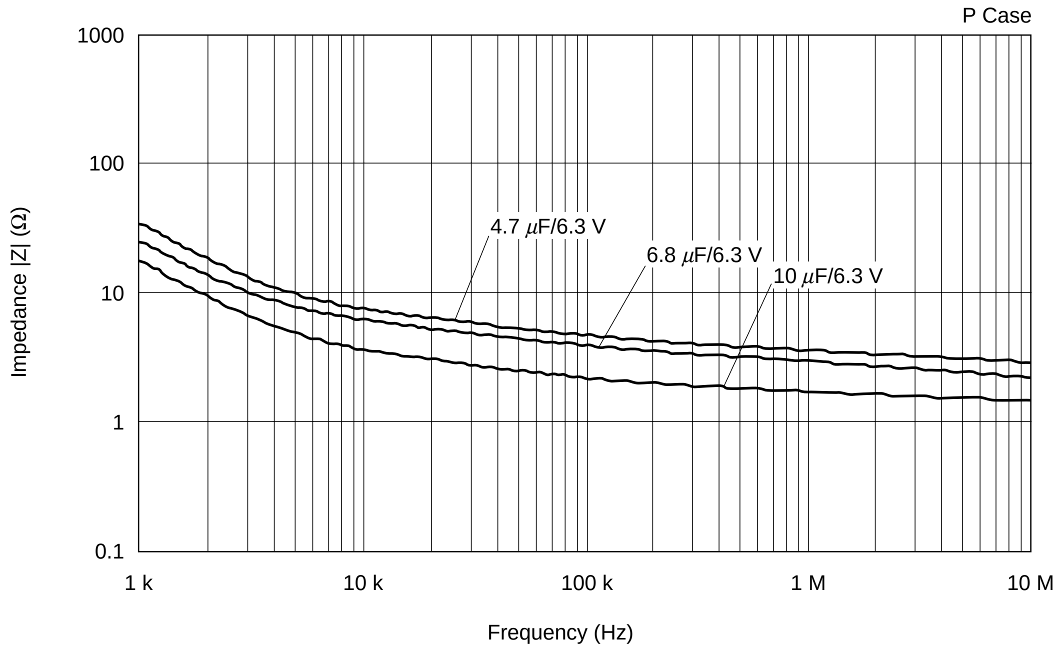


2.2 μF/2.5 V



1 μF/6.3 V

Impedance – Frequency Characteristics



SVH SERIES

NEC's SVH series solid tantalum capacitors have been developed for automotive application.

Compared to the conventional type (R series), the higher reliability and higher performance have been built in the same case size with NEC's original technologies.

FEATURES

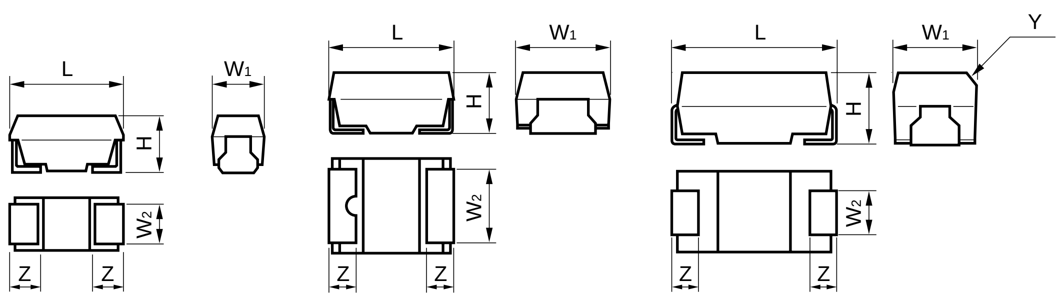
The SVH-series has the highest level of reliability and performance in the tantalum chip capacitors as shown below.

- Damp Heat, Steady state : 85˚C, 85% RH, 1000 hours
- Rapid Change of Temperature : –55˚C to +125˚C, 1000 cycles
- Resistance to Soklering Heat : 260˚C, 10 sec (Fully Immersed to Solder)
- Failure Rate : 0.5 %/1000 hours (at 85˚C, Rated Voltage Applied)

APPLICATIONS

- Automotive Electronics
- Other electronic equipment that requires high reliability and performance

OUTLINE DRAWINGS AND DIMENSIONS



[A Case] [B2 Case] [C, D2 Cases]

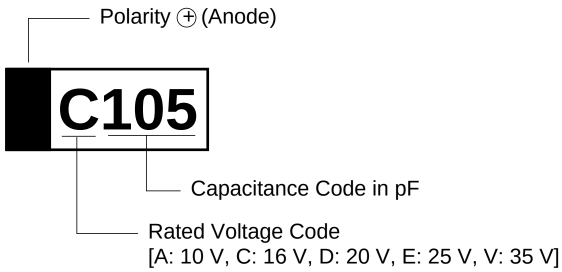
Unit : mm (inch)

Case Size	EIA Code	L	W_1	W_2	H	Z	Y
A	3216	3.2±0.2 (0.126±0.008)	1.6±0.2 (0.063±0.008)	1.2±0.1 (0.047±0.004)	1.6±0.2 (0.061±0.008)	0.8±0.3 (0.031±0.012)	—
B2	3528	3.2±0.2 (0.138±0.008)	2.8±0.2 (0.110±0.008)	2.3±0.1 (0.091±0.004)	1.9±0.2 (0.075±0.008)	0.8±0.3 (0.031±0.012)	—
C	6032	6.0±0.3 (0.236±0.012)	3.2±0.3 (0.126±0.012)	2.2±0.1 (0.087±0.004)	2.5±0.3 (0.098±0.012)	1.3±0.3 (0.051±0.012)	0.4C (0.016)
D2	–	5.8±0.3 (0.228±0.012)	4.6±0.2 (0.181±0.012)	2.4±0.1 (0.094±0.004)	3.2±0.3 (0.126±0.012)	1.3±0.3 (0.051±0.012)	—

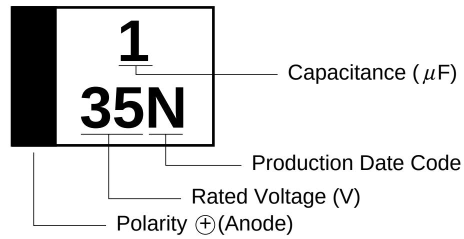
MARKING

— Top View —

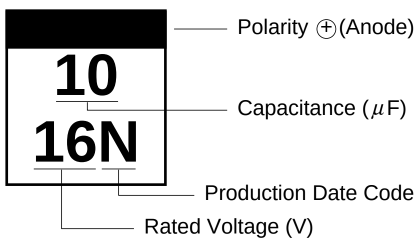
[A Case]



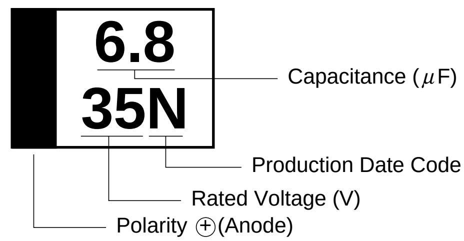
[B2 Case]



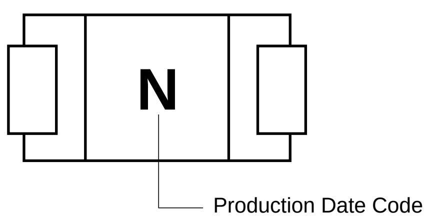
[C Case]



[D2 Case]



— Bottom View —
(for A Case)



[Production Date Code]

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1998	N	P	Q	R	S	T	U	V	W	X	Y	Z
1999	a	b	c	d	e	f	g	h	j	k	l	m
2000	n	p	q	r	s	t	u	v	w	x	y	z
2001	A	B	C	D	E	F	G	H	J	K	L	M

Date code will resume beginning in 2002.

PRODUCT LINE UP AND CASE SIZE

Capacitance (μF) \ Rated voltage (V dc)	10 V	16 V	20 V	25 V	35 V
0.1					A
0.15					A
0.22					A
0.33					A
0.47				A	B2
0.68			A		B2
1		A			B2
1.5		A		B2	C
2.2	A		B2		C
3.3		B2			C
4.7	B2			C	D2
6.8			C		D2
10		C		D2	
15	C		D2		
22		D2			
33	D2				

PART NUMBERING SYSTEM

– Bulk –

SVH B2 1V 105 M

- M: Capacitance Tolerance
  M: ±20% K: ±10%
- 105: Capacitance Code in pF
  First two digits represent significant figures.
  Third digit specifies number of zeros to follow.
- 1V: DC Rated Voltage
  1A: 10 V 1C: 16 V 1D: 20 V
  1E: 25 V 1V: 35 V
- B2: Case Size
- SVH: SVH Series

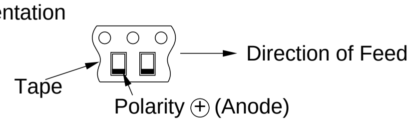
– Tape and Reel –

TE SVHB21V105M 8 R E

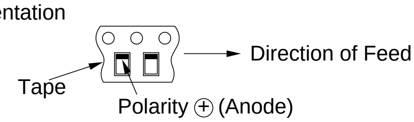
- SVHB21V105M: Same as Bulk Part
- TE: Tape and Reel
  TE: Reel Diameter 178 mm (7 inch)
  TL: Reel Diameter 330 mm (13 inch)
- 8: Tape Width
  8 mm for A & B2 Case
  12 mm for C & D2 Cases
- R: Packing Orientation (See below)
- E: In case of the necessity of the hole in embossment of the carrier tape, "E" is put to end of part number.
  (Available for 330 mmϕ Reel Only)

– Packing Orientation –

R: Orientation



L: Orientation



PERFORMANCE CHARACTERISTICS

<table>
<tr><th colspan="2">Item</th><th colspan="6">Specification</th><th>Test Method</th></tr>
<tr><td colspan="2">Operating Temperature Range</td><td colspan="6">–55 to +125˚C</td><td></td></tr>
<tr><td colspan="2">Rated Voltage</td><td>10</td><td>16</td><td>20</td><td>25</td><td>35</td><td>Vdc</td><td>Temperature: 85˚C</td></tr>
<tr><td colspan="2">Surge Voltage</td><td>13</td><td>20</td><td>26</td><td>33</td><td>46</td><td>Vdc</td><td>Temperature: 85˚C</td></tr>
<tr><td colspan="2">Category Voltage</td><td>6.3</td><td>10</td><td>13</td><td>16</td><td>22</td><td>Vdc</td><td>Temperature: 125˚C (*1)</td></tr>
<tr><td colspan="2">Capacitance Range</td><td colspan="6">0.1 to 33 μF</td><td rowspan="2">Frequency: 120 Hz</td></tr>
<tr><td colspan="2">Capacitance Tolerance</td><td colspan="6">±20% (±10%)</td></tr>
<tr><td colspan="2">Leakage Current (L.C.)</td><td colspan="6">0.01 CV (μA) or 0.5 μA whichever is greater</td><td>5 min, after rated voltage applied</td></tr>
<tr><td colspan="2">Tangent of Loss Angle (tan δ)</td><td colspan="6">0.1 to 4.7 μF: 0.04 max.
6.8 to 33 μF: 0.06 max.</td><td>Frequency: 120 Hz</td></tr>
<tr><td colspan="2">Surge Voltage Test</td><td colspan="6">ΔC/C : ±5%
tan δ : Initial Requirement
L.C. : Initiail Requirement</td><td>Temperature: 8.5˚C
Surge Voltage for 30 sec.
Series Resistance: 1 kΩ
Discharge Voltage for 5 min. 30 sec.
1000 cycles</td></tr>
<tr><td rowspan="4">Characteristics at High and Low Temperature</td><td>Temp.</td><td colspan="2">–55˚C</td><td colspan="2">+85˚C</td><td colspan="2">+125˚C</td><td rowspan="4">Step 1: 20˚C
Step 2: –55˚C
Step 3: 20˚C
Step 4: 85˚C
Step 5: 125˚C
Step 6: 20˚C</td></tr>
<tr><td>ΔC/C</td><td colspan="2">0, –12%</td><td colspan="2">+12, 0%</td><td colspan="2">+15, 0%</td></tr>
<tr><td>tan δ</td><td colspan="2">0.1 to 4.7 μF: 0.08 max.
6.8 to 33 μF: 0.10 max.</td><td colspan="2">Initial Requirement</td><td colspan="2">0.1 to 4.7 μF: 0.06 max.
6.8 to 33 μF: 0.08 max.</td></tr>
<tr><td>L.C.</td><td colspan="2">–</td><td colspan="2">0.1 CV or 5 μA whichever is greater</td><td colspan="2">0.125 CV or 6.25 μA whichever is greater</td></tr>
<tr><td colspan="2">Rapid Change of Temperature</td><td colspan="6">ΔC/C : ±10%
tan δ : Initial Requirement
L.C. : Initial Requirement</td><td>–55 to +125˚C
1000 cycles</td></tr>
<tr><td colspan="2">Resistance to Soldering Heat</td><td colspan="6">ΔC/C : ±5%
tan δ : Initial Requirement
L.C. : Initial Requirement</td><td>Fully immersion to solder, 260˚C, 10 sec.</td></tr>
<tr><td colspan="2">Damp Heat, Steady State</td><td colspan="6">ΔC/C : 10%
tan δ : Initial Requirement × 1.5
L.C. : Initial Requirement</td><td>Temperature: 85˚C
85% RH
1000 hours</td></tr>
<tr><td colspan="2">Endurance</td><td colspan="6">ΔC/C : ±10%
tan δ : Initial Requirement
L.C. : Initial Requirement × 1.25</td><td>Temperature: 85˚C
Rated Voltage Applied
Temperature: 125˚C
Category Voltage Applied 2000 hours</td></tr>
<tr><td colspan="2">Failure Rate</td><td colspan="6">λ_0 = 0.5 %/1000H</td><td></td></tr>
</table>

LEGEND
CV : Product of capacitance in μF and voltage in V
ΔC/C : Capacitance Change Ratio

*1: Category voltage at 85˚C or more is calculated by following expression.

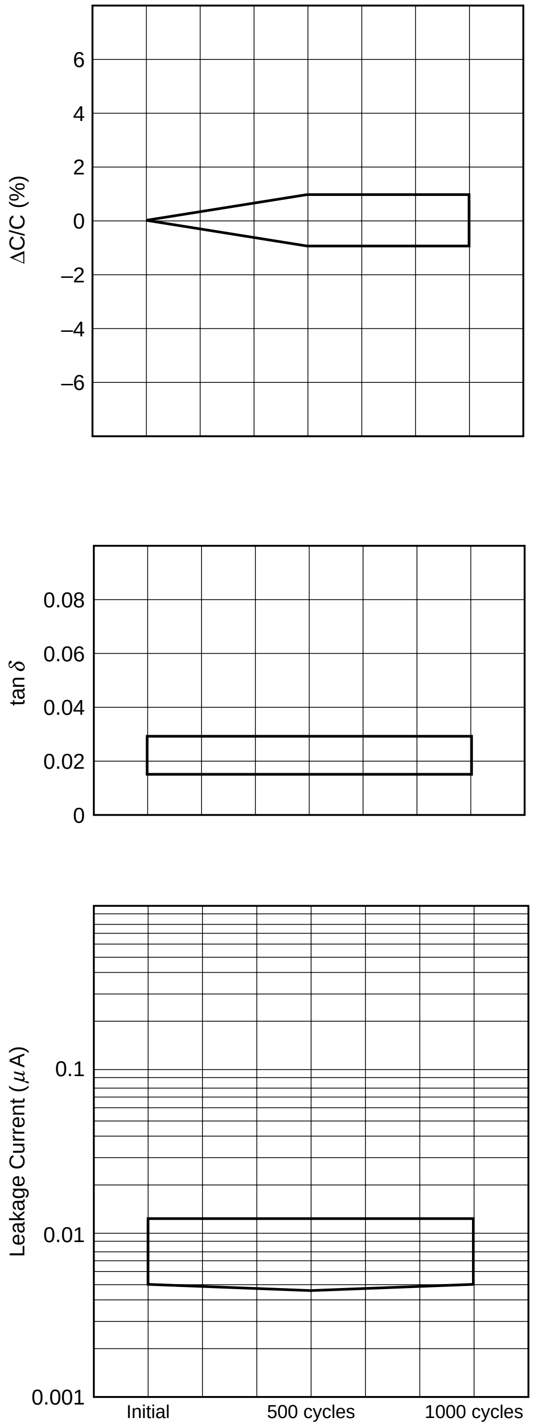
$$U_T = U_R - \frac{U_R - U_C}{40} (T - 85)$$

U_R : Rated Voltage
U_C : Category Voltage at 125˚C

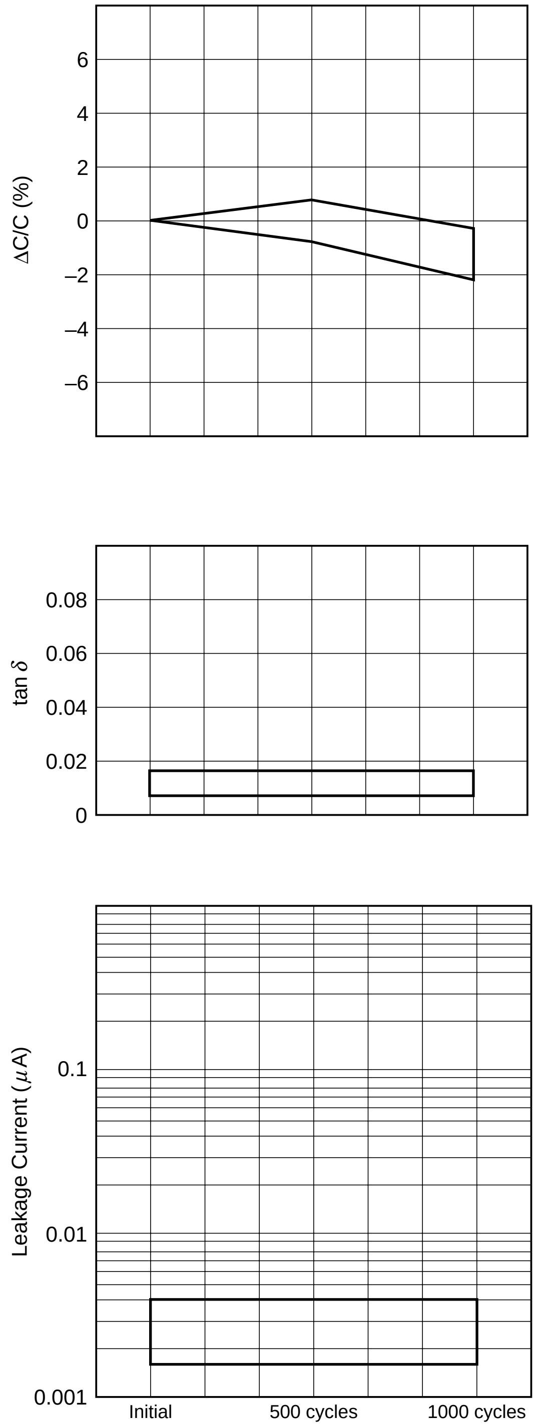
DC Rated Voltage @85°C (125°C) Vdc	Capacitance @20°C, 120 Hz μF	Case Size	Part Number	Leakage Current @20°C μA Max.	tan δ @20°C, 120 Hz % Max.
10 (6.3)	2.2	A	SVHA1A225M	0.5	4
	4.7	B2	SVHB21A475M	0.5	4
	15	C	SVHC1A156M	1.5	6
	33	D2	SVHD21A335M	3.3	6
16 (10)	1	A	SVHA1C105M	0.5	4
	1.5	A	SVHA1C155M	0.5	4
	3.3	B2	SVHB21C335M	0.5	4
	10	C	SVHC1A106M	1.6	6
	22	D2	SVHD21A226M	3.5	6
20 (13)	0.68	A	SVHA1D684M	0.5	4
	2.2	B2	SVHB21D225M	0.5	4
	6.8	C	SVHC1D685M	1.4	6
	15	D2	SVHD21D156M	3.0	6
25 (16)	0.47	A	SVHA1E474M	0.5	4
	1.5	B2	SVHB21E155M	0.5	4
	4.7	C	SVHC1E475M	1.1	4
	10	D2	SVHD21E106M	2.5	6
35 (22)	0.1	A	SVHA1V104M	0.5	4
	0.15	A	SVHA1V154M	0.5	4
	0.22	A	SVHA1V224M	0.5	4
	0.33	A	SVHA1V334M	0.5	4
	0.47	B2	SVHB21V474M	0.5	4
	0.68	B2	SVHB21V684M	0.5	4
	1	B2	SVHB21V105M	0.5	4
	1.5	C	SVHC1V155M	0.5	4
	2.2	C	SVHC1V225M	0.7	4
	3.3	C	SVHC1V335M	1.2	4
	4.7	D2	SVHD21V475M	1.6	4
	6.8	D2	SVHD21V685M	2.3	6

CHARACTERISTICS DATA

Rapid Change of Temperature (–55 to +125˚C)

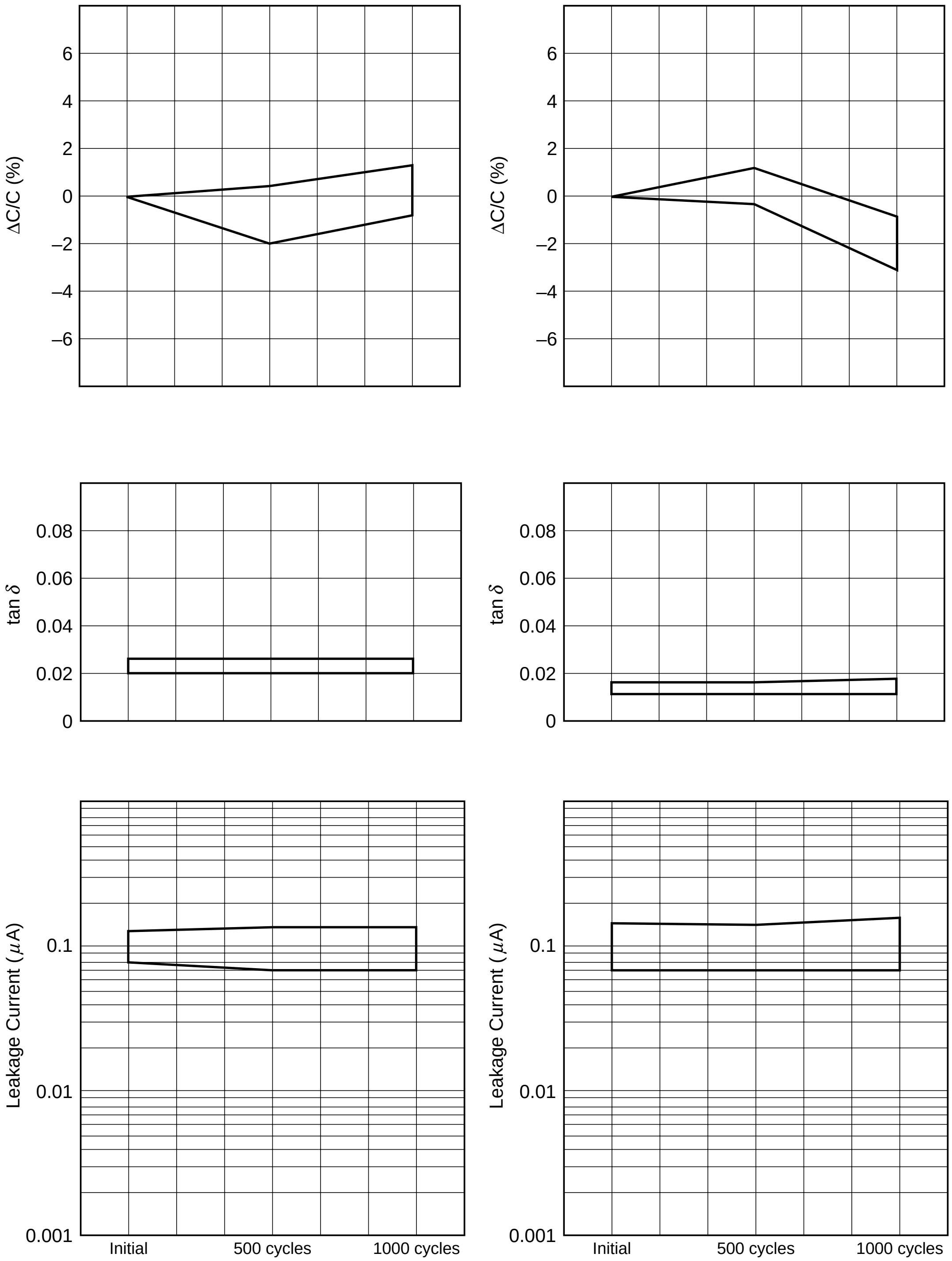


2.2 µF/10 V A Case



0.33 µF/35 V A Case

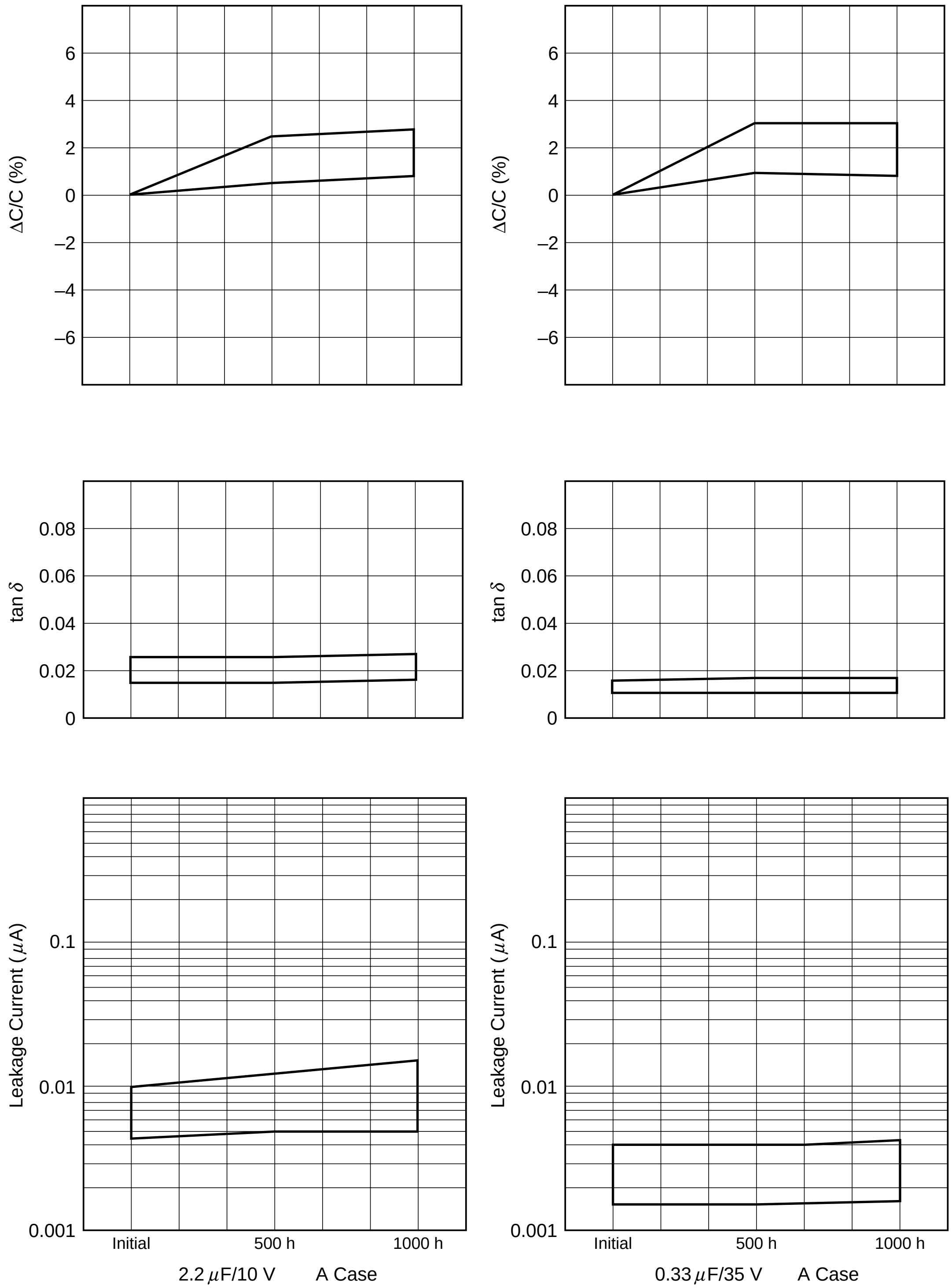
Rapid Change of Temperature (–55 to +125˚C)



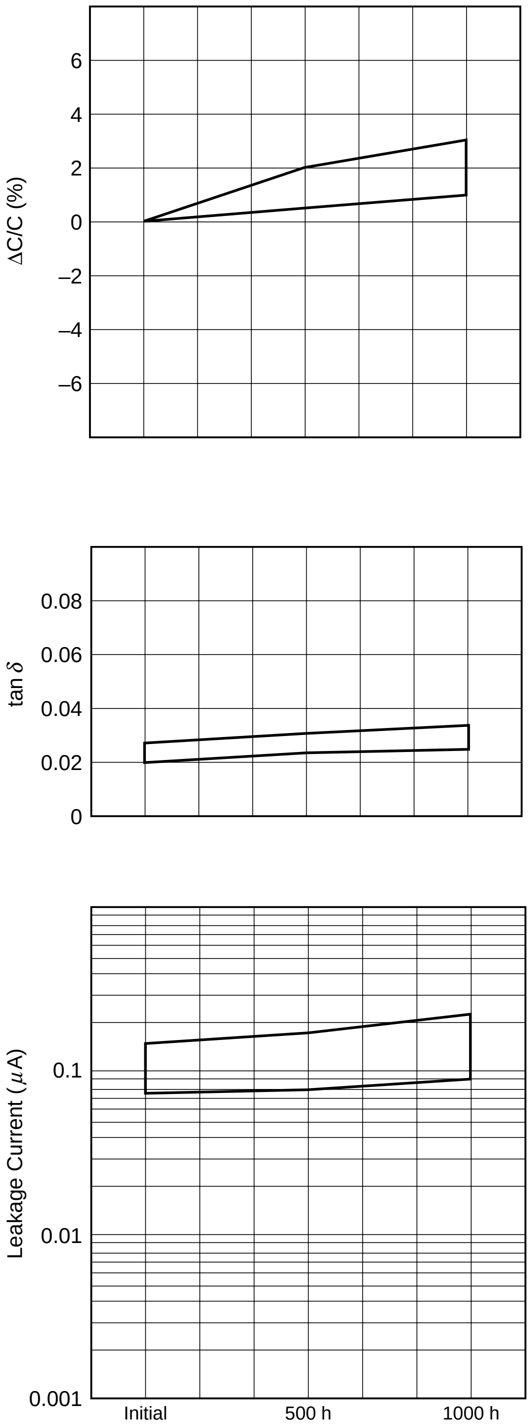
33 µF/10 V D2 Case

6.8 µF/35 V D2 Case

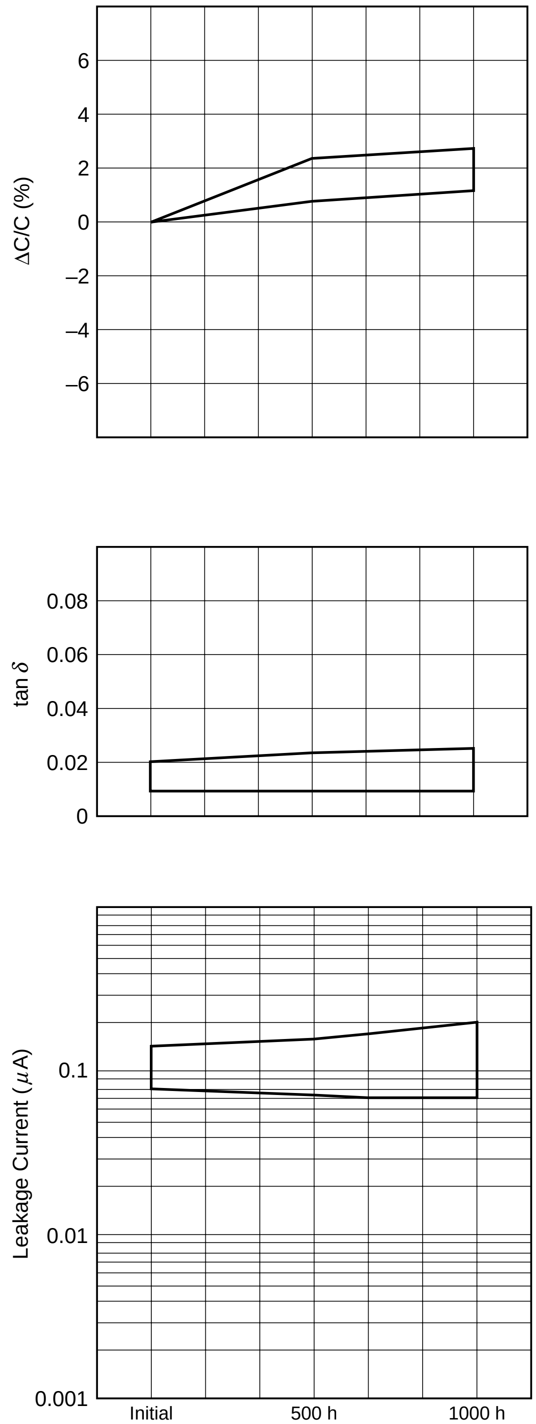
Damp Heat, Steady State (85˚C, 85% RH)



Damp Heat, Steady State (85˚C, 85% RH)

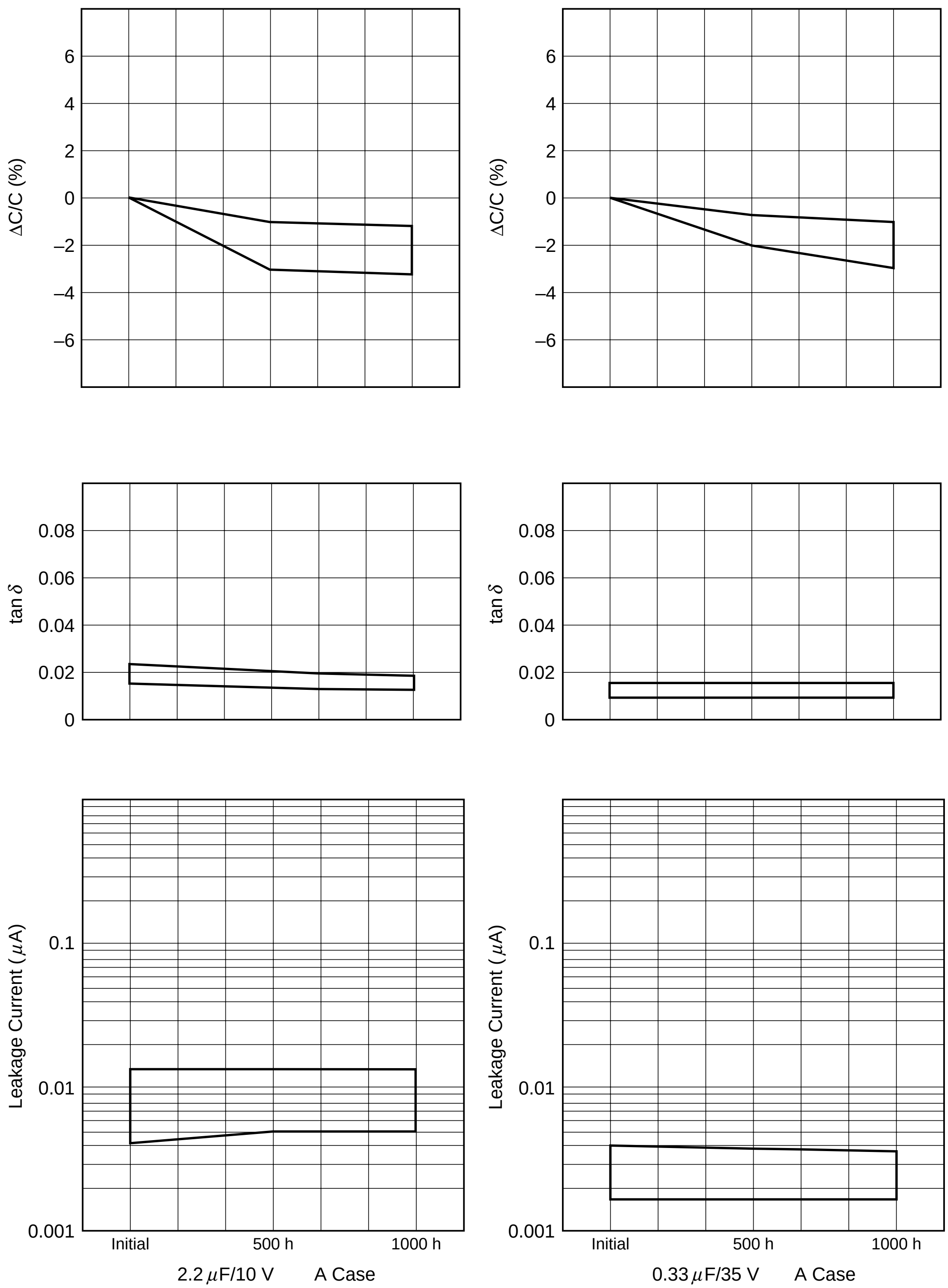


33 μF/10 V D2 Case

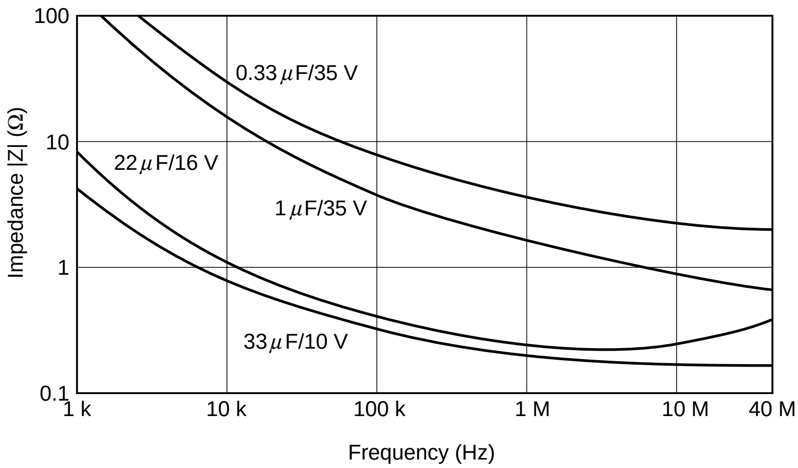


6.8 μF/35 V D2 Case

Endurance (85˚C, Rated Voltage × 1.3 Applied)
(Reference Data)



Impedance – Frequency Characteristics



SVF SERIES

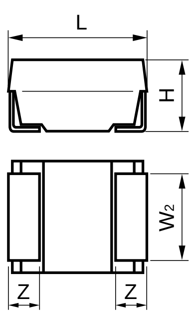
NEC’s SVF series capacitors feature a built-in fuse to minimize circuit damage from over current.

Thers fuse-protected capacitors are suitable for noise absorption applications such as those required for computers, terminals and measuring instruments.

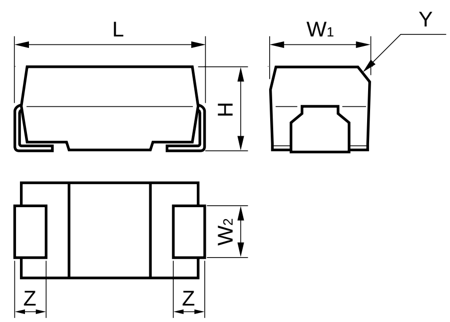
FEATURES

- Built-In Fuse Protection (2A)
- High-Temperature Durability for Either Wave Soldering or Reflow Soldering Applications
- The Same Excellent Performance as NEC’s R Series
- Wide Operating Temperature Range (–55˚C to –125˚C)
- High Reliability (Failure Rate = 1%/1 000 H at 85˚C, DC Rated Voltage Applied)

OUTLINE DRAWINGS AND DIMENSIONS



[B2 Case]

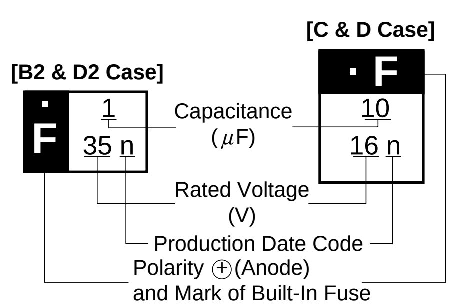


[C, D2 & D Cases]

Unit : mm (inch)

Case Size	EIA Code	L	W_1	W_2	H	Z	Y
B2	3528	3.5±0.2 (0.138±0.008)	2.8±0.2 (0.110±0.008)	2.3±0.1 (0.091±0.004)	1.9±0.2 (0.075±0.008)	0.8±0.3 (0.031±0.012)	—
C	6032	6.0±0.3 (0.236±0.012)	3.2±0.3 (0.126±0.012)	1.8±0.1 (0.071±0.004)	2.5±0.3 (0.098±0.012)	1.3±0.3 (0.051±0.012)	0.4C (0.016)
D2	–	5.8±0.3 (0.228±0.012)	4.6±0.3 (0.181±0.008)	2.4±0.1 (0.094±0.004)	3.2±0.3 (0.126±0.012)	1.3±0.3 (0.051±0.012)	—
D	7343	7.3±0.3 (0.287±0.012)	4.3±0.3 (0.169±0.008)	2.4±0.1 (0.094±0.004)	2.8±0.3 (0.110±0.012)	1.3±0.3 (0.051±0.012)	0.5C (0.020)

MARKING



[Marking of Production Date Code]

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1998	N	P	Q	R	S	T	U	V	W	X	Y	Z
1999	a	b	c	d	e	f	g	h	j	k	l	m
2000	n	p	q	r	s	t	u	v	w	x	y	z
2001	A	B	C	D	E	F	G	H	J	K	L	M

Date code will resume beginning in 2002.

PRODUCT LINE-UP AND CASE SIZE

Capacitance (μF) \ Rated Voltage (V dc)	10	16	20	25	35	50
1.0					B2	C
1.5				B2		
2.2			B2		C	
3.3		B2		C		D2
4.7	B2	C	C		D2, D	
6.8		C		D2, D	D	
10		C	D2, D	D		
15	C, D2	D2	D			
22		D2, D	D			
33	D2, D	D				
47	D					

PART NUMBERING SYSTEM

– Bulk –

SVF B2 1V 105 M

- **M** — Capacitance Tolerance
  M: ±20% K: ±10%
- **105** — Capacitance Code in pF
  First two digits represent significant figures.
  Third digit specifies number of zeros to follow.
- **1V** — DC Rated Voltage
  1A: 10 V 1C: 16 V 1D: 20 V
  1E: 25 V 1V: 35 V 1H: 50 V
- **B2** — Case Size
- **SVF** — SVF Series

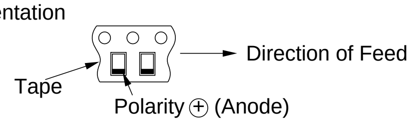
– Tape and Reel –

TE SVFB21V105M 8 R E

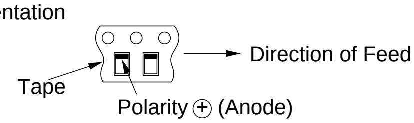
- **SVFB21V105M** — Same as Bulk Part
- **TE** — Tape and Reel
  TE: Reel Diameter 178 mm (7 inch)
  TL: Reel Diameter 330 mm (13 inch)
- **E** — In case of the necessity of the hole in embossement of the carrier tape, "E" is put to end of part number. (Available for 330 mmϕ Reel Only)
- **R** — Packing Orientation (See below)
- **8** — Tape Width
  8 mm for B2 Case
  12 mm for C, D & D2 Cases

– Packing Orientation –

R: Orientation



L: Orientation



PERFORMANCE CHARACTERISTICS

<table>
<tr><th colspan="2">Item</th><th colspan="7">Specification</th><th>Test Method</th></tr>
<tr><td colspan="2">Operating Temperature Range</td><td colspan="7">–55 to +125˚C</td><td></td></tr>
<tr><td colspan="2">Rated Voltage</td><td>10</td><td>16</td><td>20</td><td>25</td><td>35</td><td>50</td><td>Vdc</td><td>Temperature: 85˚C</td></tr>
<tr><td colspan="2">Surge Voltage</td><td>13</td><td>20</td><td>26</td><td>33</td><td>46</td><td>65</td><td>Vdc</td><td>Temperature: 85˚C</td></tr>
<tr><td colspan="2">Category Voltage</td><td>6.3</td><td>10</td><td>13</td><td>16</td><td>22</td><td>32</td><td>Vdc</td><td>Temperature: 125˚C (*1)</td></tr>
<tr><td colspan="2">Capacitance Range</td><td colspan="7">1.0 to 47 μF</td><td rowspan="2">Frequency: 120 Hz</td></tr>
<tr><td colspan="2">Capacitance Tolerance</td><td colspan="7">±20% (±10%)</td></tr>
<tr><td colspan="2">Leakage Current (L.C.)</td><td colspan="7">0.01 CV (μA) or 0.5 μA whichever is greater</td><td>5 min, after rated voltage applied</td></tr>
<tr><td colspan="2">Tangent of Loss Angle (tan δ)</td><td colspan="7">1.0 to 4.7 μF: 0.04 max.
6.8 to 47 μF: 0.04 max.</td><td>Frequency: 120 Hz</td></tr>
<tr><td colspan="2">Surge Voltage Test</td><td colspan="7">ΔC/C : ±5%
tan δ : Initial Requirement
L.C. : Initiail Requirement</td><td>Temperature: 85˚C
Surge Voltage for 30 sec.
Series Resistance: 1 kΩ
Discharge Voltage for 5 min. 30 sec.
1000 cycles</td></tr>
<tr><td rowspan="4">Characteristics at High and Low Temperature</td><td>Temp.</td><td colspan="2">–55˚C</td><td colspan="2">+85˚C</td><td colspan="3">+125˚C</td><td rowspan="4">Step 1: 20˚C
Step 2: –55˚C
Step 3: 20˚C
Step 4: 85˚C
Step 5: 125˚C
Step 6: 20˚C</td></tr>
<tr><td>ΔC/C</td><td colspan="2">0, –12%</td><td colspan="2">+12, 0%</td><td colspan="3">+15, 0%</td></tr>
<tr><td>tan δ</td><td colspan="2">0.1 to 4.7 μF: 0.08 max.
6.8 to 47 μF: 0.10 max.</td><td colspan="2">Initial Requirement</td><td colspan="3">0.1 to 4.7 μF: 0.06 max.
6.8 to 47 μF: 0.08 max.</td></tr>
<tr><td>L.C.</td><td colspan="2">–</td><td colspan="2">0.1 CV or 5 μA whichever is greater</td><td colspan="3">0.125 CV or 6.25 μA whichever is greater</td></tr>
<tr><td colspan="2">Rapid Change of Temperature</td><td colspan="7">ΔC/C : ±5%
tan δ : Initial requirement
L.C. : Initial requirement</td><td>–55 to +125˚C
5 cycles</td></tr>
<tr><td colspan="2">Resistance to Soldering</td><td colspan="7">ΔC/C : ±5%
tan δ : Initial requirement
L.C. : Initial requirement</td><td>Fully immersion to solder,
260˚C, 5 sec.</td></tr>
<tr><td colspan="2">Damp Heat, Steady State</td><td colspan="7">ΔC/C : ±5%
tan δ : Initial Requirement × 1.5
L.C. : Initial Requirement</td><td>Temperature: 40˚C
90 to 95% RH
500 hours</td></tr>
<tr><td colspan="2">Endurance</td><td colspan="7">ΔC/C : ±10%
tan δ : Initial Requirement
L.C. : Initial Requirement × 1.25</td><td>Temperature: 85˚C
Rated Voltage Applied
Temperature: 125˚C
Category Voltage Applied 2000 hours</td></tr>
<tr><td colspan="2">Failure Rate</td><td colspan="7">λ_0 = 1%/1000H</td><td></td></tr>
<tr><td colspan="2">Fuse Blow-out Characteristics</td><td colspan="7">B2: 2A - 5 sec. Max.
C: 2A - 10 sec. Max.
D2, D: 2A - 20 sec. Max.</td><td>Temperature: 25˚C</td></tr>
</table>

LEGEND
CV : Product of capacitance in μF and voltage in V
ΔC/C : Capacitance Change Ratio

*1: Category voltage at 85˚C or more is calculated by following expression.

$$U_T = U_R - \frac{U_R - U_C}{40} (T - 85)$$

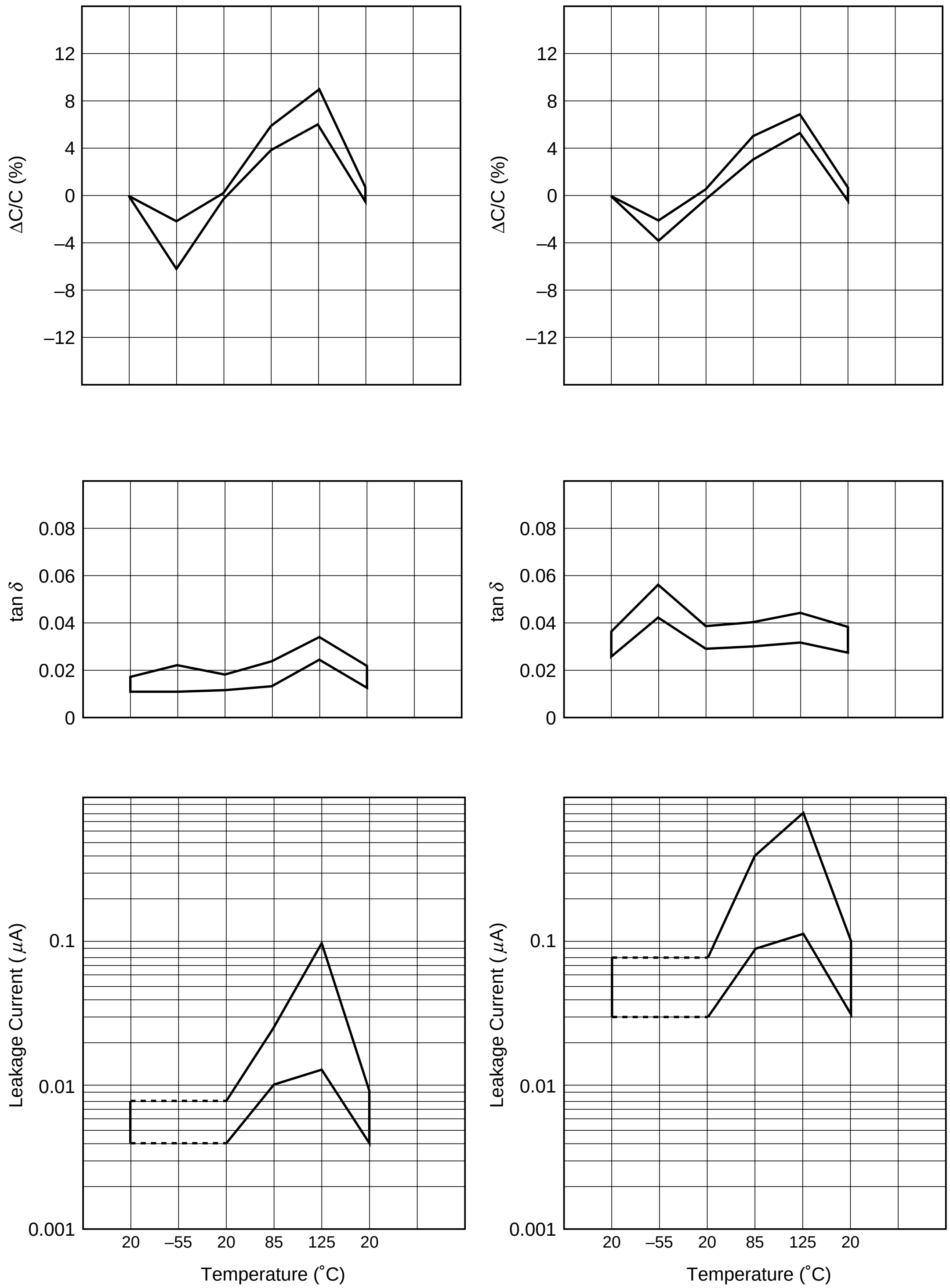
U_R : Rated Voltage
U_C : Category Voltage at 125˚C

RATINGS

DC Rated Voltage @85°C (125°C) Vdc	Capacitance @20°C, 120 Hz μF	Case Size	Part Number	Leakage Current @20°C μA Max.	tan δ @20°C, 120 Hz % Max.
10 (6.3)	4.7	B2	SVFB21A475M	0.5	4
	15	C	SVFC1A156M	1.5	6
	15	D2	SVFD21A156M	1.5	6
	33	D2	SVFD21A336M	3.3	6
	33	D	SVFD1A336M	3.3	6
	47	D	SVFD1A476M	4.7	6
16 (10)	3.3	B2	SVFB21C335M	0.5	4
	4.7	C	SVFC1C475M	0.7	4
	6.8	C	SVFC1C685M	1.0	6
	10	C	SVFC1C106M	1.6	6
	15	D2	SVFD21C156M	2.4	6
	22	D2	SVFD21C226M	3.5	6
	22	D	SVFD1C226M	3.5	6
	33	D	SVFD1C336M	5.2	6
20 (13)	2.2	B2	SVFB21D225M	0.5	4
	4.7	C	SVFC1D475M	0.9	4
	10	D2	SVFD21D106M	2.0	6
	10	D	SVFD1D106M	2.0	6
	15	D	SVFD1D157M	3.0	6
	22	D	SVFD1D226M	4.4	6
25 (16)	1.5	B2	SVFB21E155M	0.5	4
	3.3	C	SVFC1E335M	0.8	4
	6.8	D2	SVFD21E685M	1.7	6
	6.8	D	SVFD1E685M	1.7	6
	10	D	SVFD1E106M	2.5	6
35 (22)	1	B2	SVFB21V105M	0.5	4
	2.2	C	SVFC1V225M	0.7	4
	4.7	D2	SVFD21V475M	1.6	4
	4.7	D	SVFD1V475M	1.6	4
	6.8	D	SVFD1V685M	2.3	6
50 (32)	1	C	SVFC1H105M	0.5	4
	3.3	D2	SVFD21H335M	1.6	4

CHARACTERISTICS DATA

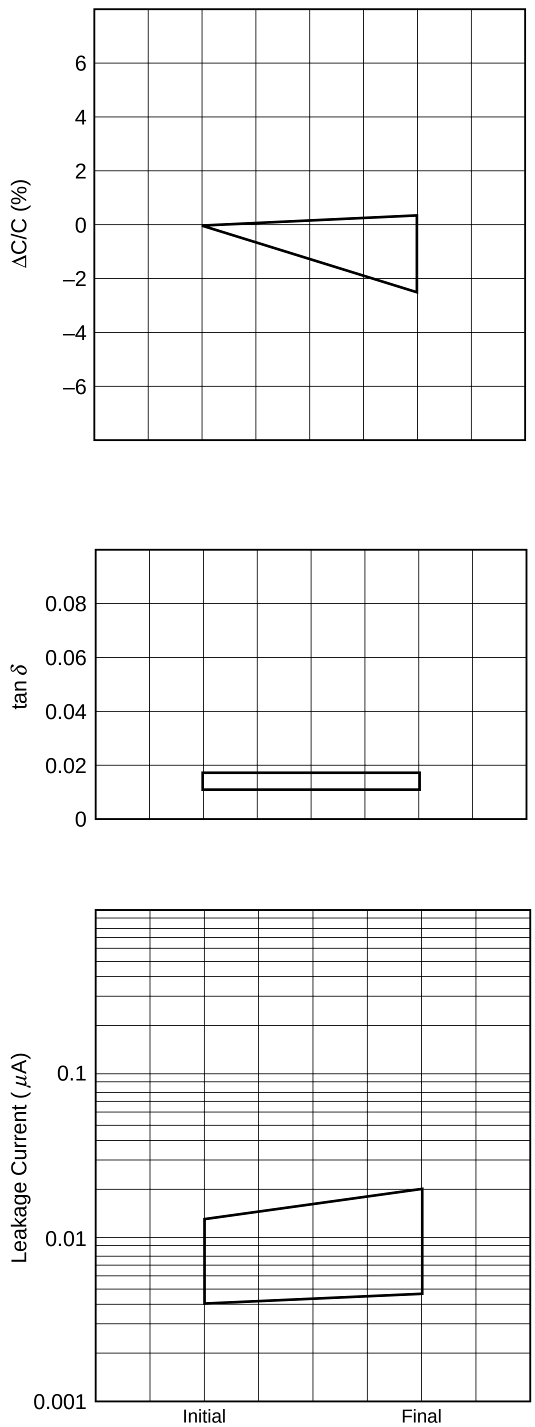
Characteristics at High and Low Temperature



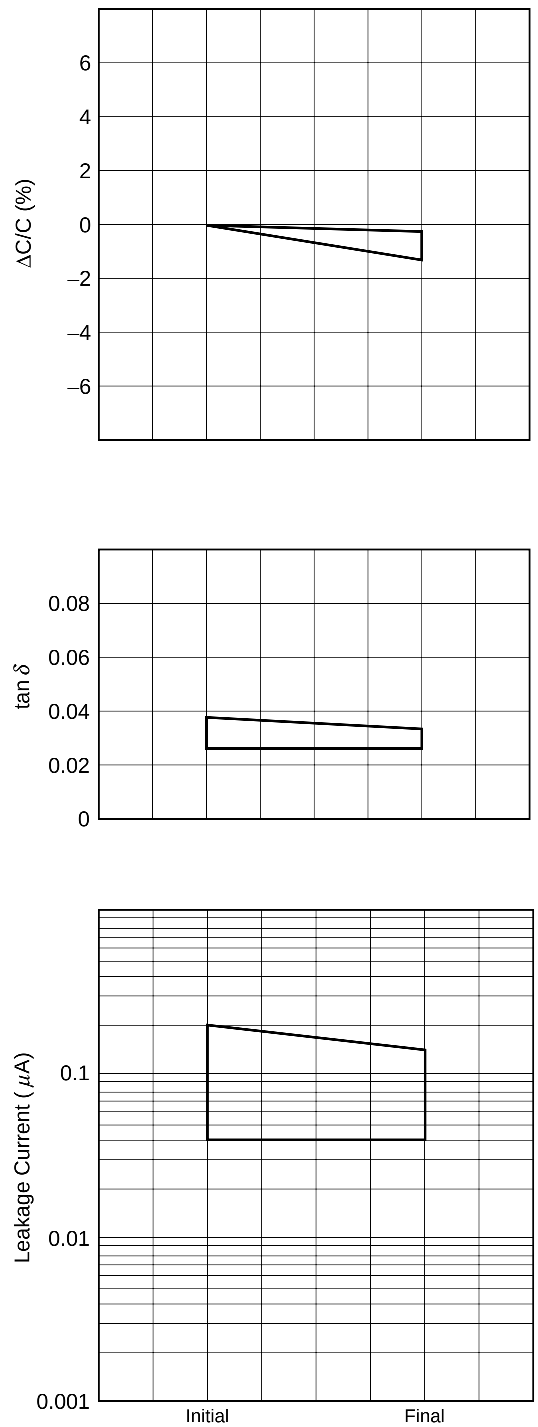
1 µF/35 V B2 Case

33 µF/10 V D Case

Resistance to Soldering Heat (Immersing for 10 sec. at 260˚C)
(Reference Data)

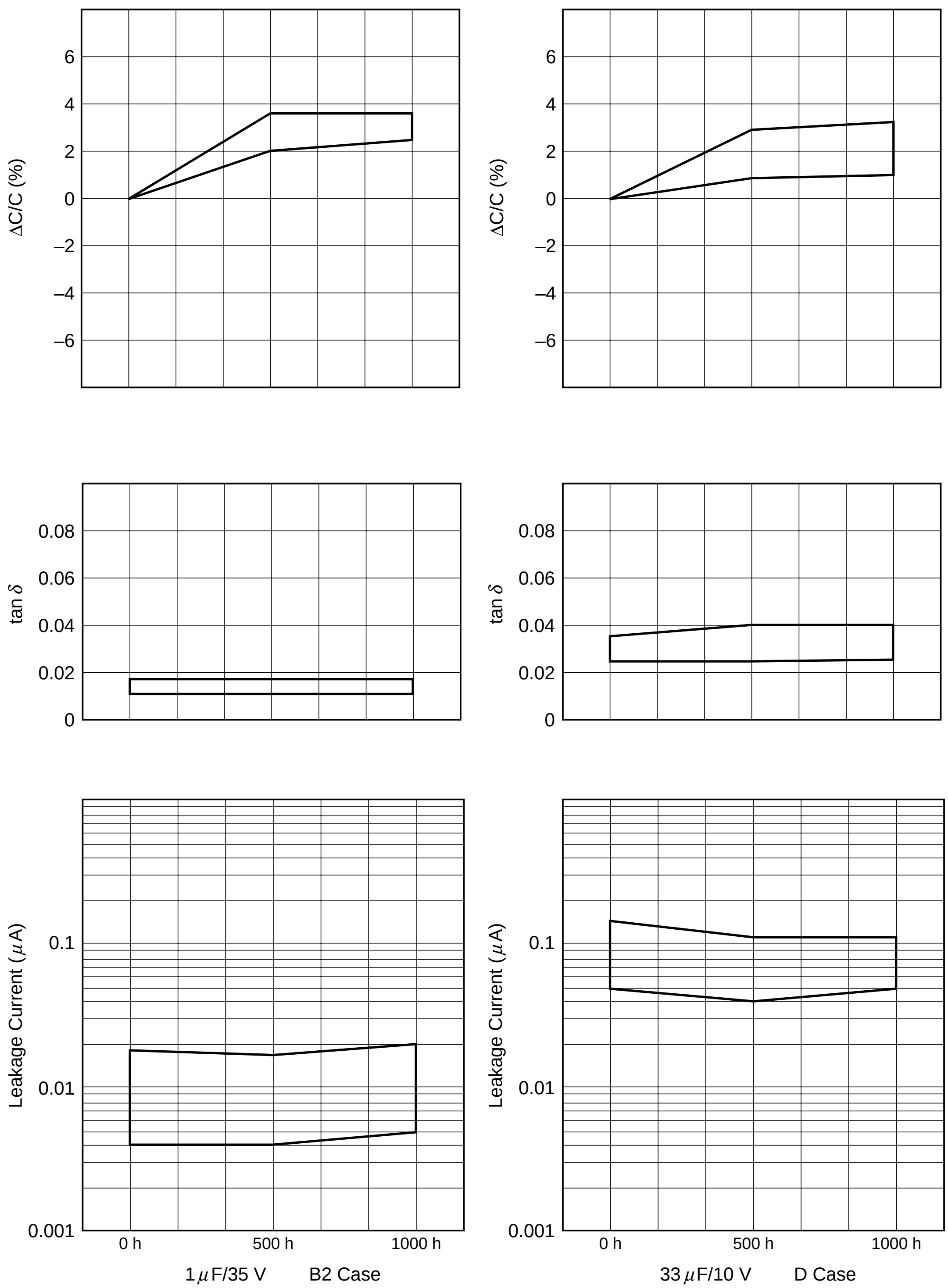


1 μF/35 V B2 Case

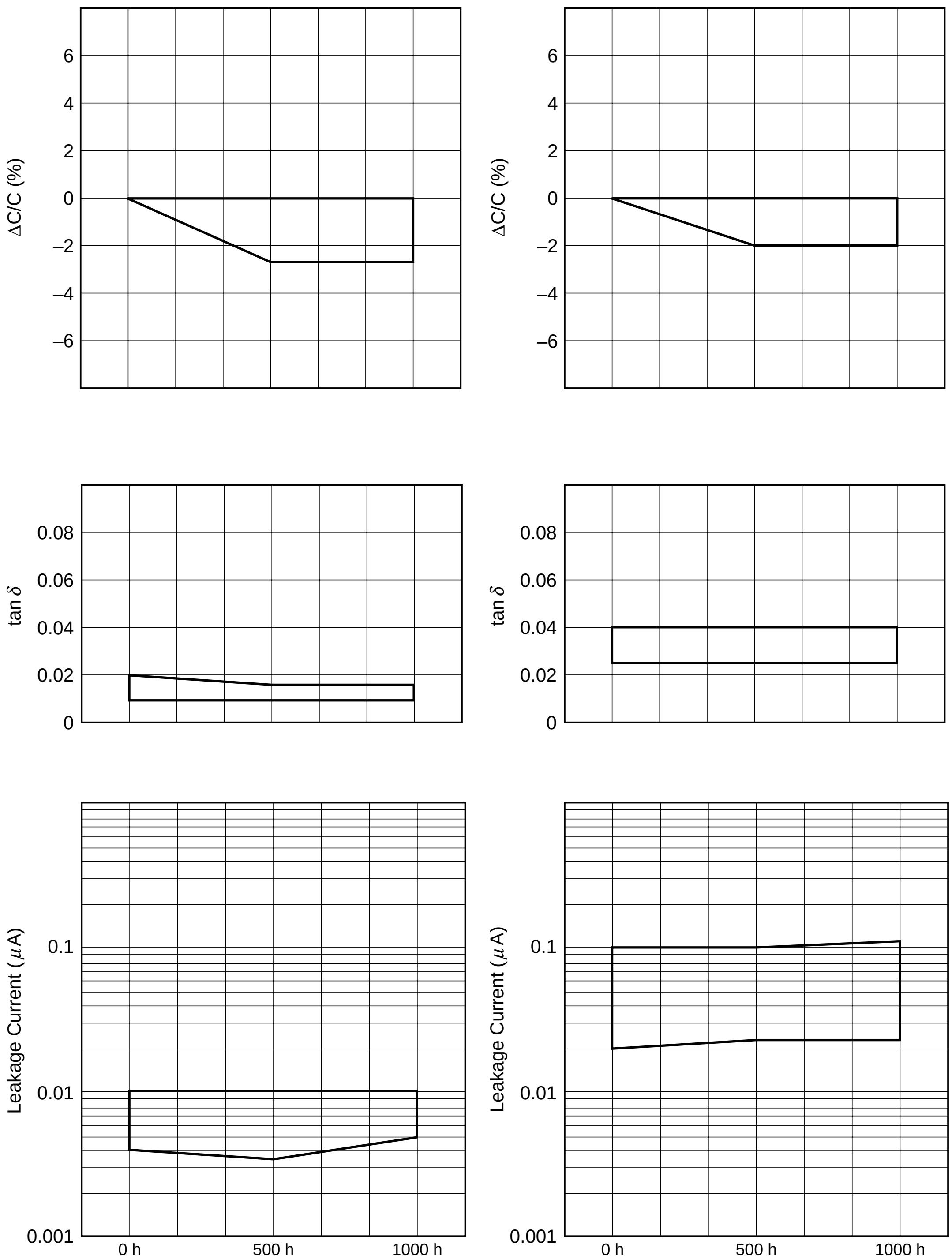


33 μF/10 V D Case

Damp Heat, Steady State (65˚C, 90 to 95% RH)
(Reference Data)

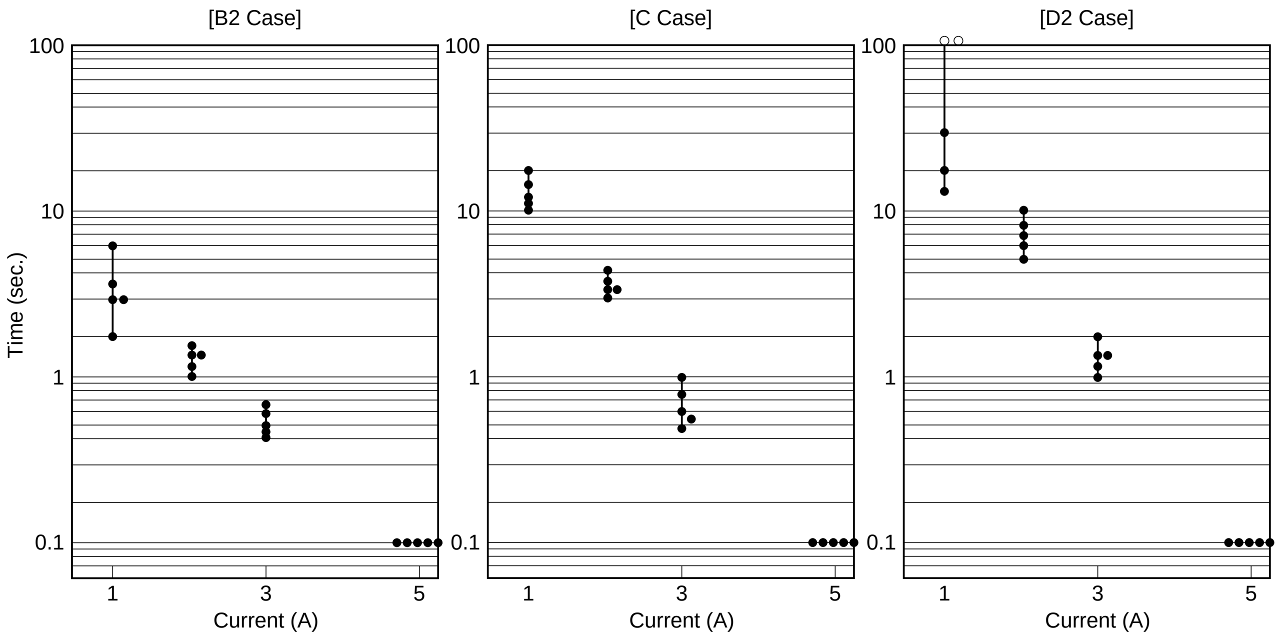


Endurance (85˚C, Rated Voltage × 1.3 Applied)
(Reference Data)



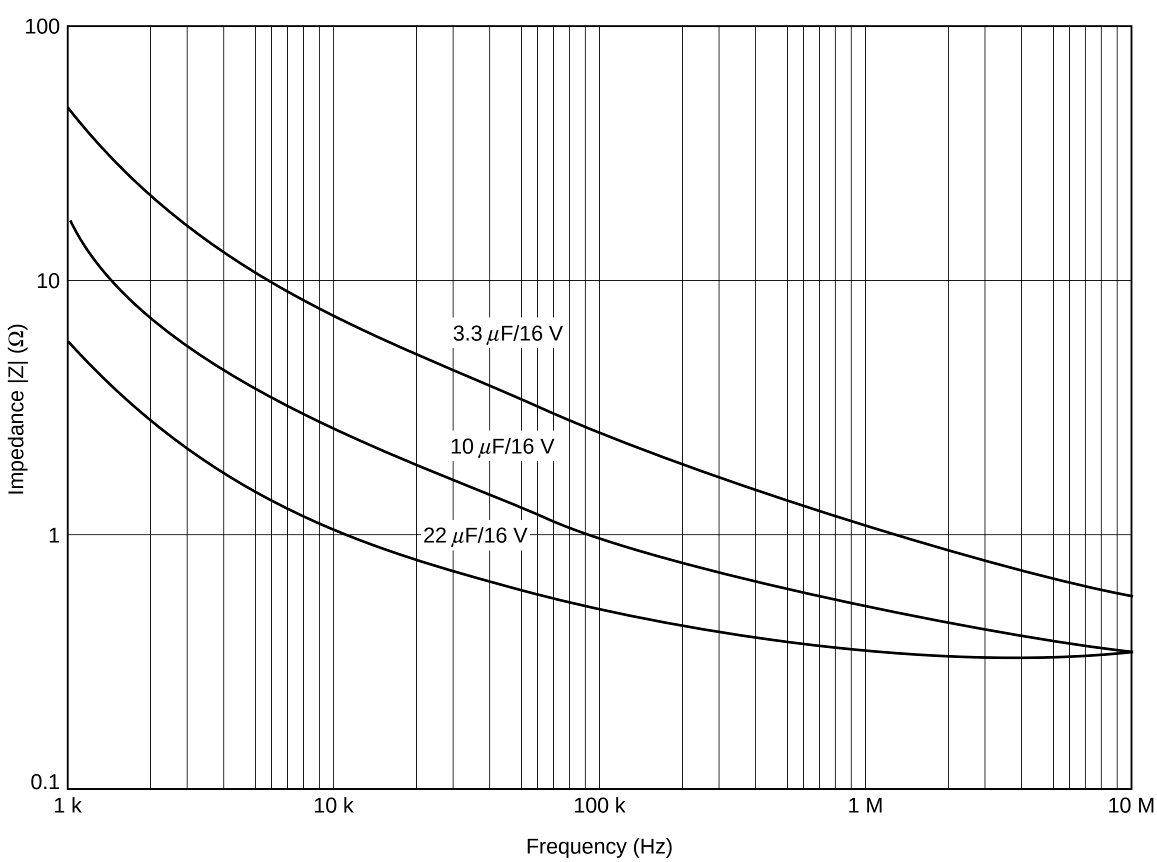
1 μF/35 V B2 Case 33 μF/10 V D Case

Fuse Blow-Out Characteristics



Note: "○" indicates no blow-out.

Impedance – Frequency Characteristics



SVZ SERIES

NEC's SVZ series solid tantalum capacitors have low ESR value.
These capacitors are suitable for noise reduction in a high-frequency application with its low ESR.

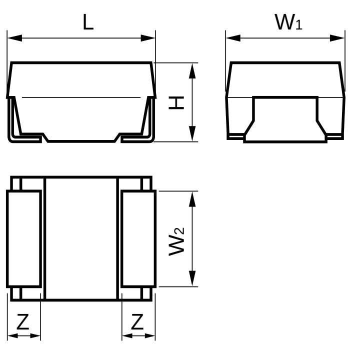
FEATURES

- Low Impedance ESR
- Same case sizes as NEC's R series are available

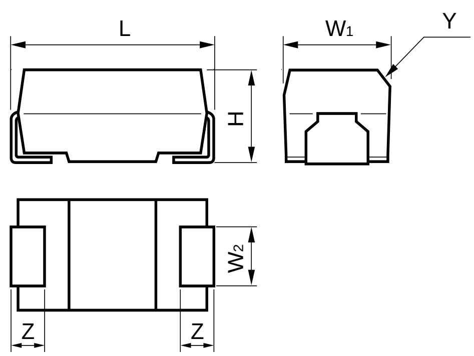
APPLICATIONS

- Decoupling Capacitor of CPU and HDD
- Mobile Telephone
- Modem

OUTLINE DRAWINGS AND DIMENSIONS



[B2 Case]



[C & D Cases]

Unit : mm (inch)

Case Size	EIA Code	L	W_1	W_2	H	Z	Y
B2	3528	3.5±0.2 (0.138±0.008)	2.8±0.2 (0.110±0.008)	2.3±0.1 (0.091±0.004)	1.9±0.2 (0.075±0.008)	0.8±0.3 (0.031±0.012)	—
C	6032	6.0±0.3 (0.236±0.012)	3.2±0.3 (0.126±0.012)	2.2±0.1 (0.087±0.004)	2.5±0.3 (0.098±0.012)	1.3±0.3 (0.051±0.012)	0.4C (0.016)
D	7343	7.3±0.3 (0.287±0.012)	4.3±0.3 (0.169±0.012)	2.4±0.1 (0.094±0.004)	2.8±0.3 (0.110±0.012)	1.3±0.3 (0.051±0.012)	0.5C (0.020)

PERFORMANCE CHARACTERISTICS

Item	Specification				Test Method
Operating Temperature Range	–55 to +125˚C				
Rated Voltage	4	6.3	10	Vdc	Temperature: 85˚C
Surge Voltage	5.2	8	13	Vdc	Temperature: 85˚C
Category Voltage	2.5	4	6.3	Vdc	Temperature: 125˚C (*1)
Capacitance Range	10 to 330 μF				Frequency: 120 Hz
Capacitance Tolerance	±20%				
Leakage Current (L.C.)	0.01 CV (μA) or 0.5 μA whichever is greater				5 min, after rated voltage applied
Tangent of Loss Angle (tan δ)	0.08 max. (*2)				Frequency: 120 Hz
Equivalent Series Resistance (ESR)	Refer to standard ratings				Frequency: 100 Hz
Surge Voltage Test	ΔC/C : ±5% (*3) tan δ : Initial Requirement L.C. : Initiail Requirement				Temperature: 85˚C Surge Voltage for 30 sec. Series Resistance: 1 kΩ Discharge Voltage for 5 min. 30 sec. 1000 cycles
Characteristics at High and Low Temperature	Temp.	–55˚C	+85˚C	+125˚C	Step 1: 20˚C Step 2: –55˚C Step 3: 20˚C Step 4: 85˚C Step 5: 125˚C Step 6: 20˚C
	ΔC/C	0, –12%	+12, 0%	+15, 0%	
	tan δ	0.12 max. (*4)	Initial Requirement	0.10 max. (*5) Requirement	
	L.C.	–	0.1 CV or 5 μA whichever is greater	0.125 CV or 6.25 μA whichever is greater	
Rapid Change of Temperature	ΔC/C : ±5% (*3) tan δ : Initial Requirement L.C. : Initial Requirement				–55 to +125˚C 5 cycles
Resistance to Soldering Heat	ΔC/C : ±5% (*3) tan δ : Initial Requirement L.C. : Initial Requirement				Fully immersion to solder, 260˚C, 5 sec.
Damp Heat, Steady State	ΔC/C : ±5% (*3) tan δ : Initial Requirement × 1.5 L.C. : Initial Requirement				Temperature: 40˚C 90 to 95% RH 500 hours
Endurance	ΔC/C : ±10% (*3) tan δ : Initial Requirement L.C. : Initial Requirement × 1.25				Temperature: 85˚C Rated Voltage Applied Temperature: 125˚C Category Voltage Applied 2000 hours
Failure Rate	λ_0 = 1%/1000H				

LEGEND
CV : Product of capacitance in μF and voltage in V
ΔC/C : Capacitance Change Ratio

*1: Category voltage at 85˚C or more is calculated by following expression.

$$U_T = U_R - \frac{U_R - U_C}{40}(T - 85)$$

U_R : Rated Voltage
U_C : Category Voltage at 125˚C

*2: tan δ of the specific products of SVZ series is shown in the following table

Product	tan δ
D case: 10 V/150 μF	0.10 max.
D case: 6.3V/220 μF	0.12 max.
D case: 4 V/330 μF	0.14 max.

*3: The specific products of SVZ series in the following table are applied to Capacitance change of ±12%

Case Size	Product
D	4 V/330 μF, 6.3 V/220 μF, 10 V/150 μF

*4: tan δ of the specific products of SVZ series is shown in the following table

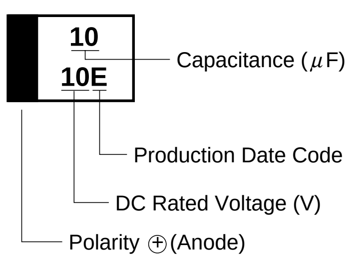
Product	tan δ
D case : 4 V/330 μF, 6.3 V/220 μF, 10 V/150 μF	0.18 max.

*5: tan δ of the specific products of SVZ series is shown in the following table

Product	tan δ
D case : 10 V/150 μF	0.12 max.
D case : 6.3 V/220 μF	0.14 max.
D case : 4 V/330 μF	0.16 max.

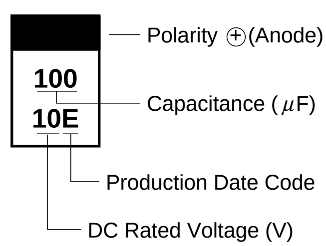
MARKING

10 μF 10 V



[B2 Case]

100 μF 10 V



[C & D Cases]

[Marking of Production Date Code]

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1998	N	P	Q	R	S	T	U	V	W	X	Y	Z
1999	a	b	c	d	e	f	g	h	j	k	l	m
2000	n	p	q	r	s	t	u	v	w	x	y	z
2001	A	B	C	D	E	F	G	H	J	K	L	M

Date code will resume beginning in 2002.

PRODUCT LINE-UP AND CASE SIZE

Capacitance (μF) \ Rated Voltage (V dc)	4	6.3	10
10			B2
15			
22		B2	C
33			C
47			C
68			
100			D
150		D	D
220	D	D	
330	D		

PART NUMBERING SYSTEM

– Bulk –

SVZ D 1A 107 M

- **M** — Capacitance Tolerance (±20%)
- **107** — Capacitance Code in pF
  First two digits represent significant figures.
  Third digit specifies number of zeros to follow.
- **1A** — DC Rated Voltage
  0G: 4 V 0J: 6.3 V 1A: 10 V
- **D** — Case Size
- **SVZ** — SVZ Series

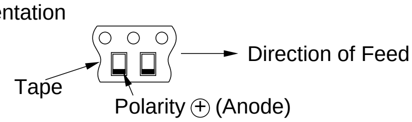
– Tape and Reel –

TE SVZD1A107M 12 R E

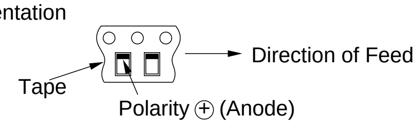
- **SVZD1A107M** — Same as Bulk Part
- **TE** — Tape and Reel
  TE: Reel Diameter 178 mm (7 inch)
  TL: Reel Diameter 330 mm (13 inch)
- **E** — In case of the necessity of the hole in embossment of the carrier tape, "E" is put to end of part number. (Available for 330 mm ϕ Reel only)
- **R** — Packing Orientation (See below)
- **12** — Tape Width
  8 mm for B2 Case
  12 mm for C & D Cases

– Packing Orientation –

R: Orientation



L: Orientation

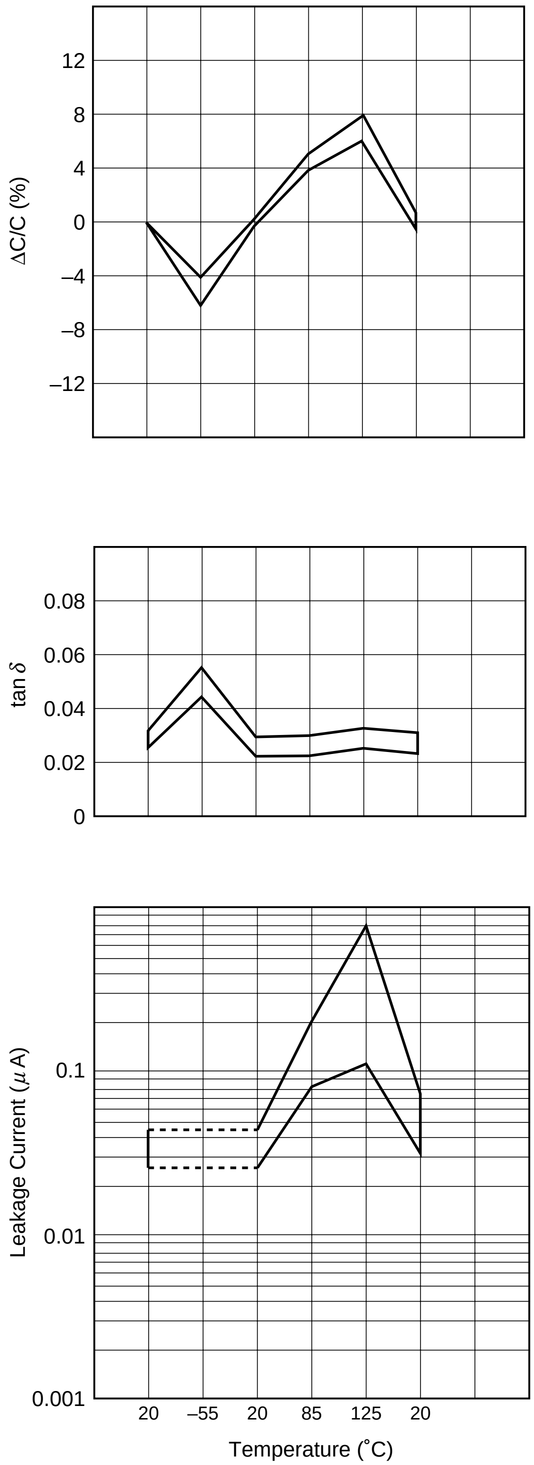


RATINGS

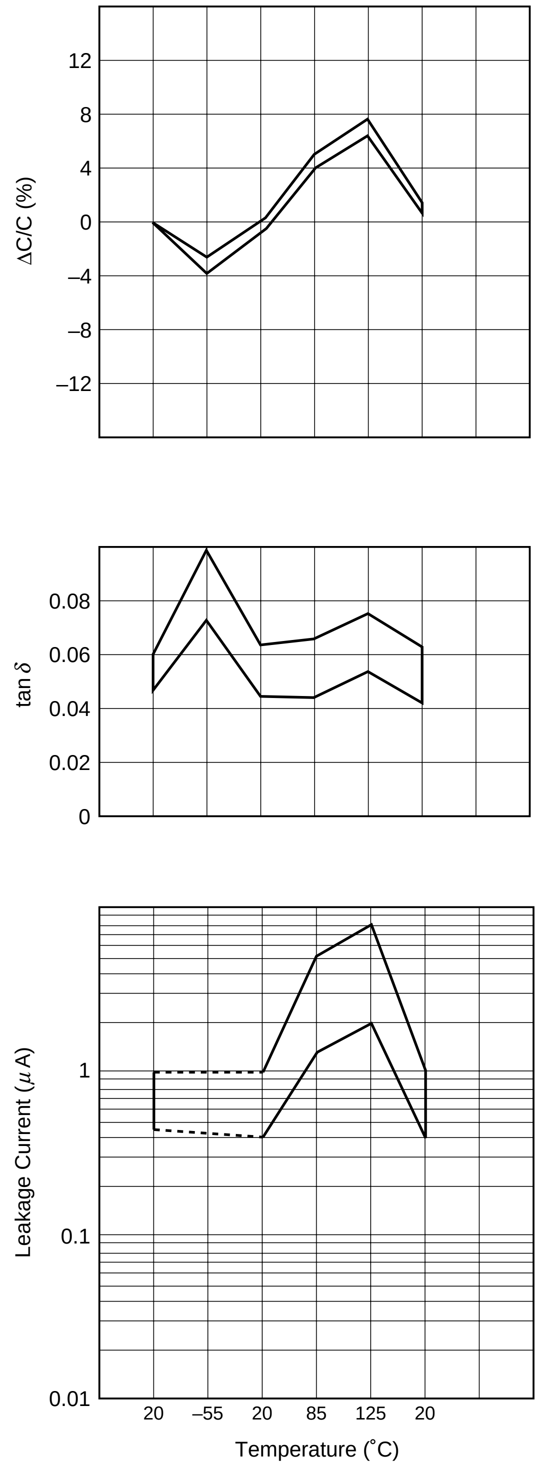
DC Rated Voltage @85°C (125°C) Vdc	Capacitance @20°C, 120 Hz μF	Case Size	Part Number	Leakage Current @20°C μA Max.	tan δ @20°C, 120 Hz % Max.	ESR @20°C, 100 kHz Ω Max.
4 (2.5)	220	D	SVZD0G227M	8.8	8	100
	330	D	SVZD0G337M	13.2	14	100
6.3 (4)	22	B2	SVZB20J226M	1.3	8	800
	150	D	SVZD0J157M	9.4	8	100
	220	D	SVZD0J227M	13.8	12	100
10 (6.3)	10	B2	SVZB21A106M	1.0	8	900
	22	C	SVZC1A226M	2.2	8	500
	33	C	SVZC1A336M	3.3	8	400
	47	C	SVZC1A476M	4.7	8	300
	100	D	SVZD1A107M	10.0	8	100
	150	D	SVZD1A157M	15.0	10	100

CHARACTERISTICS DATA

Characteristics at High and Low Temperature

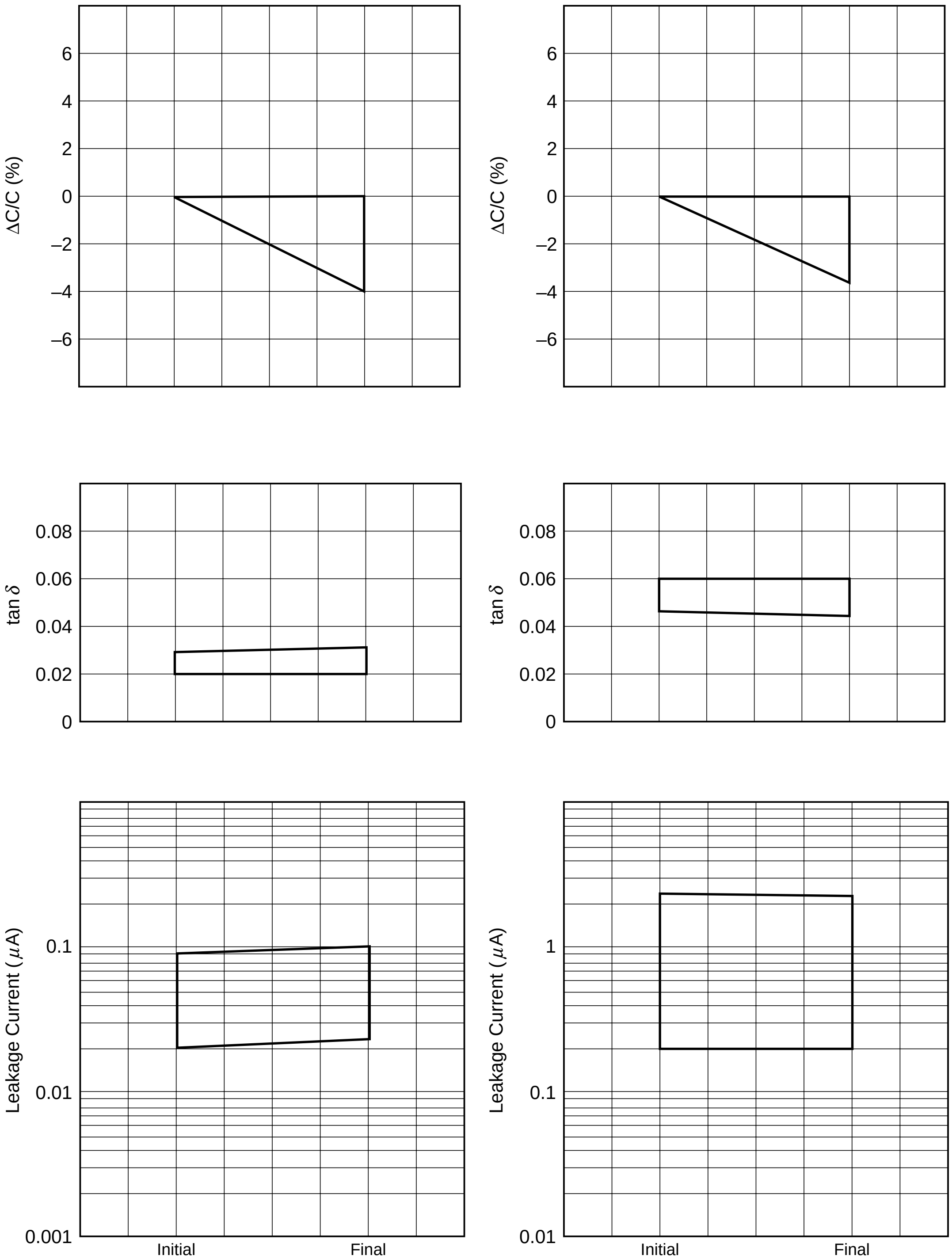


22 μF/6.3 V B2 Case



100 μF/10 V D Case

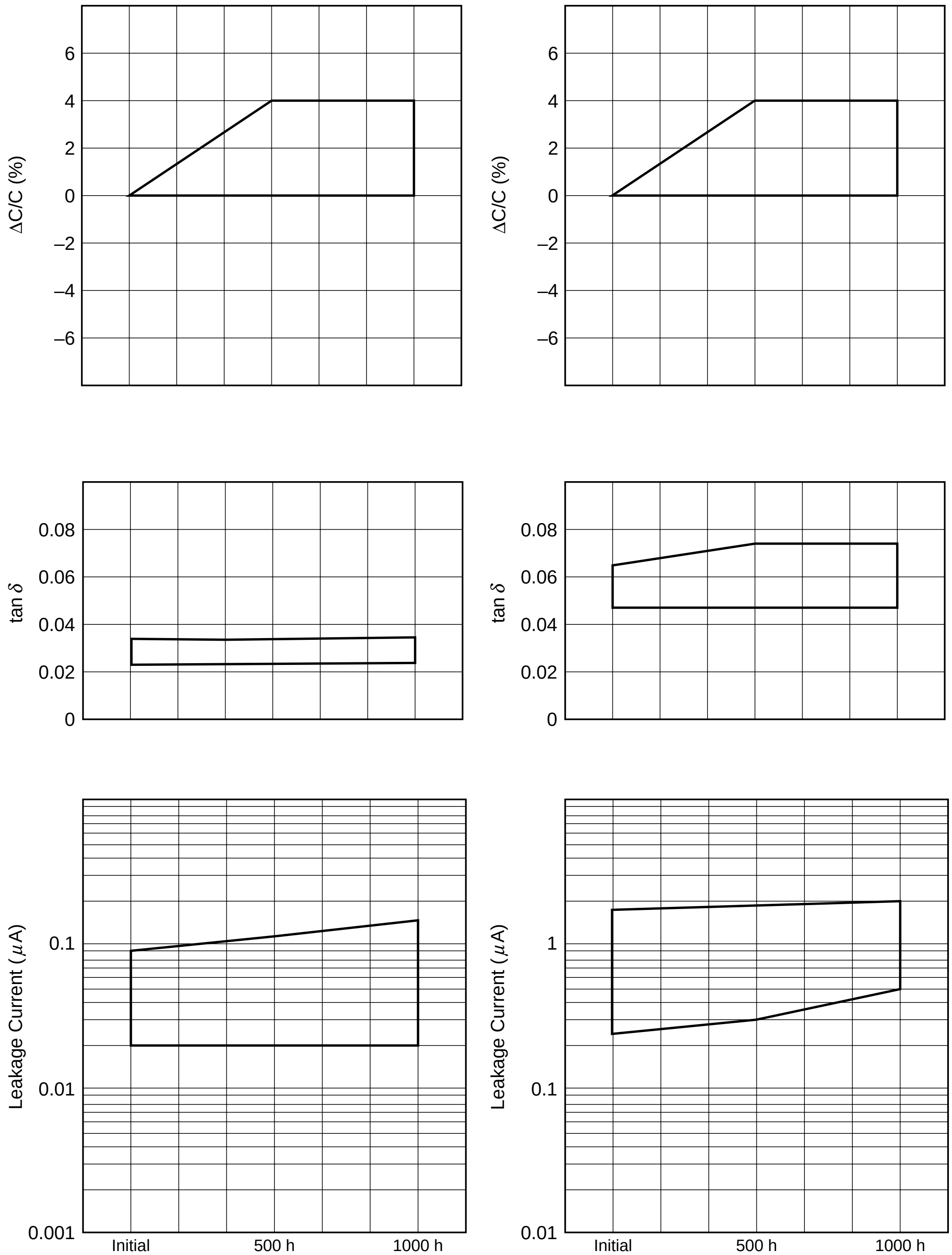
Resistance to Soldering Heat (Immersing for 10 sec. at 260˚C)



22 µF/6.3 V B2 Case

100 µF/10 V D Case

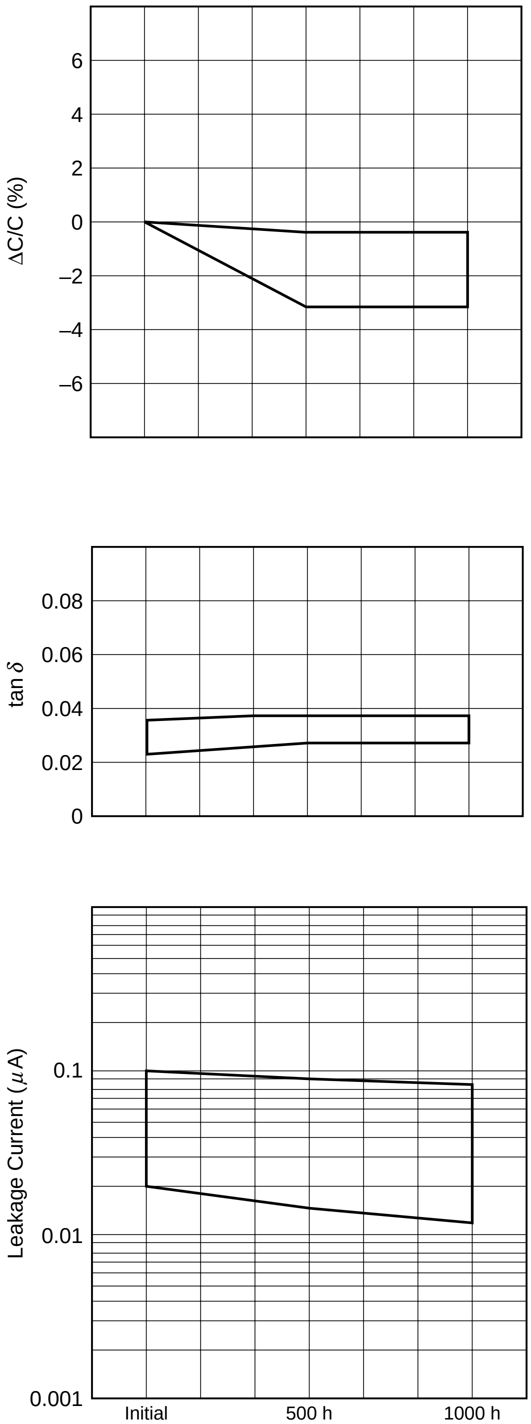
Damp Heat, Steady State (65˚C, 90 to 95% RH)



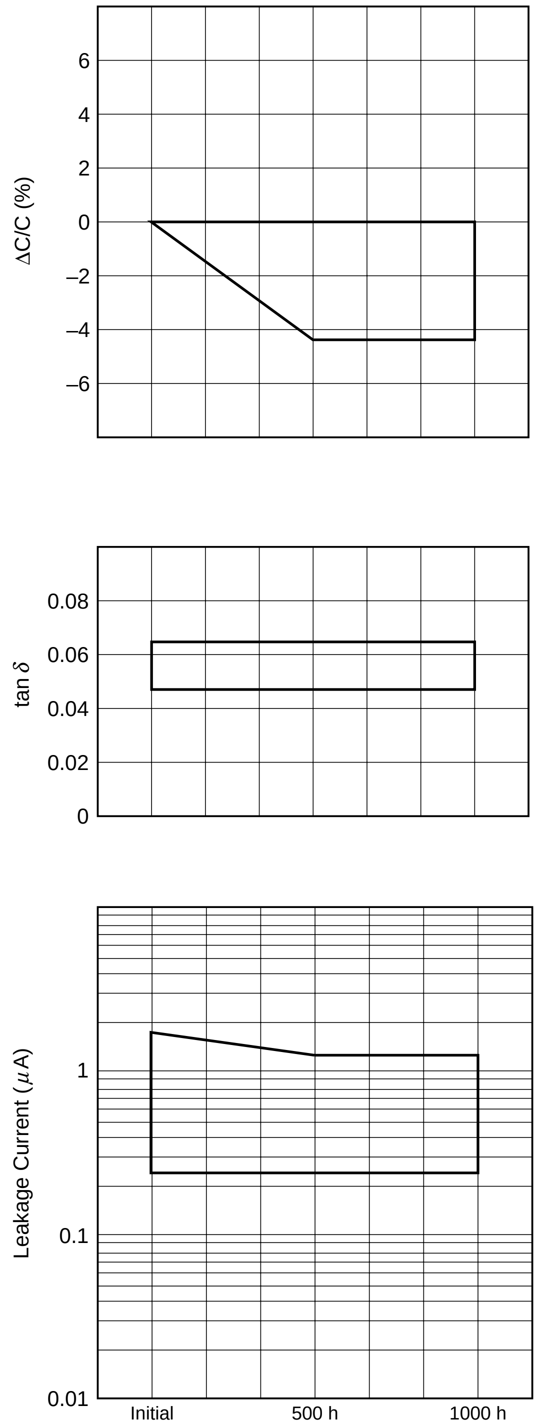
22 μF/6.3 V B2 Case

100 μF/10 V D Case

Endurance (85˚C Rated Voltage × 1.3 Applied)

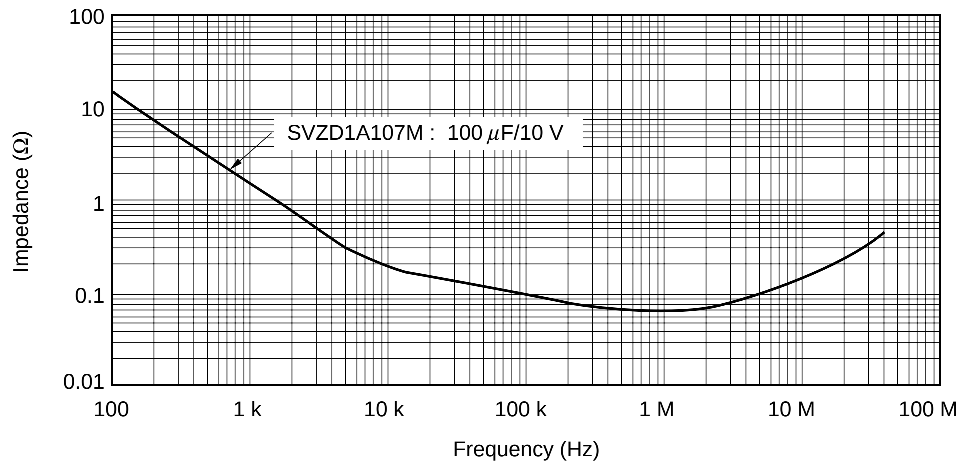


22 μF/6.3 V B2 Case

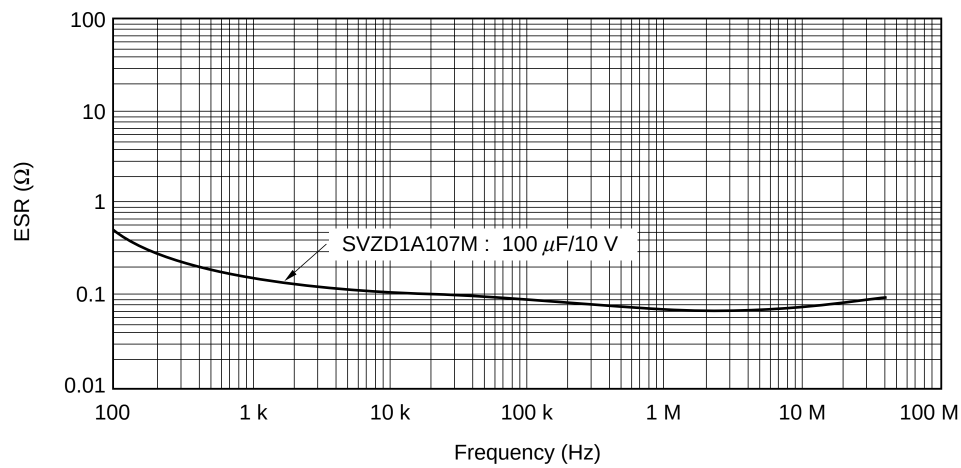


100 μF/10 V D Case

Impedance – Frequency Characteristics

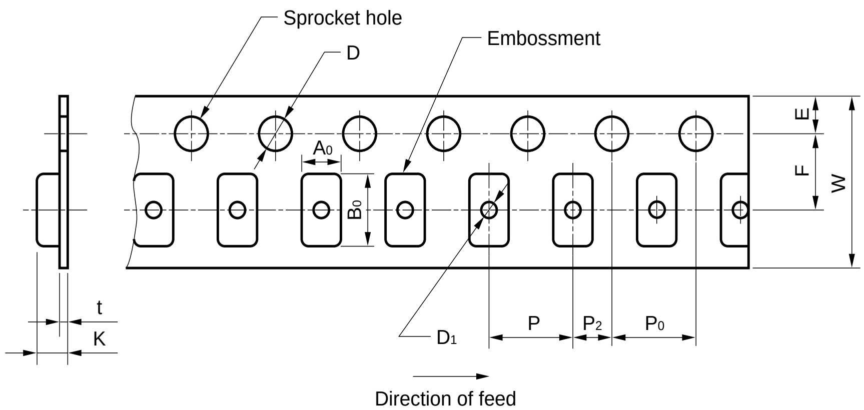


ESR – Frequency Characteristics



• TAPE AND REEL SPECIFICATIONS

Carrier Tape

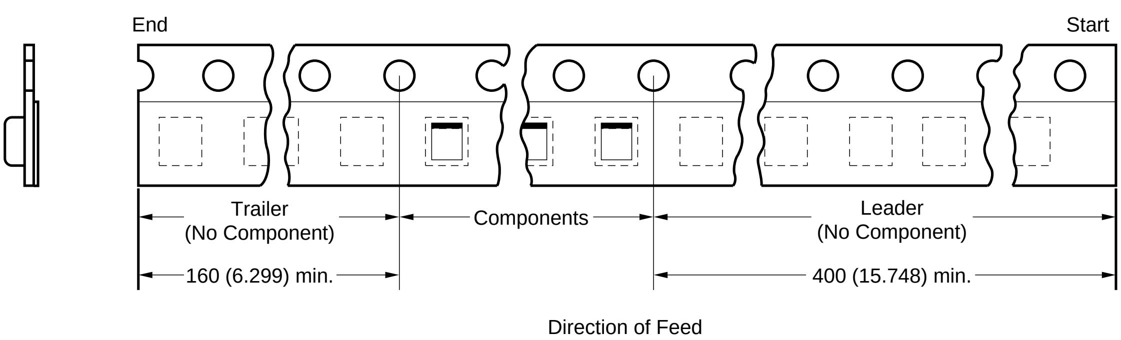


Case Code	EIA Code	W±0.3 (±0.012)	F±0.05 (±0.002)	E±0.1 (±0.004)	P±0.1 (±0.004)	P_2±0.05 (±0.002)	P_0±0.1 (±0.004)	$D_0{}^{+0.1}_{0}$ $\left({}^{+0.004}_{0}\right)$	D_1 Min.(*)	t	A_0±0.2 (±0.008)	B_0±0.2 (±0.008)	K±0.2 (±0.008)
P	2012										1.4 (0.055)	2.2 (0.087)	1.4 (0.055)
A2	3216L										1.9 (0.075)	3.5 (0.138)	
A	3216	8 (0.315)	3.5 (0.138)		4 (0.157)				ϕ1.0 (0.039)	0.2 (0.008)			1.9 (0.075)
B3	3528L										3.2 (0.126)	3.8 (0.150)	1.4 (0.055)
B2	3528			1.75 (0.069)		2 (0.079)	4 (0.157)	ϕ1.5 (0.059)			3.3 (0.130)	3.8 (0.150)	2.1 (0.083)
B	-									0.3 (0.012)	3.1 (0.122)	5.1 (0.201)	2.6 (0.102)
C	6032	12 (0.472)	5.5 (0.217)		8 (0.315)				ϕ1.5 (0.059)		3.7 (0.146)	6.4 (0.252)	3.0 (0.118)
D2	-									0.4 (0.016)	5.1 (0.201)	6.2 (0.244)	3.6 (0.142)
D	7343									0.3 (0.012)	4.8 (0.189)	7.7 (0.303)	3.3 (0.130)

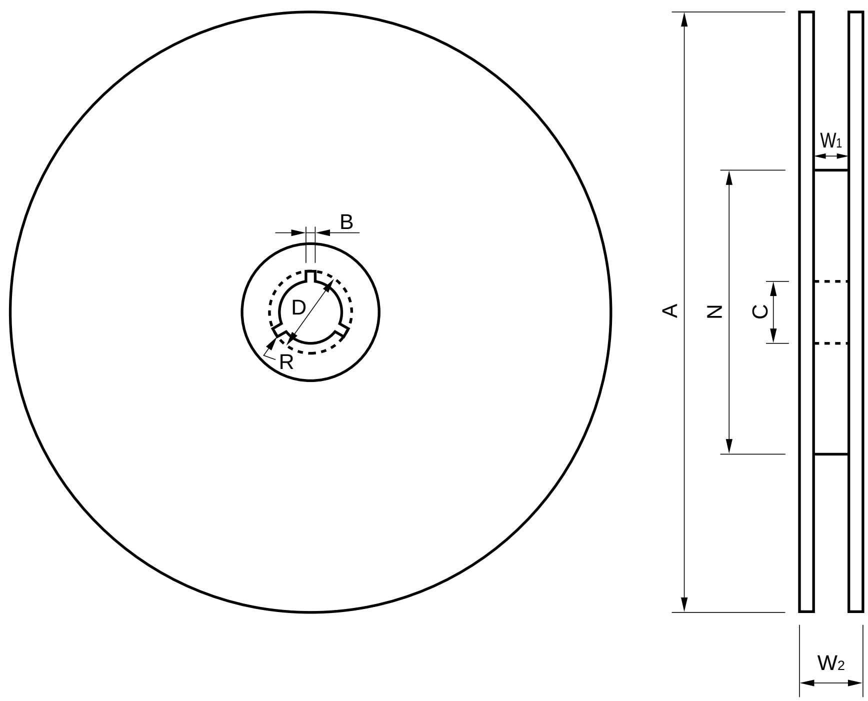
(*): ϕ 330 only

Leader and Trailer

Unit: mm (inch)



Reel



Unit: mm (inch)

Tape Width	A±0.2 (±0.079)	N Min.	C±0.5 (±0.020)	D±0.5 (±0.020)	B±0.5 (±0.020)	W_1	W_2 Max.	R
8 (0.315)	ϕ178 (7)	ϕ20 (1.969)	ϕ13 (0.512)	ϕ21 (0.827)	2 (0.079)	10±1.0 (0.394±0.039)	14.5 (0.571)	1 (0.039)
12 (0.472)						14.5±1.0 (0.571±0.039)	18.5 (0.728)	
8 (0.315)	ϕ330 (13)	ϕ80 (3.150)	ϕ13 (0.512)	ϕ21 (0.827)	2 (0.079)	9.5±0.5 (0.374±0.020)	14.5 (0.571)	1 (0.039)
12 (0.472)						13.5±0.50 (0.531±0.020)	18.5 (0.728)	

[QUANTITY PER REEL]

Case Size	ϕ178	ϕ330
P	3,000	-
A2	3,000	10,000
A	2,000	9,000
B3	3,000	10,000
B2	2,000	5,000
B	1,500	5,000
C, D2, D	500	2,500

Notes on Correct Use

1. Circuit Design

(1) Expecting Reliability

The reliability of the solid tantalum capacitor is heavily influenced by environmental conditions such as temperature, humidity, shock, vibration, mechanical stresses, and electric stresses including applied voltage, current, ripple current, transient current and voltage, and frequency. When using solid tantalum capacitors, therefore, provide enough margin to theses conditions, so that the reliability of the capacitors is maintained.

Voltage and temperature are important parameters when estimating the reliability (field failure rate).

The field failure rate of a solid tantalum capacitor can be calculated by the following expression if emphasis is placed only on the voltage and temperature:

$$\lambda = \lambda_0 \, (V/V_0)^3 \times 2^{(T-T_0)/10}$$

where,

λ : estimated failure rate in actual working condition temperature: T, voltage: V

λ_0 : failure rate under rated load (See table below.) temperature: T_0, voltage: V_0

Failure Rate

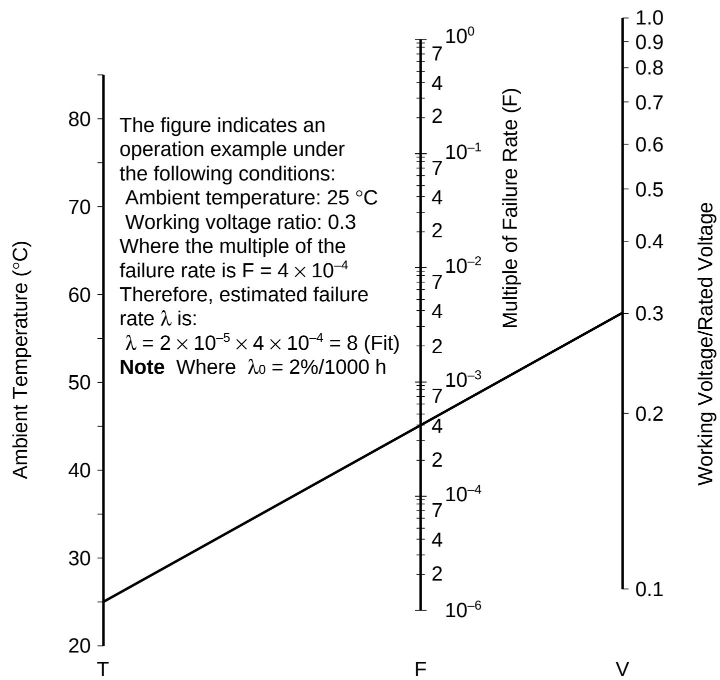
Series	Failure Rate
R (standard)	1%/1000 h
R (extended)	1%/1000 h
SVS	1%/1000 h
SVH	0.5%/1000 h
SVF	1%/1000 h
SVZ	1%/1000 h

<Test Conditions>

Temperature: 85˚C

Voltage: Rated Voltage

Rs: 3 Ω



This figure graphically indicates $(V/V_0)^3 \times 2^{(T-T_0)/10}$ in the expression $\lambda = \lambda_0 \, (V/V_0)^3 \times 2^{(T-T_0)/10}$. By using this figure, the estemated failure rate can be easily calculated.

Connect the desired temperature and voltage ratio with a straight line (form the leftmost vertical axis in the figure to the rightmost axis) in the figure. The multiple of the failure rate can be obtained at the intersection of the line drawn and the middle vertical axis in the figure.

Therefore

$$\lambda = \lambda_0 \times F.$$

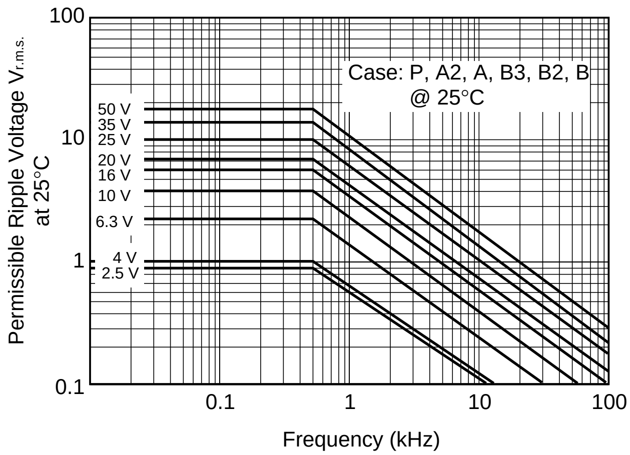
where,

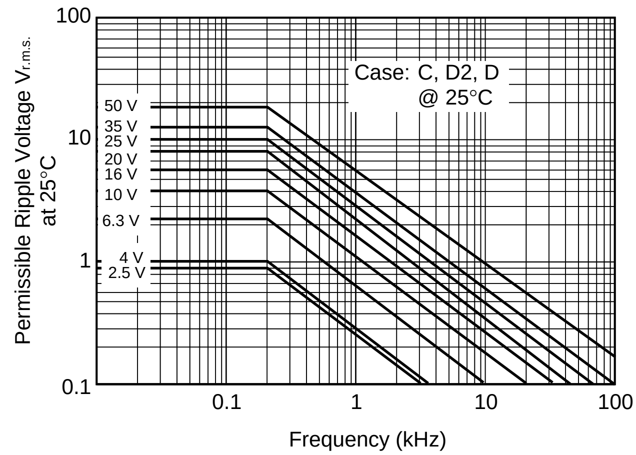
F: multiple of failure rate at given temperature and ratio of working voltage to rated voltage.

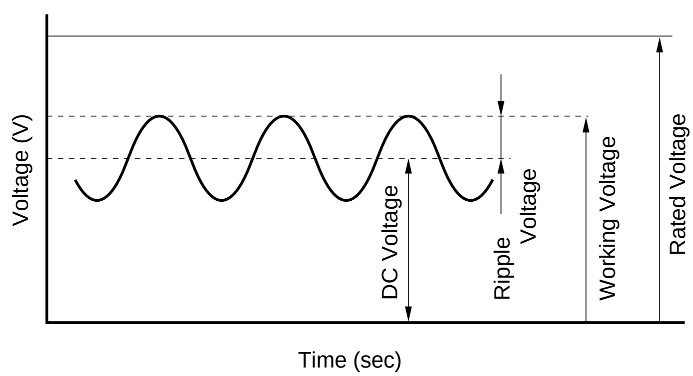
2. Ripple Voltage

(1) Keep the sum of the DC voltage and peak value of the ripple voltage to within the rated voltage.

(2) If a ripple voltage is applied to the capacitor, the peak value of the ripple voltage must be kept to within the values shown in the following figures:





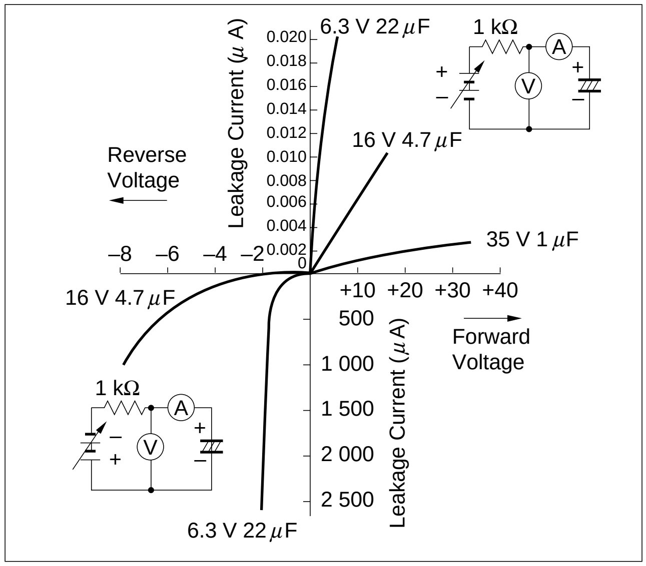


Calculate the permissible ripple voltage at a temperature higher than that specified in these figure by using the following expression;

$V_{r.m.s}$ (at 50˚C) = 0.7 × $V_{r.m.s}$ (at 25˚C)
$V_{r.m.s}$ (at 85˚C) = 0.5 × $V_{r.m.s}$ (at 25˚C)
$V_{r.m.s}$ (at 125˚C) = 0.3 × $V_{r.m.s}$ (at 25˚C)

(3) Keep the negative peak value of the ripple voltage to within the permissible reverse voltage value specified in the following paragraph 3.

3. Reverse voltage



(1) Do not apply a reverse voltage to the solid tantalum capacitor because the capacitor is of polar type. If reverse voltage cannot be avoided, it must be applied for a short time and must not exceed the following value:

25 ˚C ..... 10% max. of rated voltage or 3 Vdc, which is smaller
85 ˚C ..... 5% max. of rated voltage
125˚C .... 1% max. of rated voltage

(2) The figure on the right shows the relations between current and reverse voltage.

4. Applied Voltage

(1) For general applications, apply 70% or less of the rated voltage to the capacitor.

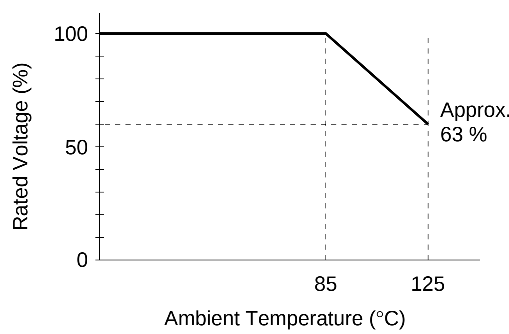
(2) When the capacitor is used in a power line or a low-impedance circuit, keep the applied voltage to within 30% (50% max.) of the rated voltage to avoid adverse influence of inrush current.

(3) Derated voltage at 85˚C or more.
When using the capacitor at a temperature of 85˚C or higher, calculate reduced voltage U_T from the following expression. Note, however, that the ambient temperature must not exceed 125˚C.

The rated voltage ratio is as shown in the figure on the right.

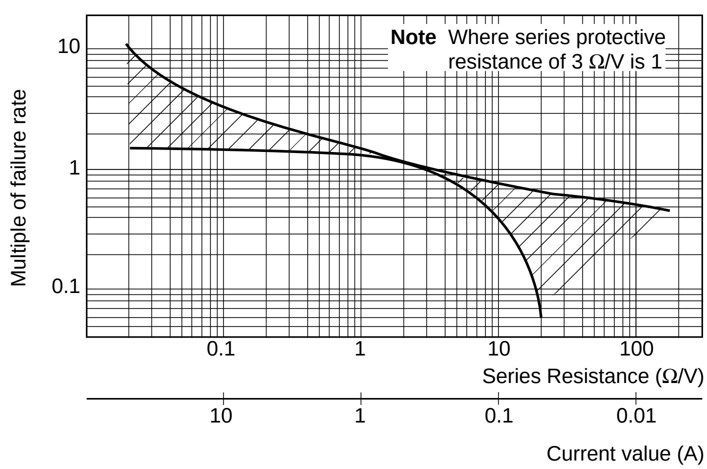
$$U_T = U_R - \frac{U_R - U_C}{40} \quad (T-85)$$

Where,
U_R : rated voltage (V)
U_C : derated volage at 125˚C
T : ambient temperature (˚C)



5. Current (Series Resistance)

As shown in the figure on the right, reliability is increased by inserting a series resistance of at least 3 Ω/V into circuits where current flow is momentary (switching circuits, charge/discharge circuits, etc). If the capacitor is in a low-impedance circuit, the voltage applied to the capacitor should be less than 1/2 to 1/3 of the DC rated volage.



6. Mounting

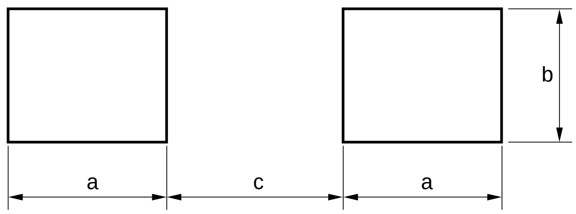
(1) Direct Soldering

Keep in mind the following points when soldering the capacitor by means of jet soldering or dip soldering:

(a) Temporarily fixing resin

Because the chip tantalum capacitors are larger in size and subject to more force than the chip multilayer ceramic capacitors or chip resistors, more resin is required to temporarily secure the solid tantalum capacitors. However, if too much resin is used, the resin adhered to the patterns on a printed circuit board may adversely affect the solderability.

(b) Pad Pattern Design



Case Size	a	b	c
P	2.2	1.4	0.7
A2, A	2.9	1.7	1.2
B3, B2	3.0	2.8	1.6
B	3.3	1.9	2.4
C	4.1	2.3	2.4
D2	5.4	2.9	2.4
D	5.2	2.9	3.7

The above dimensions are for reference only. If the capacitor is to be mounted by this method, and if the pattern is too small, the solderability may be degraded.

(c) Temperature and Time

Keep the peak temperature and time to within the following values:

Solder temperature ..... 260˚C max.
Time .... 5 seconds max. (10 seconds max. for SVH)

Whenever possible, perform preheating (at 150˚C max.) for smooth temperature profile. To maintain the reliability, mount the capacitor at a low temperature and in a short time whenever possible.

(d) Component Layout

If many types of chip components are mounted on a printed circuit board which is to be soldered by means of jet soldering, solderability may not be uniform over the entire board depending on the layout and density of the components on the bard (also take into consideration generation of flux gas).

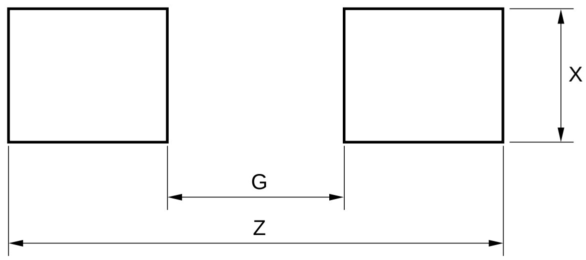
(e) Flux

Use resin-based flux. Do not use flux with strong acidity.

(2) Reflow Soldering

Keep in mind the following points when soldering the capacitor in a soldering oven or with a hot plate:

(a) Pad Pattern Design



Case Size	G max.	Z min.	X min.
P	0.5	2.6	1.2
A2, A	1.1	3.8	1.5
B3, B2	1.4	4.1	2.7
B	2.6	5.9	2.9
C	2.9	6.9	2.7
D2	2.7	6.7	2.9
D	4.1	8.2	2.9

The above dimensions are for reference only. Note that if the pattern is too big, the component may not be mounted in place.

(b) Temperature and Time

Keep the peak temperature and time to within the following values:

Solder temperature ... 260˚C max.

Time: 10 seconds max.

Whenever possible, perform preheating (at 150˚C max.) for smooth temperatue profile. To maintain the reliability, mount the capacitor at a low temperature and in a short time whenever possible. The peak temperature and time shown above are applicable when the capacitor is to be soldered in a soldering oven or with a hot plate. When the capacitor is soldered by means of infrared reflow soldering, the internal temperature of the capacitor may rise beyond the surface temperature.

(3) Using Soldering Iron

When soldering the capacitor with a soldering iron, controlling the temperature at the tip of the soldering iron is very difficult. However, it is recommended that the follwoing temperature and time be observed to maintain the reliability of the capacitor:

Iron Temperature ..... 300˚C max.

Time......................... 3 seconds max.

Iron Power .... 30 W max.

7. Cleaning

Generally, several organic solvents are used for flux cleaning of an electronic component after soldering. Many cleaning methods, such as immersion cleaning, rinse cleaning, bruch cleaning, shower cleaning, vapor cleaning, and ultrasonic cleaning, are available, and one of these cleaning methods may be used alone or two or more may be used in combination. The temperature of the organic solvent may vary from room temperature to several 10˚C, depending on the desired effect. If cleaning is carried out with emphasis placed only on cleaning effect, however, the marking on the electronic component cleaned may be erased, the appearance of the component may be damaged, and in the worst case, the component may be functionally damaged. It is therefore recommended that the R series solid tantalum capacitor be cleaned under the following conditions:

[Recommended Conditions of Flux Cleaning]

(1) Cleaning Solvent....... Isopropyl Alcohol
(2) Cleaning Method....... Shower Cleaning, Rinse Cleaning, Vapor Cleaning
(3) Cleaning Time........... 5 minutes max.

<u>*Ultasonic Cleaning</u>

This cleaning method is extremely effective for eliminating dust that has been generated as result of mechanical processes, but may pose a problem depending on the condition. As a result of an experiment conducted by NEC, it was confirmed that the external terminals of the capacitor were cut when it was cleaned with some ultrasonic cleaning machines. The cause of this phenomenon is considered metal fatigue of the capacitor terminals that occurred due to ultrasonic cleaning. To prevent the terminal from being cut, decreasing the output power of the ultrasonic cleaning machine or shortening the cleaning time may be a possible solution. However, it is difficult to specify the safe cleaning conditions because there are many factors involved such as the conversion efficiency of the ultrasonic oscillator, transfer efficiency of the cleaning bath, difference in cleaning effect depending on the location in the cleaning bath, the size and quantity of the printed circuit boards to be cleaned, and the securing states of the components on the boards. It is therefore recommended that ultrasonic cleaning be avoided as much as possible.

If ultrasonic cleaning is essential, make sure through experiments that no abnormality occur as a result to the cleaning. For further information, consult NEC.

8. Others

(1) Do not apply excessive vibration and shock to the capacitor.
(2) The solderability of the capacitor may be degraded by humidity. Store the capacitor at (–5 to +40˚C) room temperature and (40 to 60% RH) humidity.
(3) Exercise care that no external force is applied to the tape packaged products (if the packaging material is deformed, the capacitor may not be automatically mounted by a chip mounter).

[MEMO]

NEOCAPACITORs

(Conducting Polymer Tamtalum Capacitors)

1. WHAT IS NEOCAPACITOR?

There has been increasing demand for LSIs that operate at higher frequency and lower voltage, and also for an increase in scale (integration on one chip). Electronic equipment, especially portable systems, has become increasingly smaller, lighter, and high-performance.

To satisfy these demands and help realize such systems, capacitors need to be smaller in size with higher capacitance and lower impedance.

The NEOCAPACITOR (conducting polymer tantalum capacitor) has been developed to satisfy these demands, in particular the demand for low impedance.

The NEOCAPACITOR is produced by creating a tantalum oxide film on the surface of a body of sintered tantalum powder by means of anodic oxidation, employing a conducting polymer as the counter electrode.

This capacitor offers a small size and high capacitance (equivalent to solid tantalum capacitors) by using a body of sintered tantalum powder for the anode, and a dramatic reduction of impedance as well as ESR by employing a new material, the conducting polymer (polypyrrole), for the cathode.

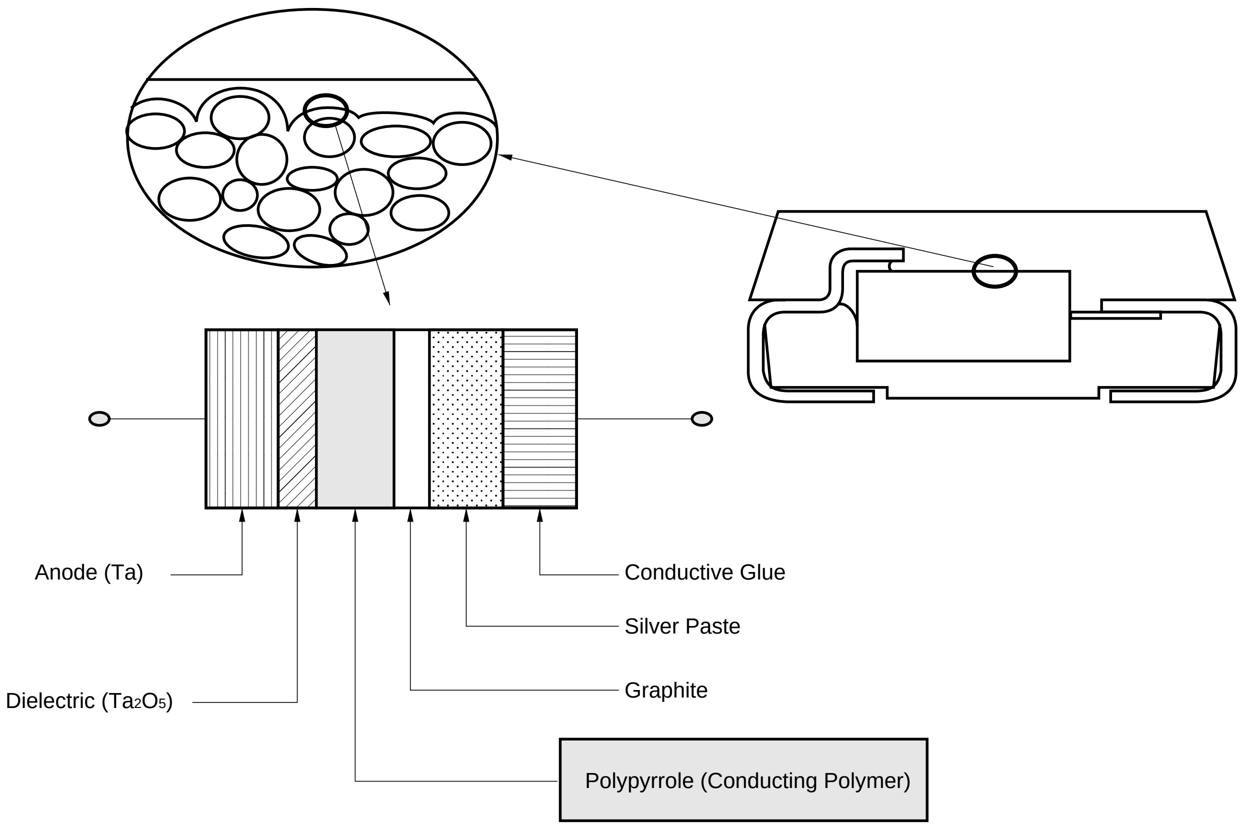


Figure 1. Structure of NEOCAPACITOR

2. WHAT IS POLYPYRROLE?

Polypyrrole is one of the popular conducting polymer.
The molecular structure is shown in Figure 2, and its features are explained in 2.1.

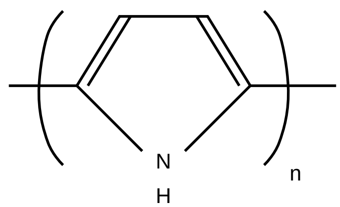


Figure 2. Molecular Structure of Polypyrrole

2.1 Features of Polypyrrole

(1) High conductivity (low resistance)
The conductivity of polypyrrole is about 20 S/cm (0.05 Ω•cm), which is more than 100 times that of manganese dioxide (i.e., its resistance is less than 1/100 of manganese dioxide), and about 10 times that of TCNQ (cathode material for OS Capacitor).
* Refer to **Figure 3 Comparison of Conductivity**.

(2) High temperature for thermal decomposition
Thermal decomposition temperature of polypyrrole is 280 to 300 °C, and is higher than soldering temperature. (TCNQ: 200 to 235 °C)

(3) Resistance increase after thermal decomposition.
→ Low possibility of smoking or burning even in the case of short circuit failure.

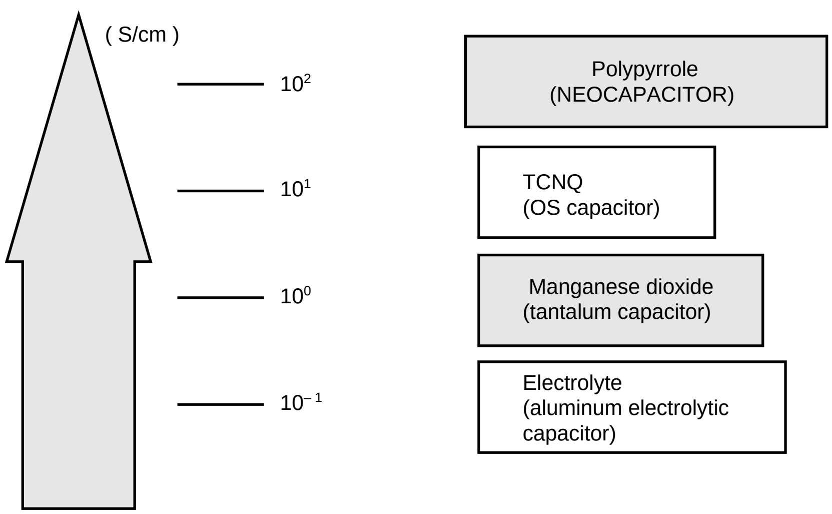


Figure 3. Comparison of Conductivity

3. FEATURES OF NEOCAPACITOR

The NEOCAPACITOR has the following features as a small, high-capacitance, and low-impedance capacitor.

(1) Excellent high-frequency noise absorption (low impedance)
(2) High permissible value of ripple current (low ESR)
(3) Stable temperature characteristics (capacitance, ESR)
(4) Surface mountability (can be soldered by means of reflow soldering)
(5) High capacitance

3.1 Excellent Noise Absorption (Impedance)

The NEOCAPACITOR offers low ESR and excellent impedance vs. frequency characteristics by using a high conducting polymer.

In particular, its characteristics are excellent in the high-frequency region (10 kHz to 10 MHz) where noise must be absorbed.

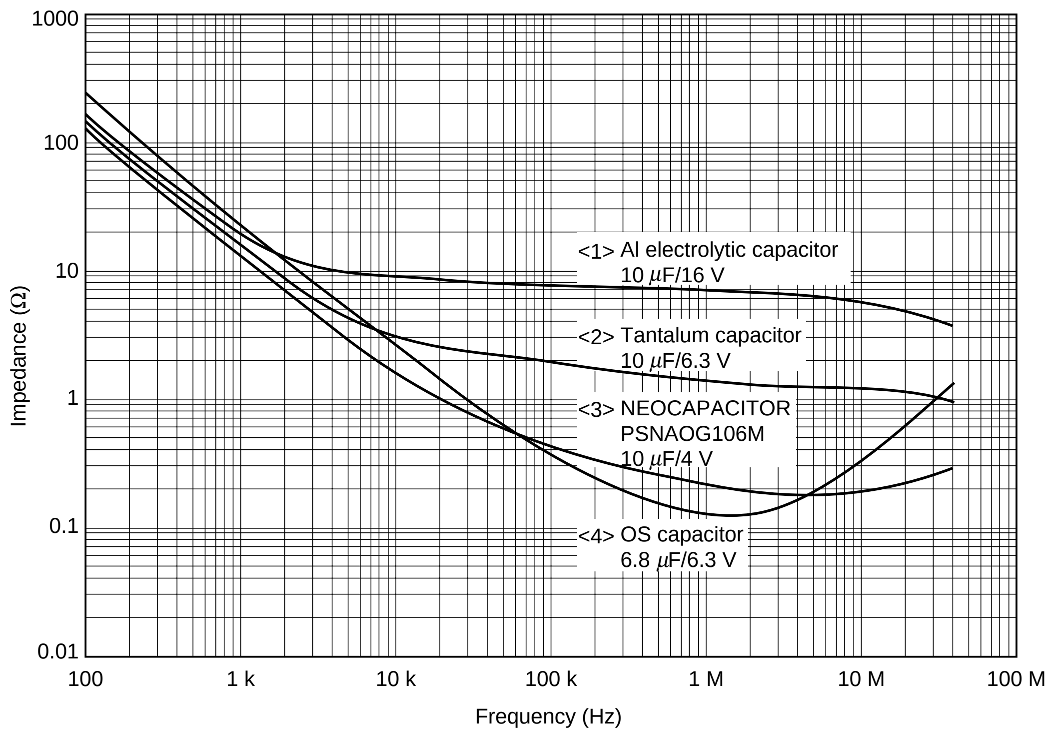


Figure 4. Impedance-Frequency Characteristics

3.2 High Ripple Current (low ESR)

The value of ripple current is one of the basic factors in the performance of a smoothing capacitor. The ripple current is determined by confirming the temperature rise of the capacitor based on the relation between self-heating and heat radiation. NEC defines permissible ripple current as the amount of ripple current which can be passed without causing the surface temperature of the capacitor to rise more than 5 °C.

The temperature rise of the NEOCAPACITOR is low because of low self-heating and the low ESR value as shown below. As a result, the value of the ripple current is high.

The frequency characteristics of ESR are shown below.

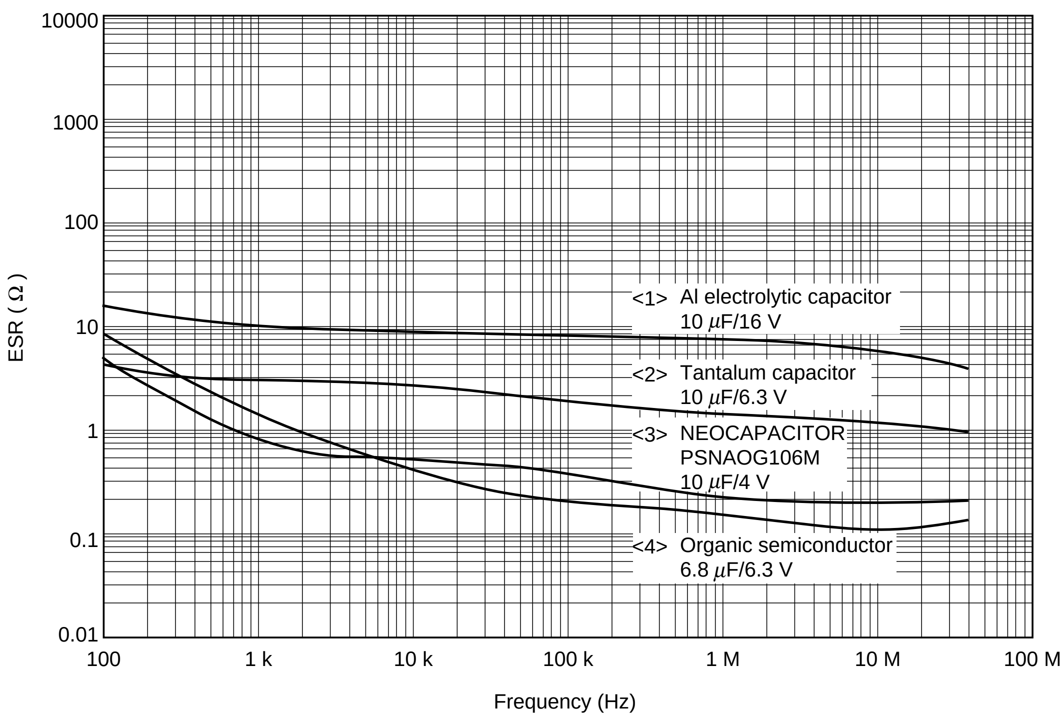


Figure 5. ESR-Frequency Characteristics

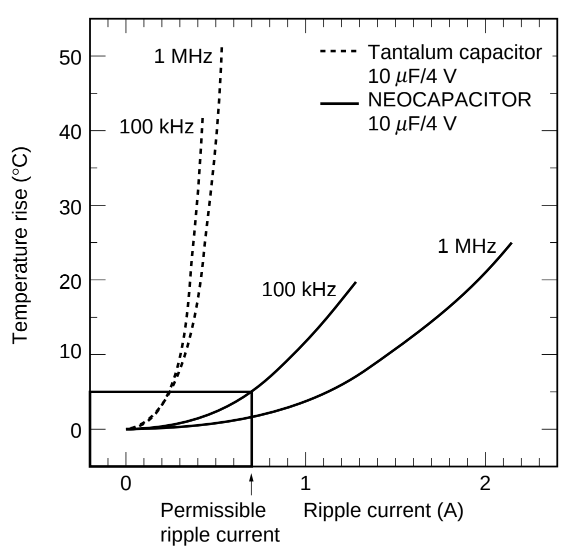


Figure 6. Ripple Current and Temperature Rise

3.3 Stable Temperature Characteristics (Capacitance, ESR)

The capacitance and ESR of the NEOCAPACITOR are barely affected by changes in the ambient temperature.

In addition to being smaller than other capacitors, NEOCAPACITOR is ideal as a noise absorbing component in portable equipments, such as cellular phones, where the ambient temperature fluctuates significantly.

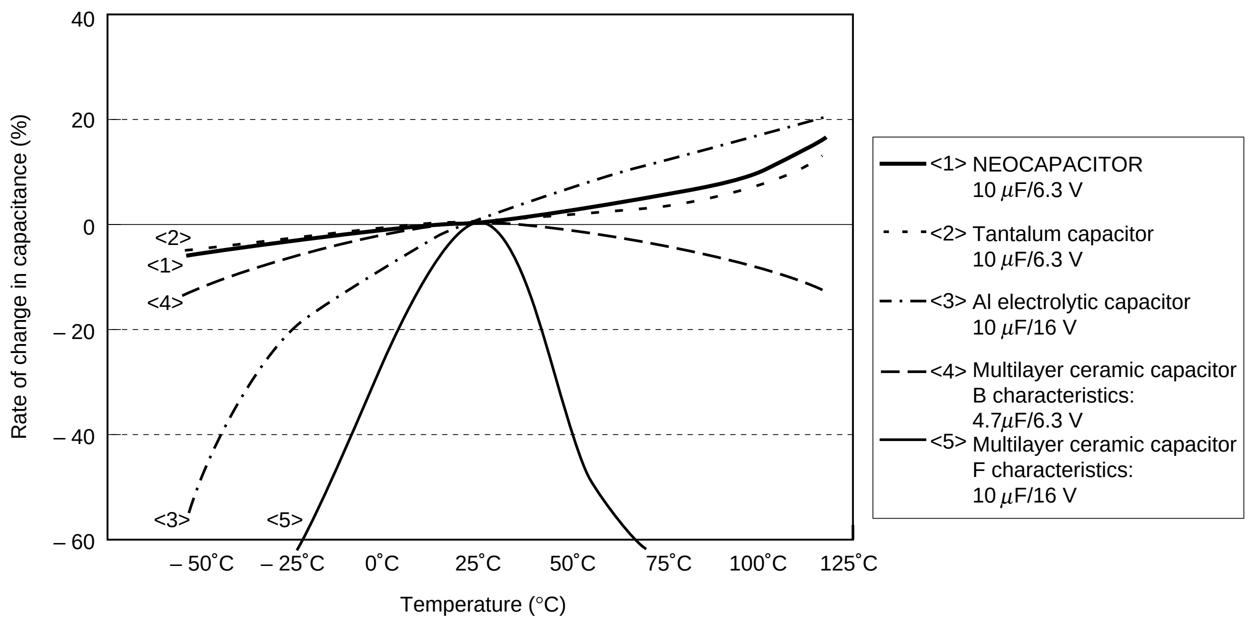


Figure 7. Temperature Characteristics of Capacitance

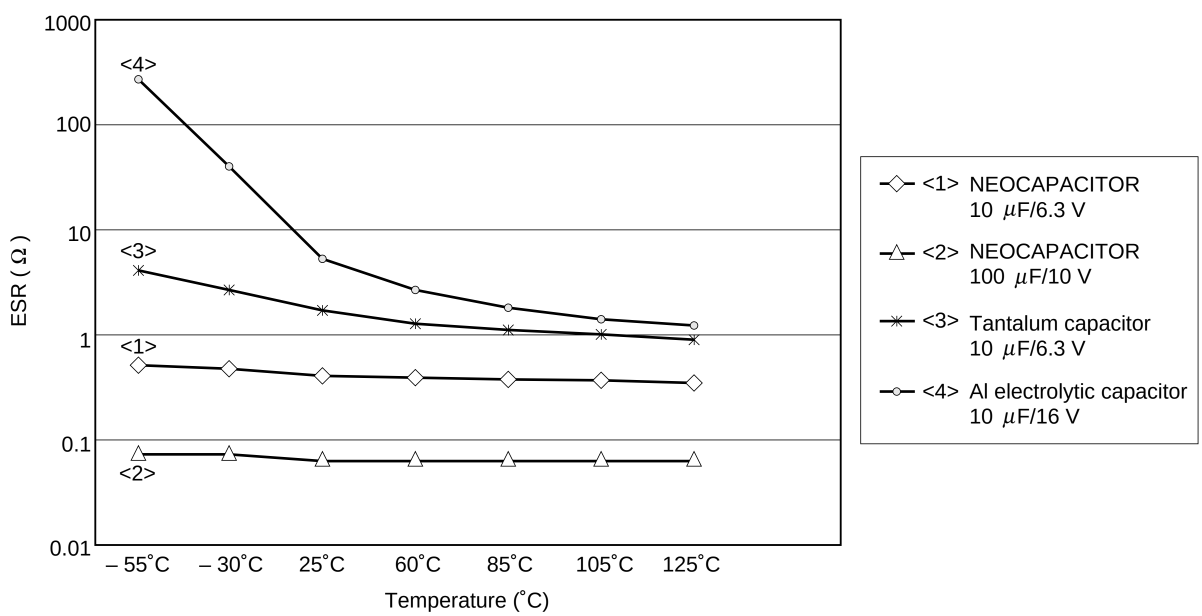


Figure 8. Temperature Characteristics of ESR

3.4 Compatibility with Standard Reflow Soldering

The cathode material (polypyrrole) of NEOCAPACITOR has higher thermal decomposition temperature (280 to 300°C) than those of other conducting polymers.

NEOCAPACITOR is therefore compatible with conventional reflow soldering (240°C, 10 seconds) without any changes.

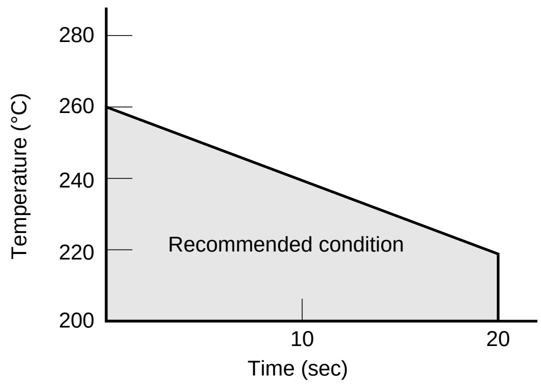


Figure 9. Recommended Temperature/Time Combinations for Reflow Soldering

3.5 Large Capacitance in Small Size

Because a sintered Ta anode and a Ta_2O_5 dielectric layer used in NEOCAPACITOR are basically the same as those of conventional chip Ta capacitor.

Therefore, the same large capacitance is actualized in small size.

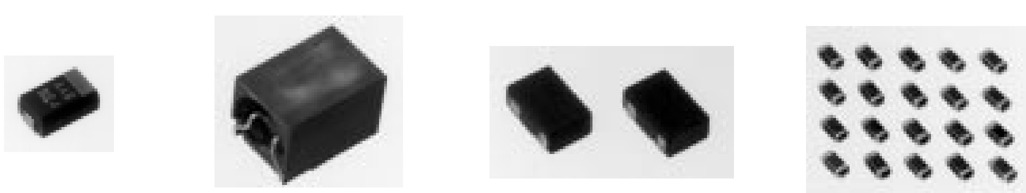
NEOCAPACITOR
10 μF/6.3 V

OS Capacitor
6.8 μF/6.3 V

Functional polymer
aluminum capacitor
10 μF/6.3 V

Multilayer ceramic
capacitor
B characteristic
4.7 μF/6.3 V × 2 pcs.

Figure 10. Comparison of Size (10 μF)



NEOCAPACITOR
100 μF/6.3 V

OS Capacitor
100 μF/10 V

Functional polymer
aluminum capacitor
47 μF/6.3 V × 2 pcs.

Multilayer ceramic
capacitor
B characteristic
4.7 μF/6.3 V × 20 pcs.

Figure 11. Comparison of Size (100 μF)

4. APPLICATIONS EXAMPLES OF NEOCAPACITOR

4.1 Smoothing Capacitor

In spite of small size, NEOCAPACITOR has high permissible ripple current as shown in Table 1. NEOCAPACITOR is the best suited to be the smoothing capacitor for portable equipment.

Table 1. Permissible Ripple Current (at 1 MHz)

Part Number	Permissible Ripple Current
PSNA0G106M	1.0 A_{P-P}
PSNA0J685M	1.0 A_{P-P}
PSNA0J106M	1.0 A_{P-P}
PSNA1A335M	1.0 A_{P-P}
PSNA1A475M	1.0 A_{P-P}
PSNA1C335M	1.0 A_{P-P}
PSNB20G226M	1.5 A_{P-P}
PSNB20J156M	1.5 A_{P-P}
PSNB21A685M	1.5 A_{P-P}
PSNB21A106M	1.5 A_{P-P}
PSNB21C475M	1.5 A_{P-P}
PSNB21C685M	1.5 A_{P-P}

Part Number	Permissible Ripple Current
PSNC0G686M	2.5 A_{P-P}
PSNC0J476M	2.5 A_{P-P}
PSNC1A156M	2.5 A_{P-P}
PSNC1A226M	2.5 A_{P-P}
PSNC1A336M	2.5 A_{P-P}
PSND0G227M	2.5 A_{P-P}
PSND0J157M	2.5 A_{P-P}
PSND1A476M	2.5 A_{P-P}
PSND1A686M	2.5 A_{P-P}
PSND1A107M	2.5 A_{P-P}
PSMD0J157M	2.5 A_{P-P}
PSMD1A107M	2.5 A_{P-P}

<Advantages of NEOCAPACITOR>

(I) Compatibility with surface mounting of power supply circuit

By surface mounting of power supply circuit,

<1> The power supply unit can be installed on the main printed circuit board.

<2> Switching frequency higher than 500 kHz becomes available, and it contributes to miniaturization of the application equipment.

(II) Large capacitance

Large capacitance from 3.3 μF to 220 μF, which cannot be realized with the multilayer ceramic capacitor, is available in NEOCAPACITOR with SMD, and NEOCAPACITOR is applicable to larger extent of load fluctuation.

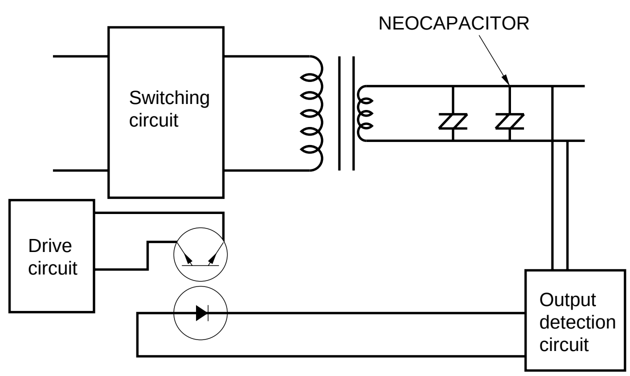


Figure 12. Example of Power Supply Circuit Using Smoothing Capacitor

4.2 Bypass Capacitor

When current consumption in the power supply circuit changes due to load fluctuation, it takes several μsec to several 10 μsec in general to detect the change of current consumption and to supply necessary current.

Bypass capacitor ensures smooth supply of necessary current to the circuit during the load fluctuation of several μsec to several 10 μsec.

To supply required current for the load fluctuation of several 10 mA, a combination of a tantalum or aluminum electrolytic capacitor having relatively large capacitance (3.3 μF or more), and a ceramic capacitor having small capacitance (1 μF or less) is widely used in the power supply. This is because the ceramic capacitor is used to respond to momentary current fluctuations (1 μsec or less) and the tantalum or aluminum electrolytic capacitor is used to supply required current until the power supply catches up to the fluctuation (several μsec to several 10 μsec).

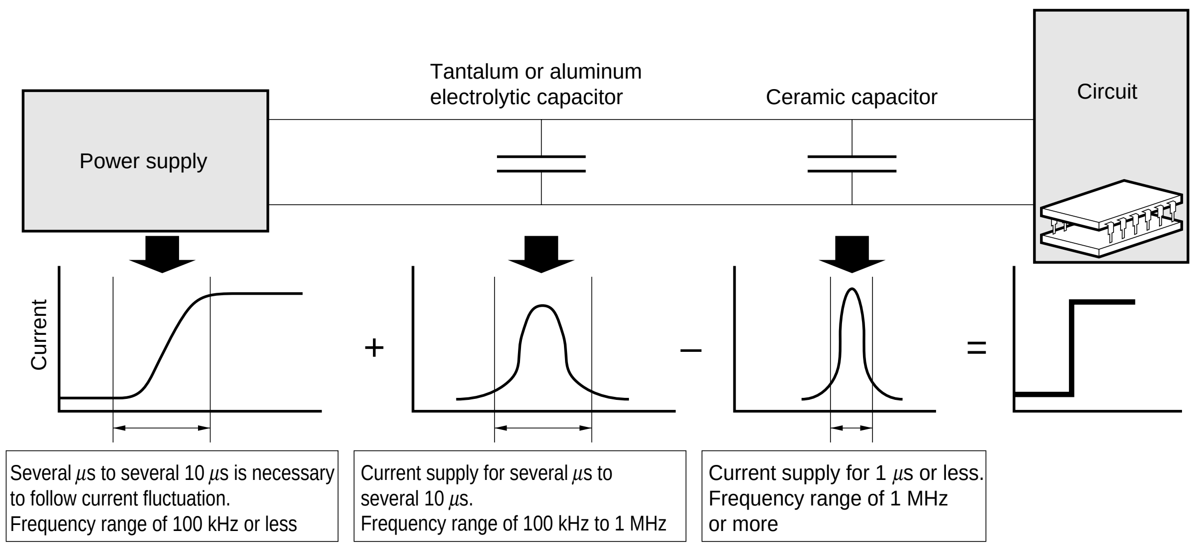


Figure 13. Function of Bypass Capacitor

The essential characteristics for bypass capacitors are sufficient capacitance and low ESR.

If the capacitance is small, or the ESR is high current cannot be supplied smoothly as shown in Figure 14 while the power supply catches up to the current fluctuation, and it causes the line voltage to drop.

Because the NEOCAPACITOR has large capacitance and low ESR, it can supply required current smoothly even at abrupt fluctuations of the current consumption in the circuit.

NEOCAPACITOR is ideal as the bypass capacitor in the low-voltage circuit where a small drop of line voltage is not acceptable.

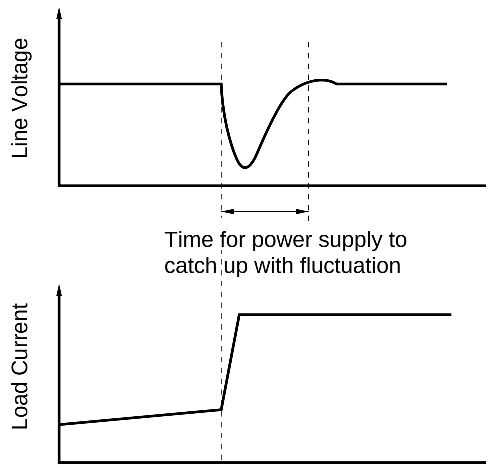


Figure 14. Line Voltage Drop in Case of Inadequate Characteristics of Bypass Capacitor

<Advantages of NEOCAPACITOR>

Table 2 shows a guideline for selecting bypass capacitor.

NEOCAPACITOR has well-balanced combination for capacitance and ESR for using as bypass capacitor, and it reveals good performance even in the circuit where heavy load fluctuation may occur.

Table 2. Guideline for Selecting Bypass Capacitor

Load Fluctuation (mA)	Necessary Capacitance (μF)	Permissible ESR Value (Ω)
1 or less	0.1	50 to100
1 to10	1	5 to10
10 to100	10	0.5 to 1
100 to 1000	100	0.05 to 0.1

Remark Above values are shown on the assumption that the fluctuation of the line voltage due to load fluctuation is less than 0.1 V.

6. NOTES FOR USAGE

6.1 Difference in Failure Mode

Thanks to the features of polypyrrole, NEOCAPACITOR's self-healing characteristics are superior to those of conventional MnO_2 type tantalum capacitor.

In addition, NEOCAPACITOR is relatively hard to smoke or burn even in the case of short-circuit failure.

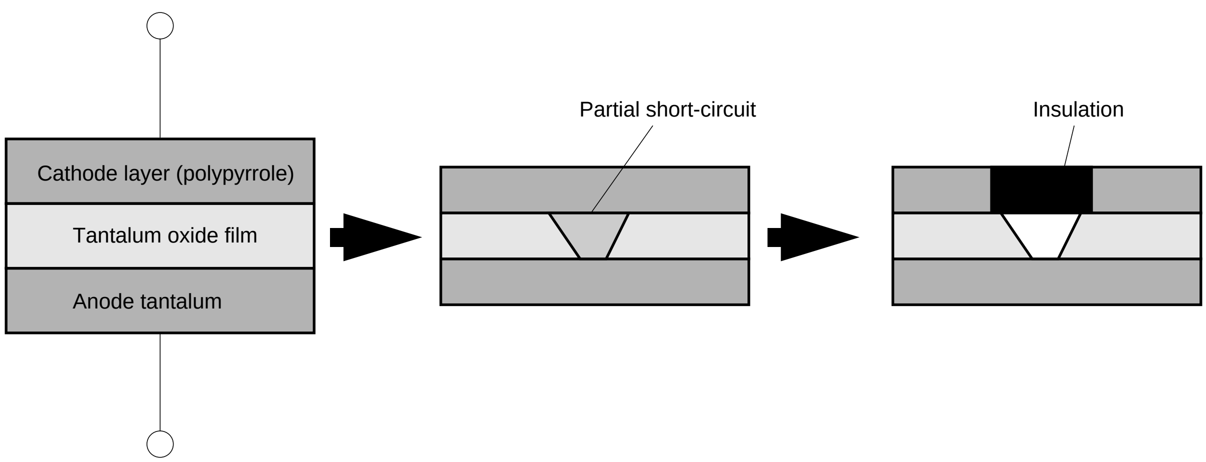
Features of polypyrrole

Polypyrrole has extremely high conductivity (low resistance) and thermally decomposes at about 300°C.

When polypyrrole thermally decomposes, it becomes less-conductive and finally to be insulating.

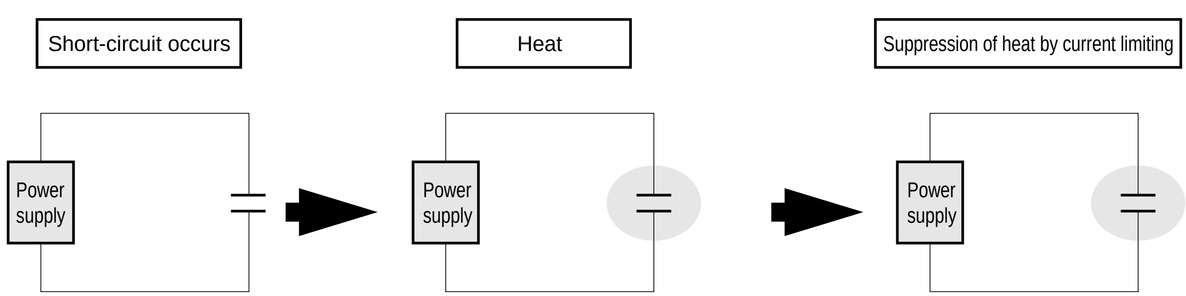
(1) Fewer failures

As a premonitory phenomenon of failure, small current flows through tiny defect in the tantalum oxide layer. Heat is generated by the current flowing through the tiny defect, and the cathode layer of polypyrrole at the defect portion will be decomposed by the heat, and rapidly insulated. Thus catastrofic failure as an avalanche in leakage current can be suppressed to occur by the insulation of polypyrrole cathode layer.



(2) Low possibility of smoking or burning in case of short-circuit failure

Should a short-circuit failure occurs, only a small amount of heat is generated by the short-circuit current because the specific resistance of NEOCAPACITOR is quite low. In addition, if the current flow increases, the entire cathode layer of polypyrrole tends to be insulated by the generated heat, and may suppress further current flow. As the result, possibility of smoking or burning of NEOCAPACITOR in case of short-circuit failure can be quite small (1/20 or less) in comparison with conventional MnO_2 type tantalum capacitor.



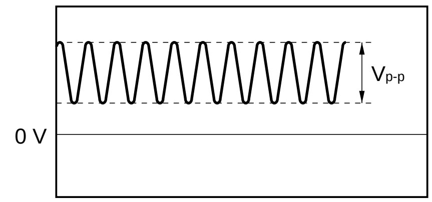
AC burning test

Test method

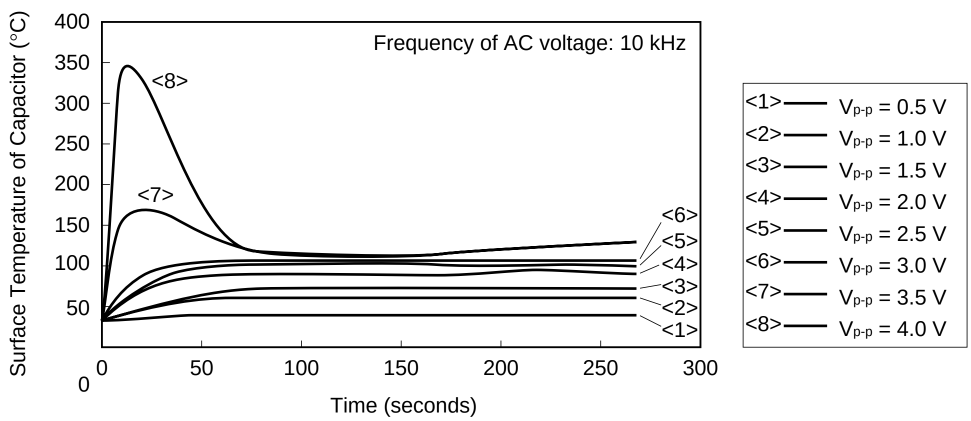
Sine-wave AC voltage is applied to the capacitor as shown on the right, to allow AC current to flow.

The AC current to flow is controled by changing peak AC voltage and the surface temperature of the capacitor is measured.

The evidence of smoking, burning and mechanical damage is visually examined during the test.



NEOCAPACITOR 100 μF/10 V (D case)



Chip Tantalum Capacitor D Case 10 V/100 μF

NEOCAPACITOR reveals quite low possibility of burning caused by AC current flow, because its cathode layer will be insulated when heat is generated by AC current, and the heat generation will be limited by suppression of AC current to flow.

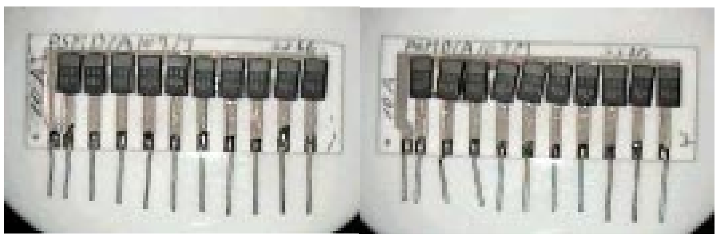
Smoking and burning in marginal test

After forcible short-circuiting by marginal load in high temperature load test, appearance of capacitor is examined for damage.

High-temperature load test (125°C, rated voltage × 1.5, 125 hours)

- In this test, a fuse shown is the following table was connected individually to the capacitor.

NEOCAPACITOR 100 μF/10 V (D case)



High-temperature load test (125°C, rated voltage × 1.5, 125 hours): Result after fuse is burnt N = 20 samples

Fuse	0.3 A		1 A		3 A		10 A	
	Number of samples shorted	Number of samples with abnormal appearance	Number of samples shorted	Number of samples with with abnormal appearance	Number of samples shorted	Number of samples with with abnormal appearance	Number of samples shorted	Number of samples with with abnormal appearance
NEOCAPACITOR	20	0	20	0	20	0	20	0

In above marginal test, NEOCAPACITOR is hard to be damaged because its cathode layer becomes insulated by generated heat caused by short-circuit current, and the heat generation becomes to be suppressed.

PSN SERIES

NEC's PSN series have lower impedance than conventional tantalum capacitor using manganese dioxided (MnO_2).

These capacitors are suitable for noise reduction in a high-frequency application with its low ESR.

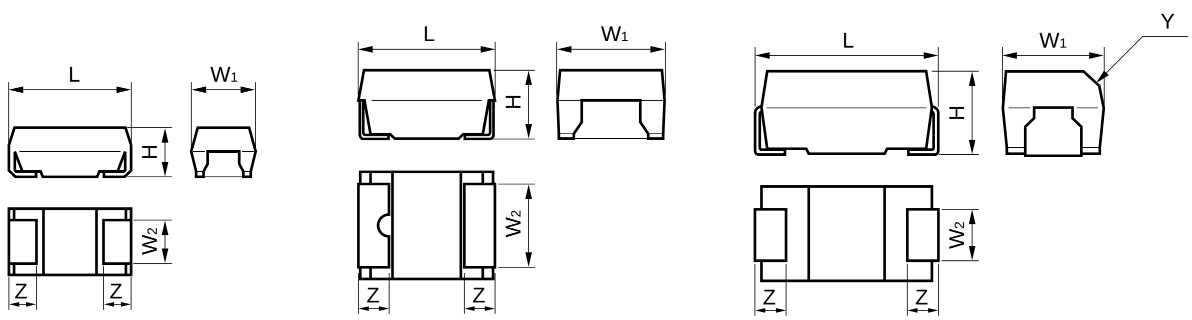
FEATURES

- Low impedance/low ESR
- High ripple current
- The same case size as NEC R series conventional tantalum capacitor.

APPLICATIONS

- D/D converter
- Suppression of oscillation for general purpose regulator
- Video camera
- Personal handy phone

OUTLINE DRAWINGS AND DIMENSIONS



[A case] [B2 case] [C & D cases]

Unit: mm (inch)

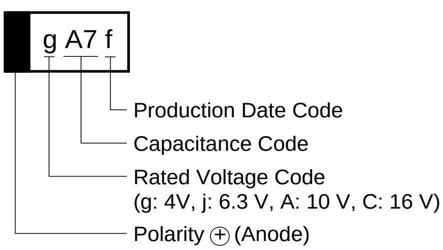
Case size	EIA Code	L	W_1	W_2	H	Z	Y
A	3216	3.2±0.2 (0.126±0.008)	1.6±0.2 (0.063±0.008)	1.2±0.1 (0.047±0.004)	1.6±0.2 (0.061±0.008)	0.8±0.3 (0.031±0.012)	—
B2	3528	3.5±0.2 (0.138±0.008)	2.8±0.2 (0.110±0.008)	2.3±0.1 (0.091±0.004)	1.9±0.2 (0.075±0.008)	0.8±0.3 (0.031±0.012)	—
C	6032	6.0±0.3 (0.236±0.012)	3.2±0.3 (0.126±0.012)	2.2±0.1 (0.087±0.004)	2.5±0.3 (0.098±0.012)	1.3±0.3 (0.051±0.012)	0.4C (0.016)
D	7343	7.3±0.3 (0.287±0.012)	4.3±0.3 (0.169±0.012)	2.4±0.1 (0.094±0.004)	2.8±0.3 (0.110±0.012)	1.3±0.3 (0.051±0.012)	0.5C (0.020)

PRODUCT LINE-UP AND CASE SIZE

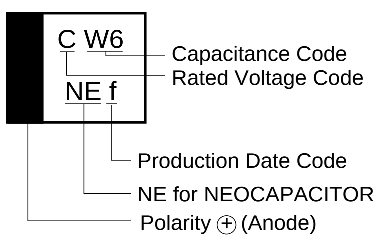
Capacitance (μF) \ Rated Voltage (V dc)	4	6.3	10	16
3.3			A	A
4.7			A	B2
6.8		A	B2	B2
10	A	A	B2	
15		B2	C	
22	B2		C	
33			C	
47		C	D	
68	C		D	
100			D	
150		D		
220	D			

MARKING

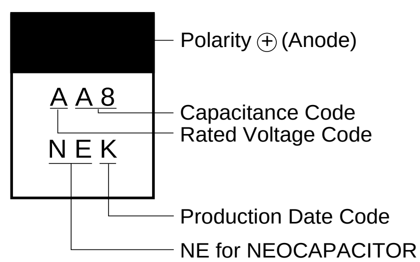
[A Case]



[B2 Case]



[C and D Case]



[Capacitance Code]

Alphabetical Code	A	E	J	N	S	W	Numerical Code	4	5	6	7	8
Number	1.0	1.5	2.2	3.3	4.7	6.8	Multiplier	10^4	10^5	10^6	10^7	10^8

Example A7: $1.0 \times 10^7 = 10^7$ pF = 10 μF

[Marking of Production Date Code]

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1998	N	P	Q	R	S	T	U	V	W	X	Y	Z
1999	a	b	c	d	e	f	g	h	j	k	l	m
2000	n	p	q	r	s	t	u	v	w	x	y	z
2001	A	B	C	D	E	F	G	H	J	K	L	M

Date code will resume beginning in 2002.

PART NUMBERING SYSTEM

[Bulk]

PSN A 0J 106 M

- M — Capacitance Tolerance (±20%)
- 106 — Capacitance in pF
  First two digits represent significant figures and third dight specifies number of zeros to follow.
- 0J — Rated Voltage
  (0G: 4 V, 0J: 6.3 V, 1A: 10 V, 1C: 16 V)
- A — Case Size
- PSN — Series

[Tape and reel]

TE PSNA0J106M 8 R

- R — Packing Orientation
  [R: Cathode on the side of sprocket hole]
- PSNA0J106M — Same as Bulk (see left)
- 8 — Tape Width (8: 8 mm, 12: 12 mm)
- TE — Tape and Reel

PERFORMANCE CHARACTERISTICS

Item		Specification					Test Method
Operating Temperature Range		–55 to +85˚C					
Rated Voltage		4	6.3	10	16	Vdc	Temperature: 85˚C
Surge Voltage		5.2	8	13	20	Vdc	Temperature: 85˚C
Capacitance Range		3.3 to 220 µF					Frequency: 1 kHz
Capacitance Tolerance		±20%					
Leakage Current (L.C.)		0.1 CV (µA) or 3 µA whichever is greater					5 min, after rated voltage applied
Tangent of Loss Angle (tan δ)		Refer to standard ratings					Frequency: 1 kHz
Equivalent Series Resistance (ESR)		Refer to standard ratings					Frequency: 100 kHz
Surge Voltage Test		ΔC/C : ±20% tan δ : Initial Requirement L.C. : Initial Requirement					Temperature: 85˚C Surge voltage for 30 sec. Series resistance: 1 kΩ Discharge voltage for 5 min. 30 sec. 1000 cycles
Characteristics at High and Low Temperature	Temp.	–55˚C		+85˚C			Step 1: 20˚C Step 2: –55˚C Step 3: 20˚C Step 4: 85˚C Step 5: 20˚C
	ΔC/C	0, –20%		+50, 0%			
	tand δ	Initial Requirement		Initial Requirement × 1.5			
	L.C.	–		Initial Requirement × 10			
Rapid Change of Temperature		ΔC/C : ±20% tan δ : Initial Requirement L.C. : Initial Requirement					–55 to +85˚C 5 cycles
Resistance to Soldering		ΔC/C : ±20% tan δ : Initial Requirement L.C. : Initial Requirement					Reflow soldering, 240˚C, 10 sec.
Damp Heat, Steady State		Capacitance: +30% to –20% of Rated Voltage tan δ : Initial Requirement × 1.5 L.C. : Initial Requirement					Temperature: 40˚C 90 to 95% RH 500 hours
Endurance		ΔC/C : ±20% tan δ : Initial Requirement × 1.5 L.C. : Initial Requirement					Temperature: 85˚C Rated voltage applied 1000 hours
Failure Rate		λ_0 = 1%/1000H					
Permissible Ripple Current		0.7 Arms, 1.0 Ap-p (A case) 0.9 Arms, 1.5 Ap-p (B2 case) 1.5 Arms, 2.5 Ap-p (C, D case)					Frequency: 1 MHz

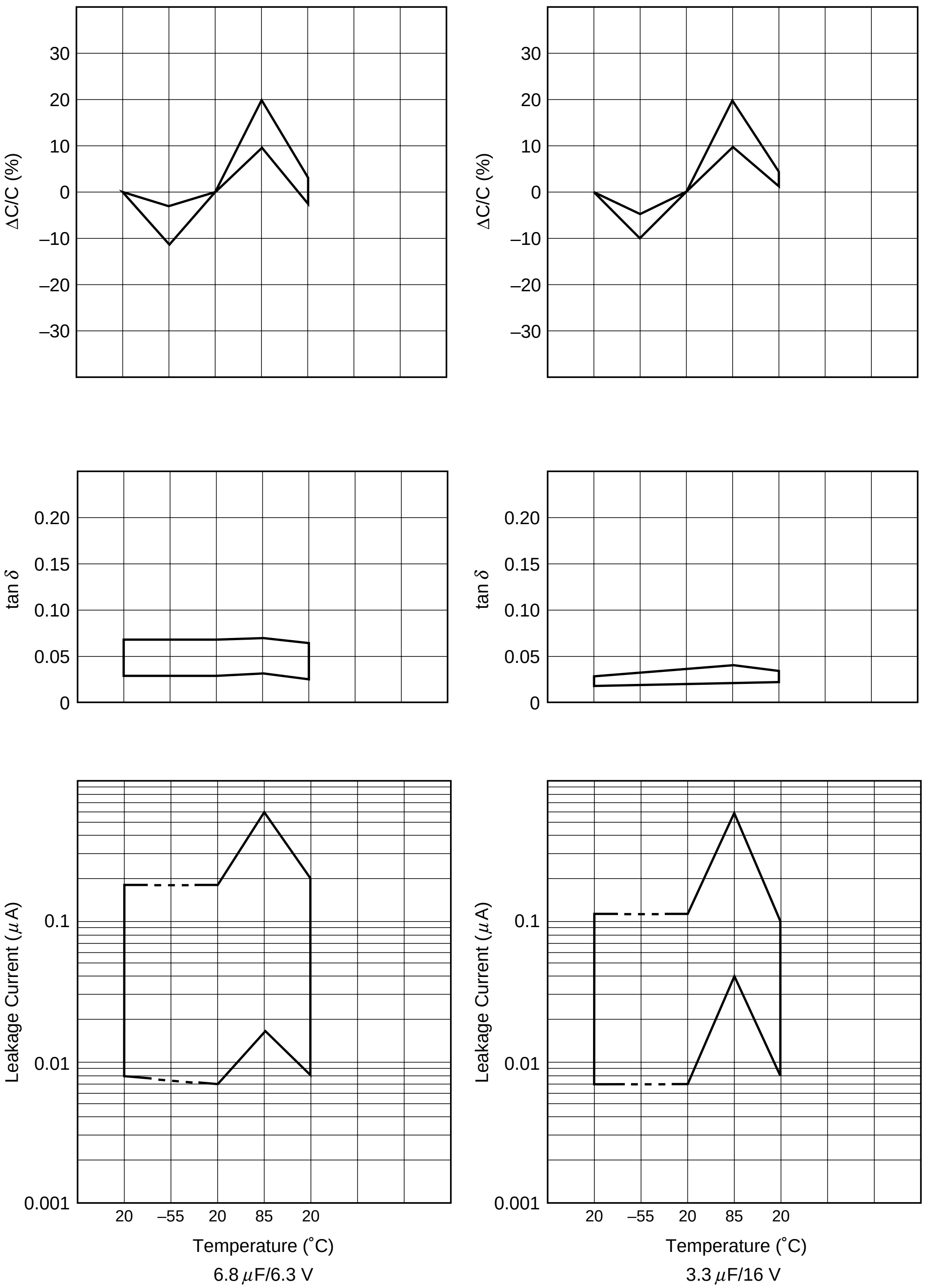
LEGEND
CV : Product of capacitance in µF and voltage in V
ΔC/C : Capacitance change ratio

DC Rated Voltage @85˚C Vdc	Capacitance @20˚C, 1 kHz μF	Case Size	Part Number	Leakage Current @20˚C μA Max.	tan δ @20˚C, 1 kHz % Max.	ESR @20˚C, 100 kHz mΩ Max.	Ripple Current @20˚C, 1 MHz Ap-p Max.
4	10	A	PSNA0G106M	4	15	600	1
	22	B2	PSNB20G226M	8.8	15	400	1.5
	68	C	PSNC0G686M	27.2	20	150	2.5
	220	D	PSND0G227M	88	50	80	2.5
6.3	6.8	A	PSNA0J685M	4.2	9	900	1
	10	A	PSNA0J106M	6.3	15	600	1
	15	B2	PSNB20J156M	9.5	15	400	1.5
	47	C	PSNC0J476M	29.6	20	150	2.5
	150	D	PSND0J157M	94.5	30	80	2.5
10	3.3	A	PSNA1A335M	3.3	9	900	1
	4.7	A	PSNA1A475M	4.7	9	900	1
	6.8	B2	PSNB21A685M	6.8	15	600	1.5
	10	B2	PSNB21A106M	10	15	400	1.5
	15	C	PSNC1A156M	15	20	250	2.5
	22	C	PSNC1A226M	22	20	200	2.5
	33	C	PSNC1A336M	33	20	150	2.5
	47	D	PSND1A476M	47	30	150	2.5
	68	D	PSND1A686M	68	30	120	2.5
	100	D	PSND1A107M	100	30	80	2.5
16	3.3	A	PSNA1C335M	5.3	9	900	1
	4.7	B2	PSNB21C475M	7.5	15	600	1.5
	6.8	B2	PSNB21C685M	10.9	15	600	1.5

7. TYPICAL PERFORMANCE CHARACTERISTICS

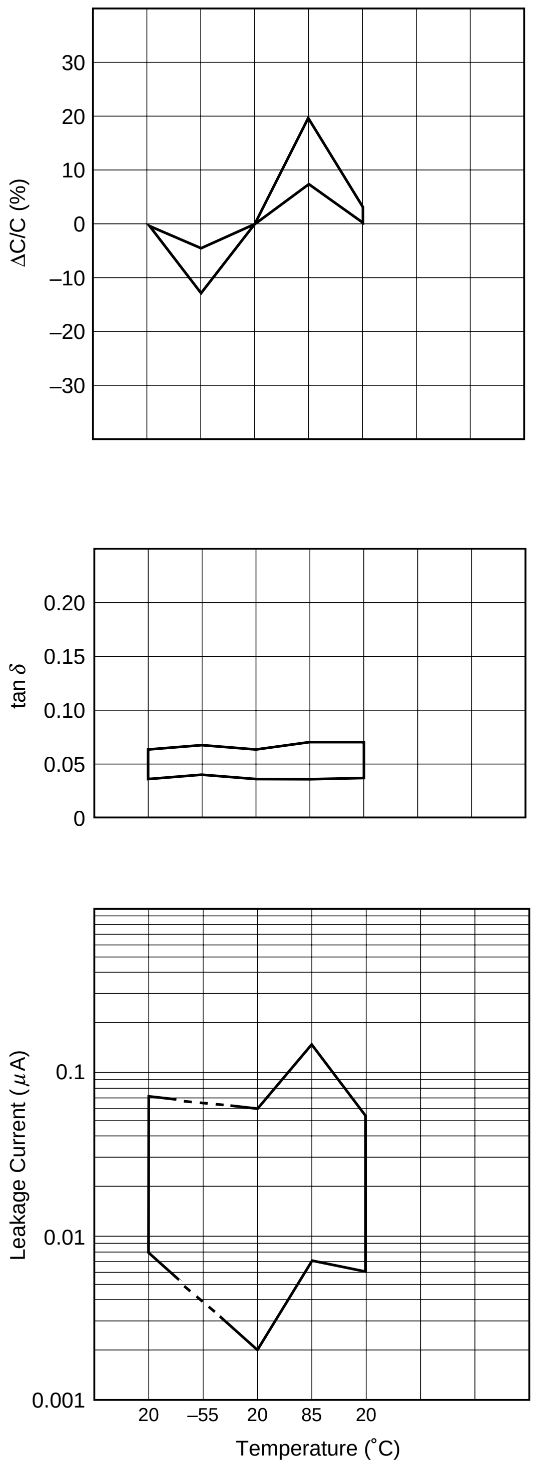
• **PSN Series: A Case**

Characteristics at High and Low Temperature

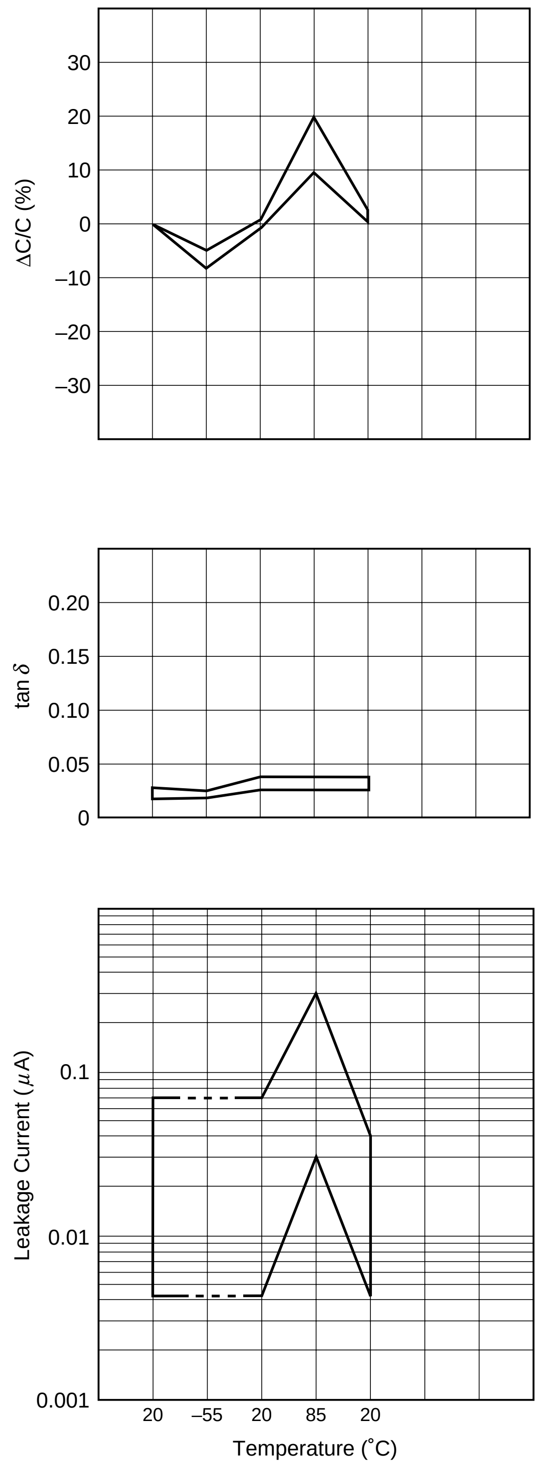


• **PSN Series: B2 Case**

Characteristics at High and Low Temperature



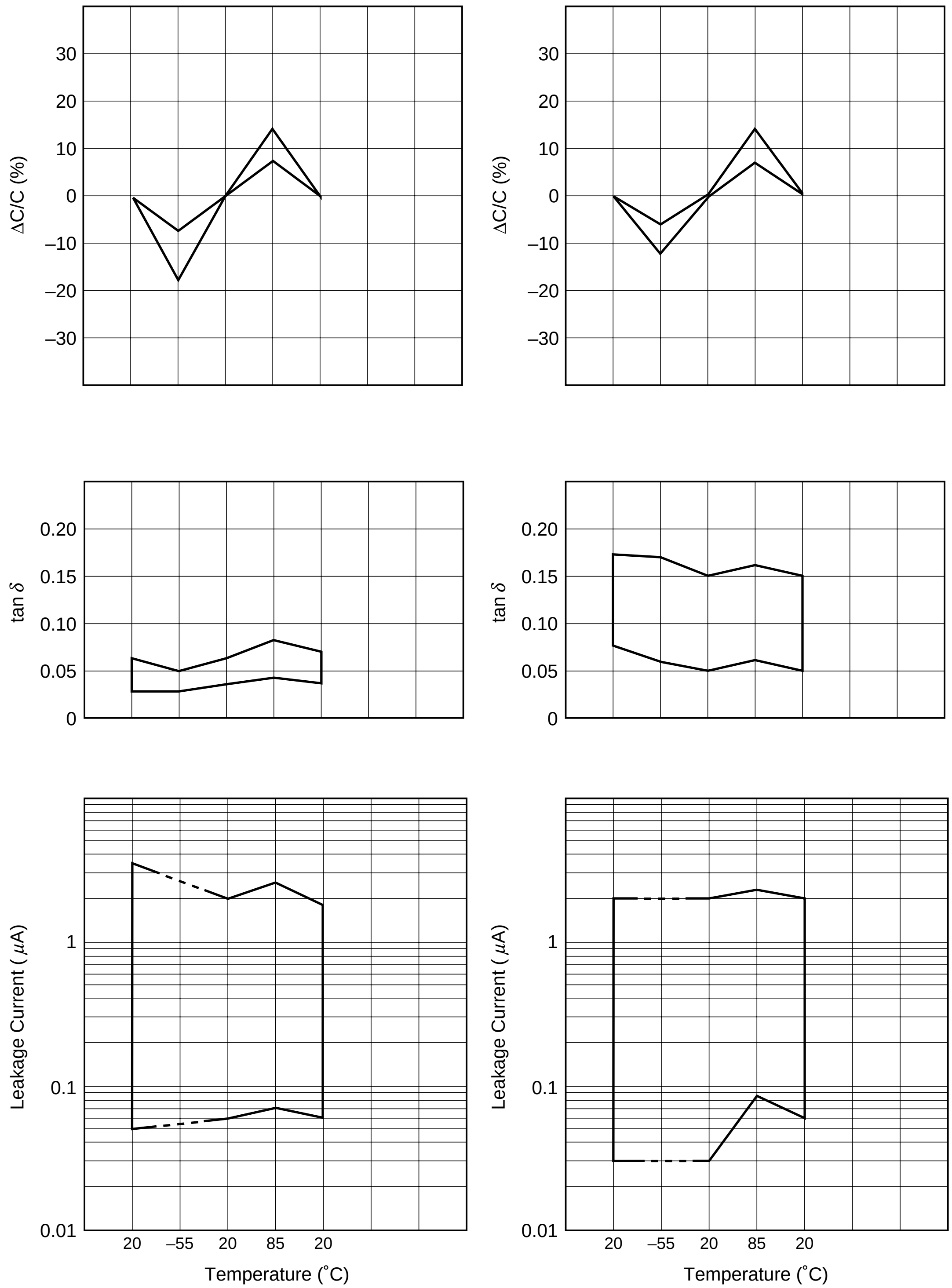
6.8 μF/6.3 V



3.3 μF/16 V

- **PSN Series: C Case**

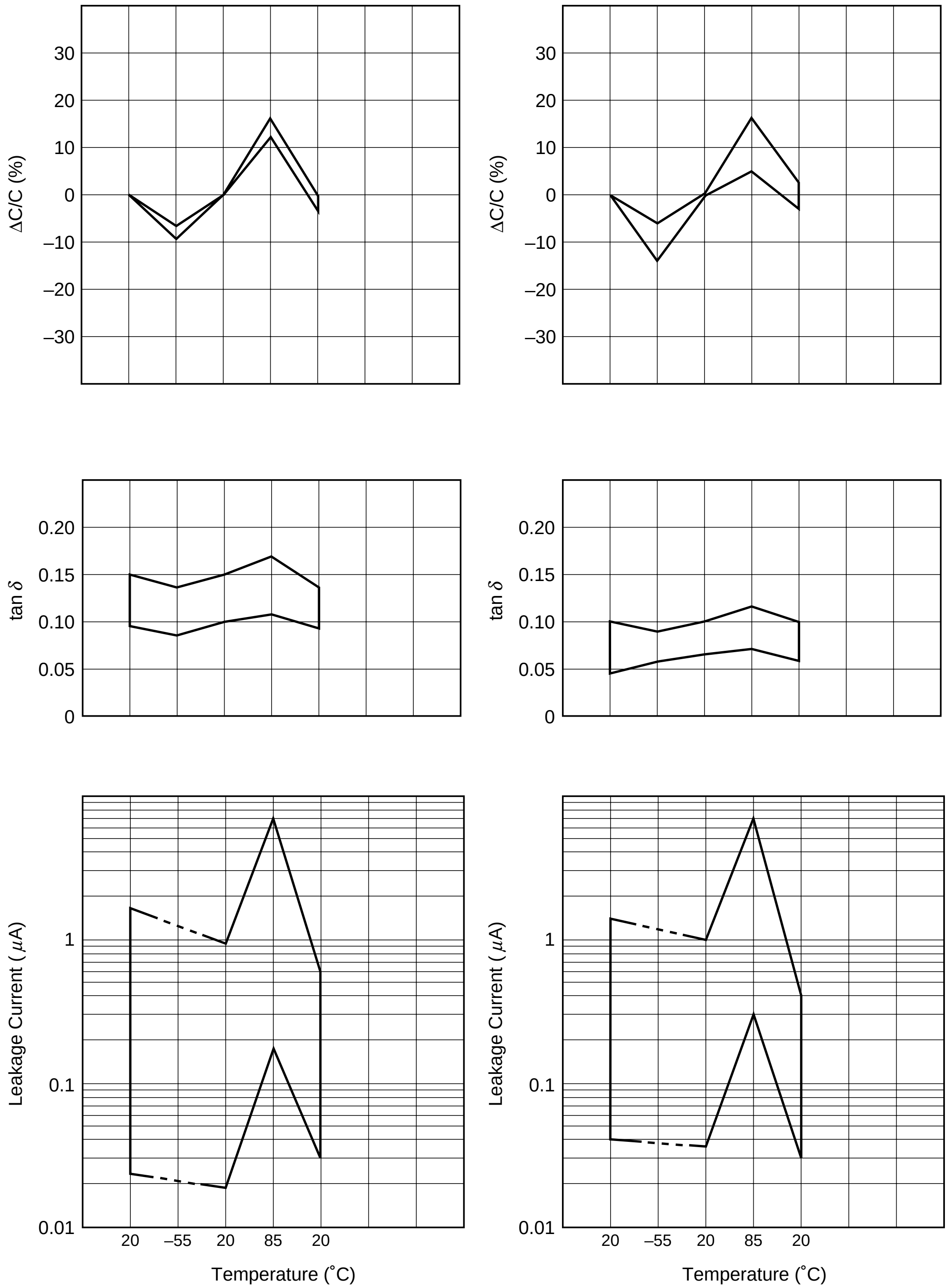
Characteristics at High and Low Temperature



47 μF/6.3 V   33 μF/10 V

• **PSN Series: D Case**

Characteristics at High and Low Temperature

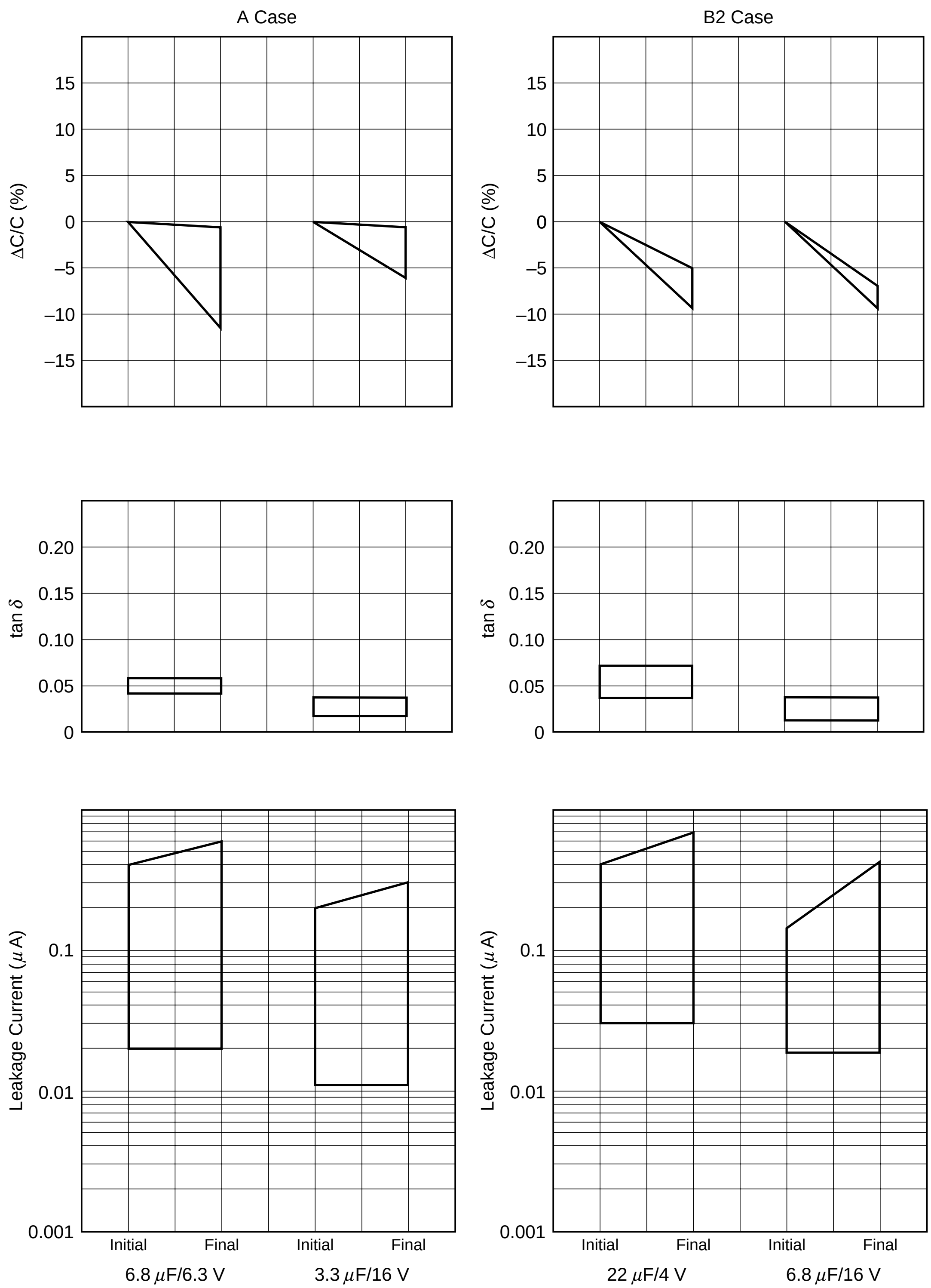


150 μF/6.3 V

100 μF/10 V

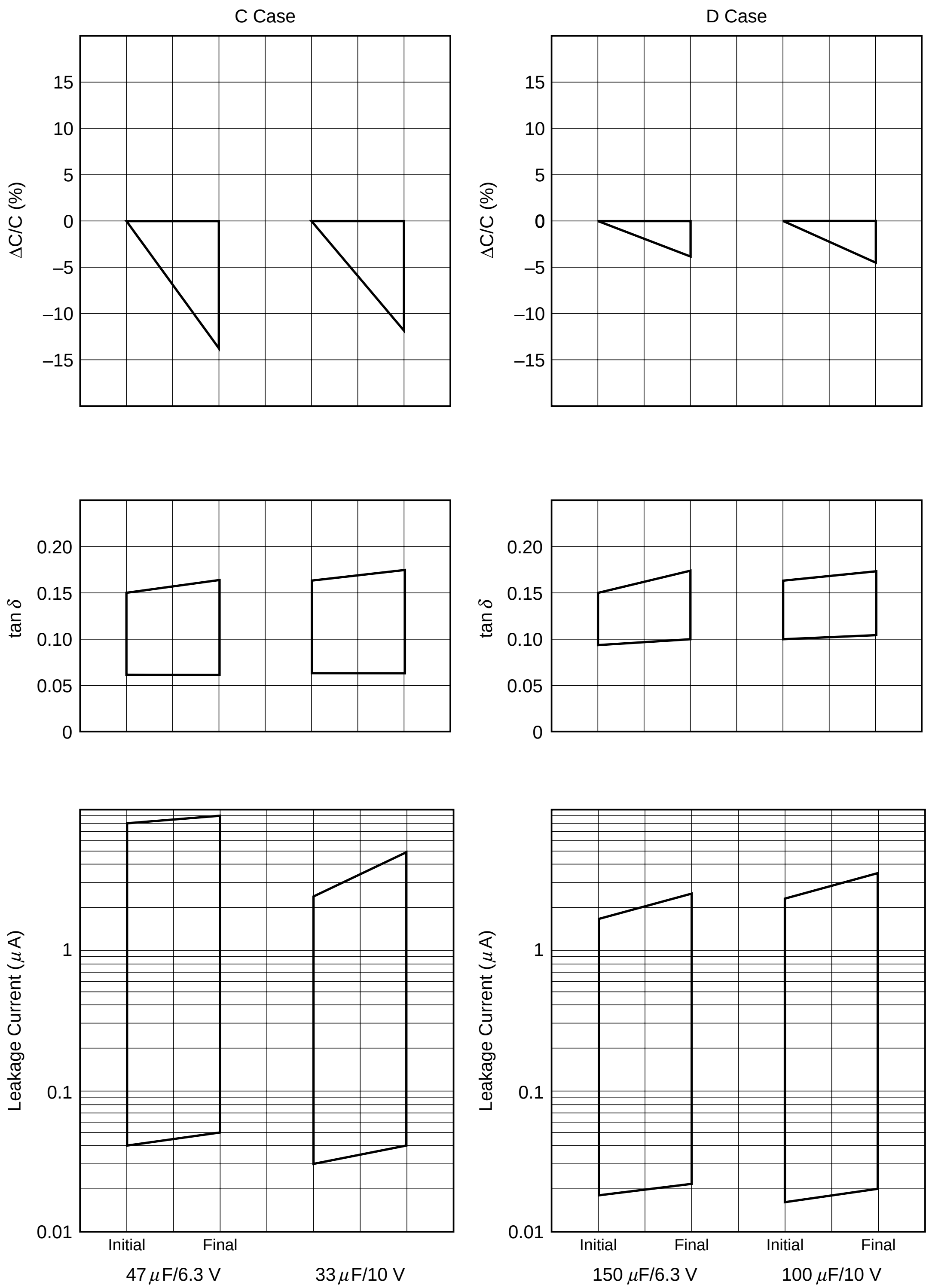
• **PSN Series**

Resistance to Soldering Heat (Reflow for 10 sec. at 240˚C)



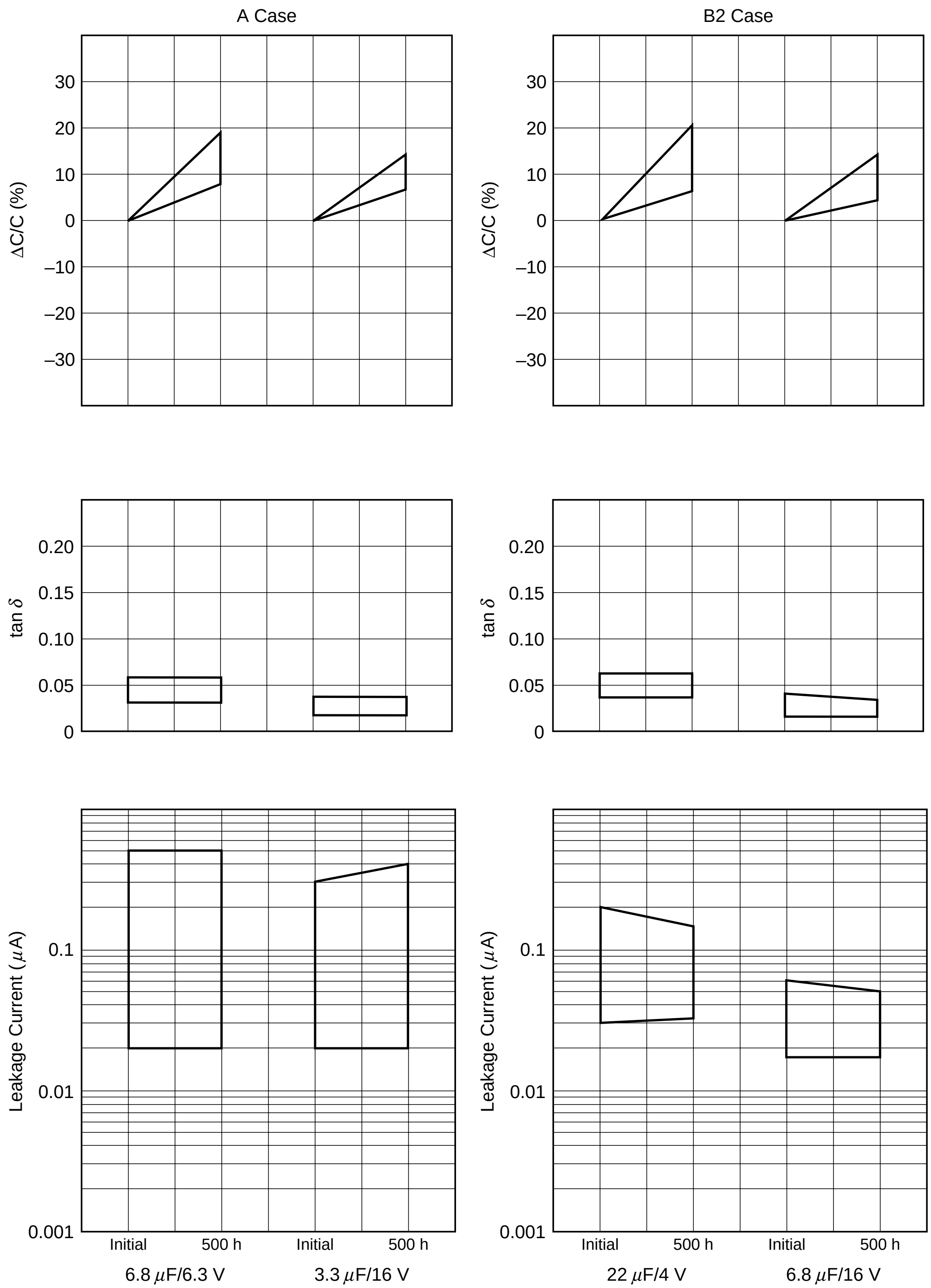
• **PSN Series**

Resistance to Soldering Heat (Reflow for 10 sec. at 240˚C)



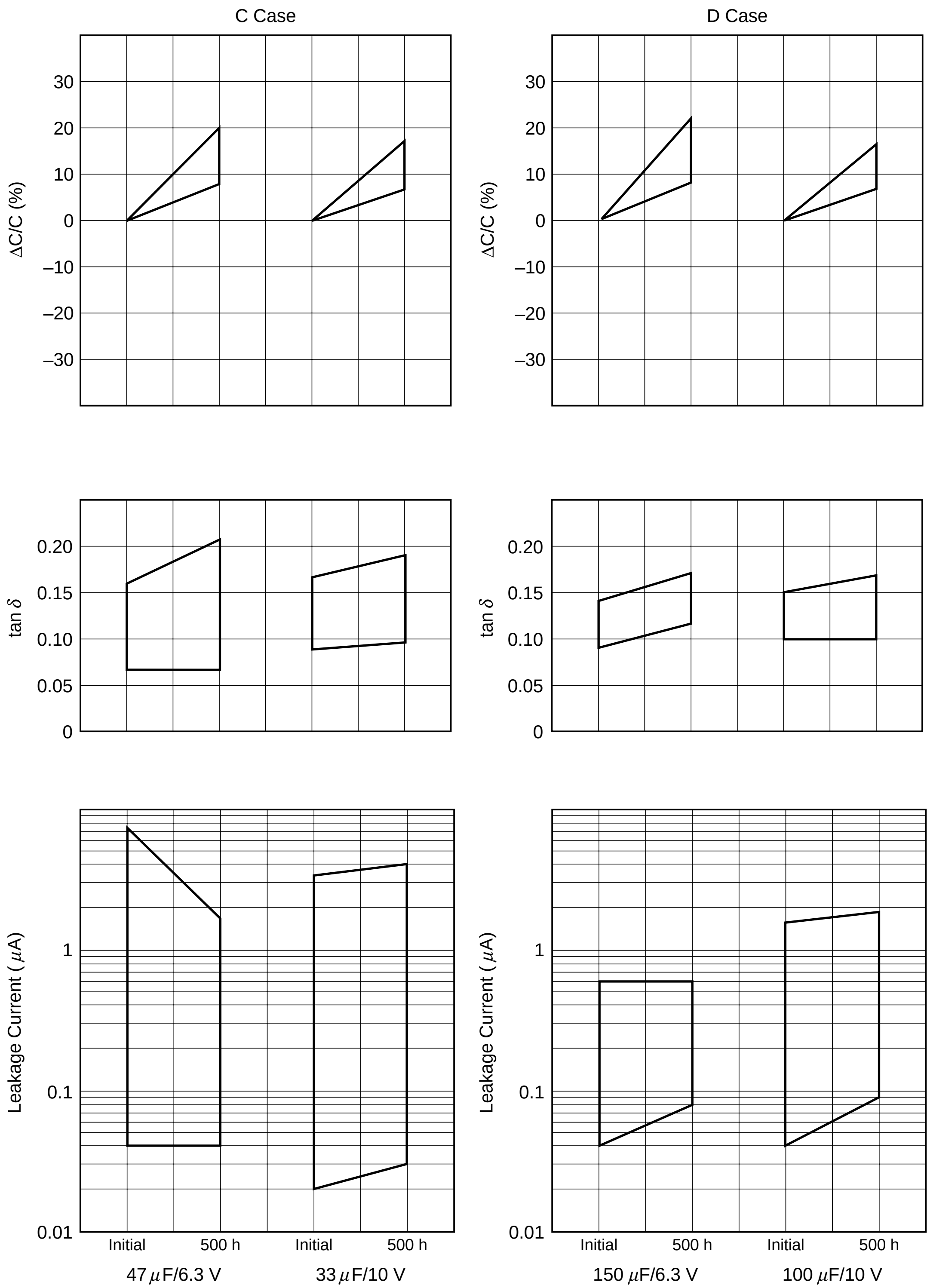
- **PSN Series**

Damp Heat, Steady State (40˚C, 90 to 95% RH)



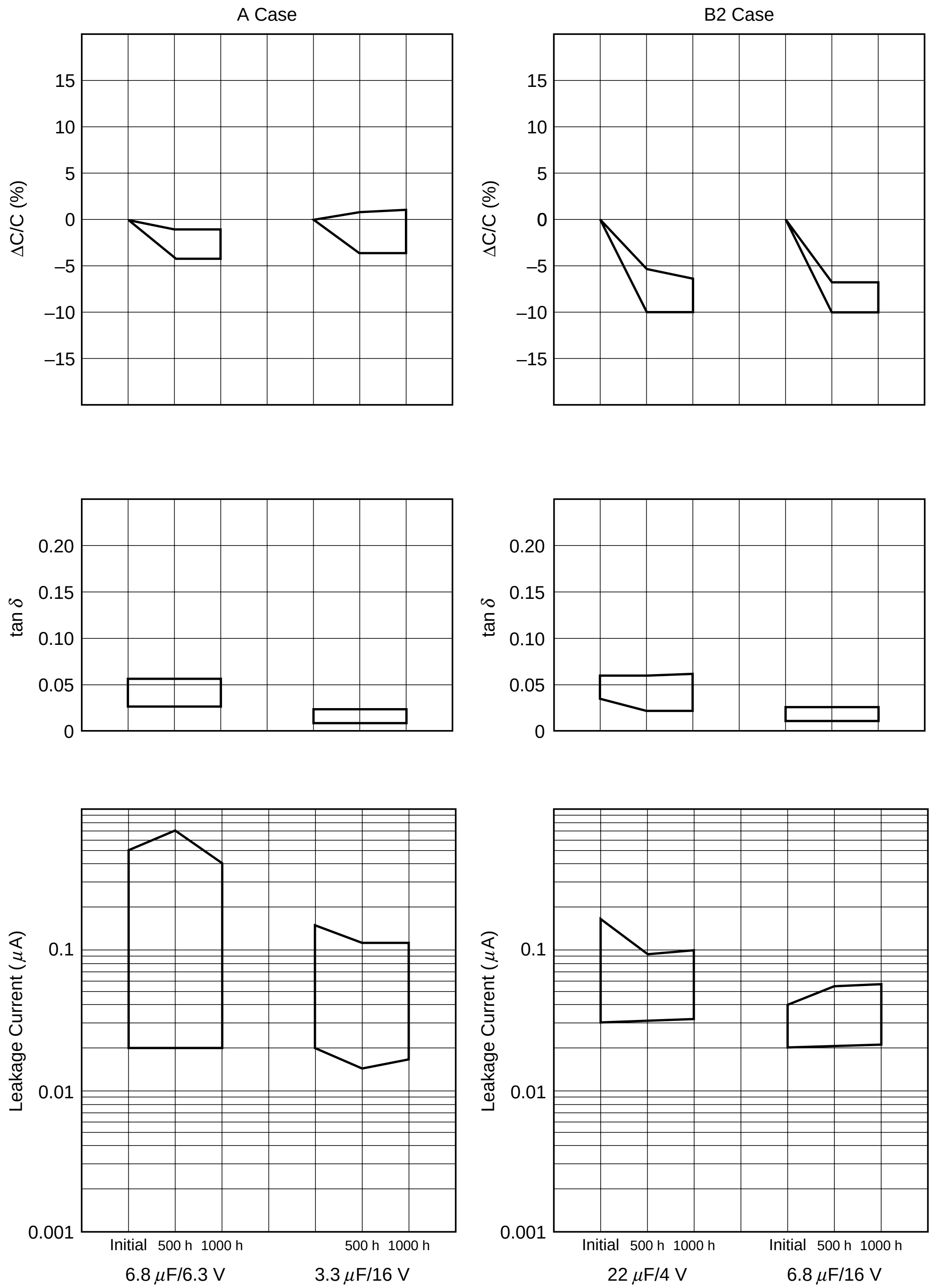
- **PSN Series**

Damp Heat, Steady State (40˚C, 90 to 95% RH)



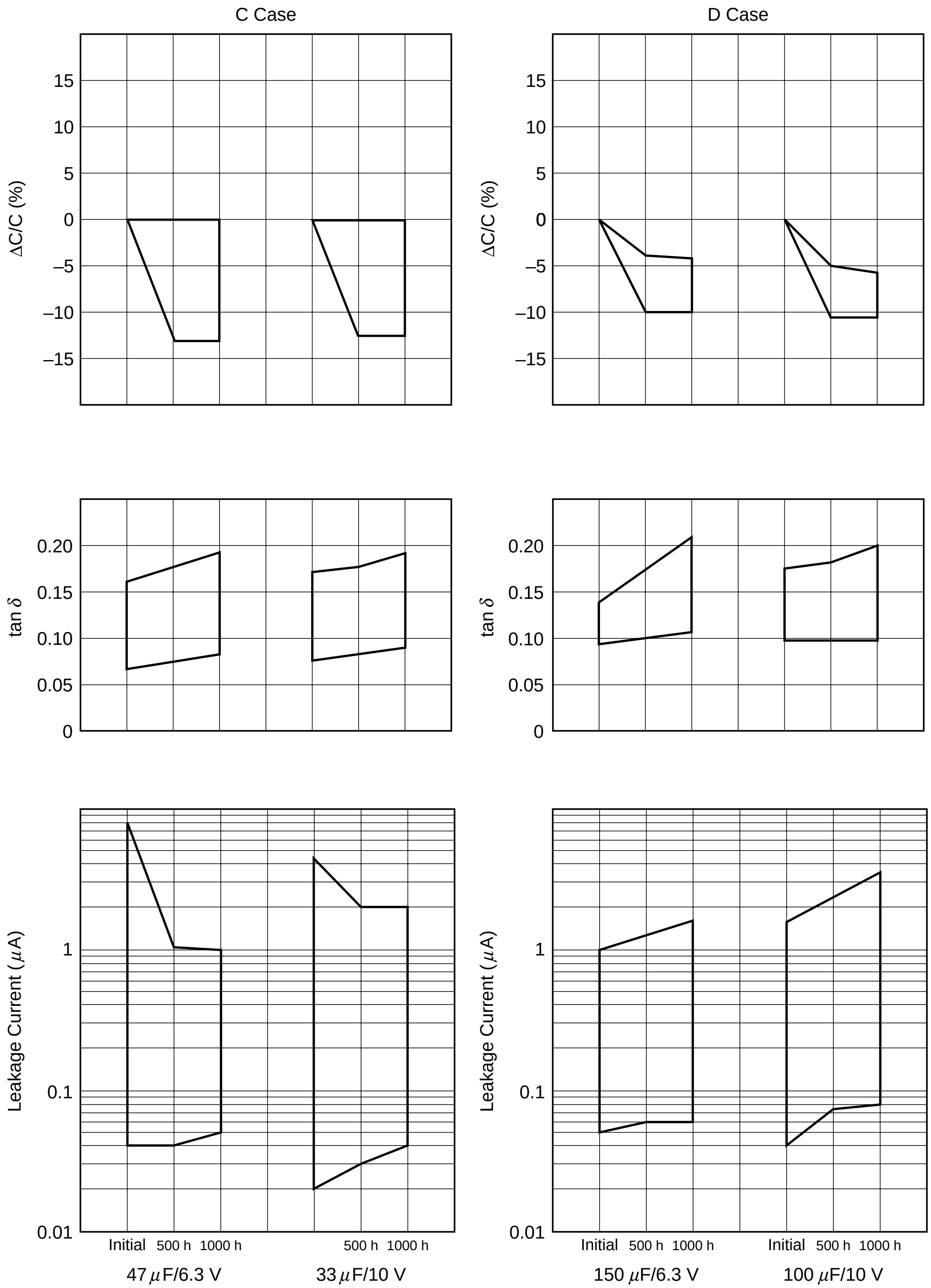
- **PSN Series**

Endurance (85˚C, Rated Voltage × 1.3)
(Reference Date)

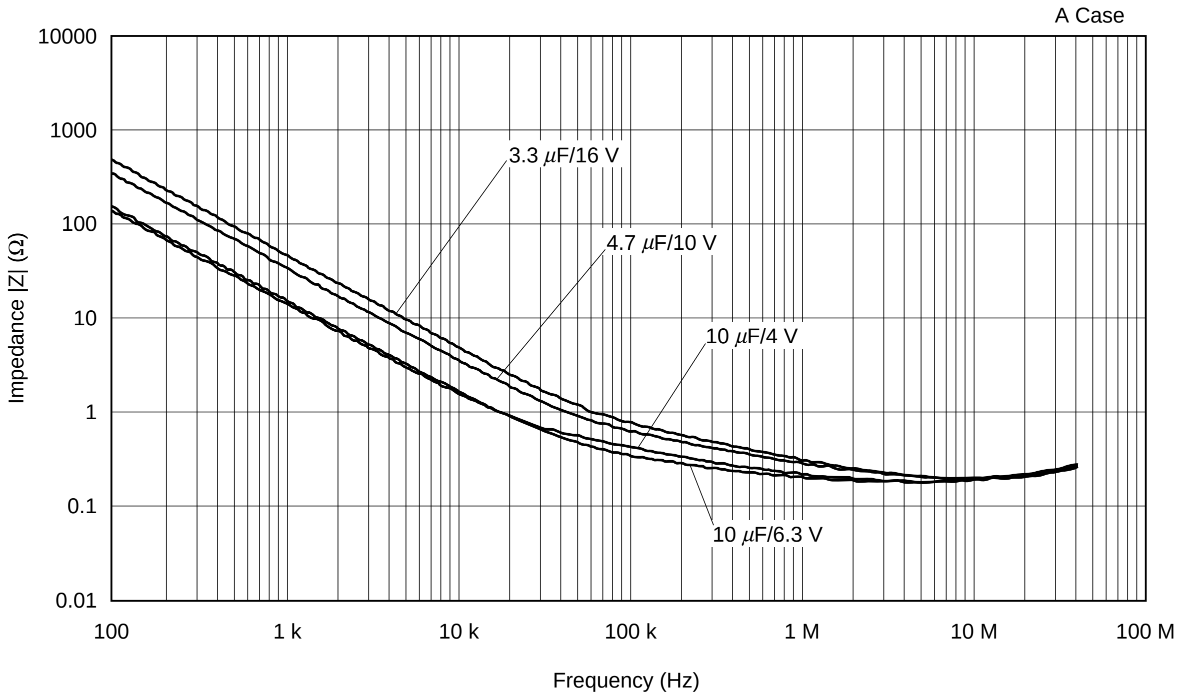


• **PSN Series**

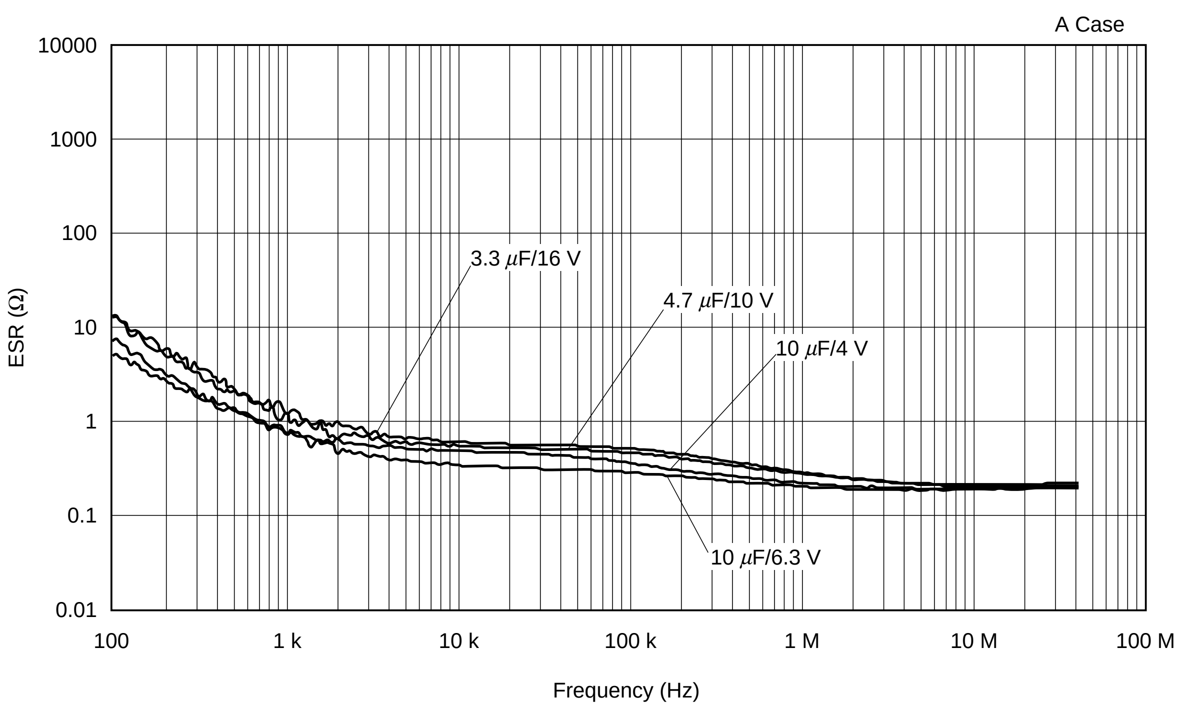
Endurance (85˚C, Rated Voltage × 1.3)
(Reference Date)



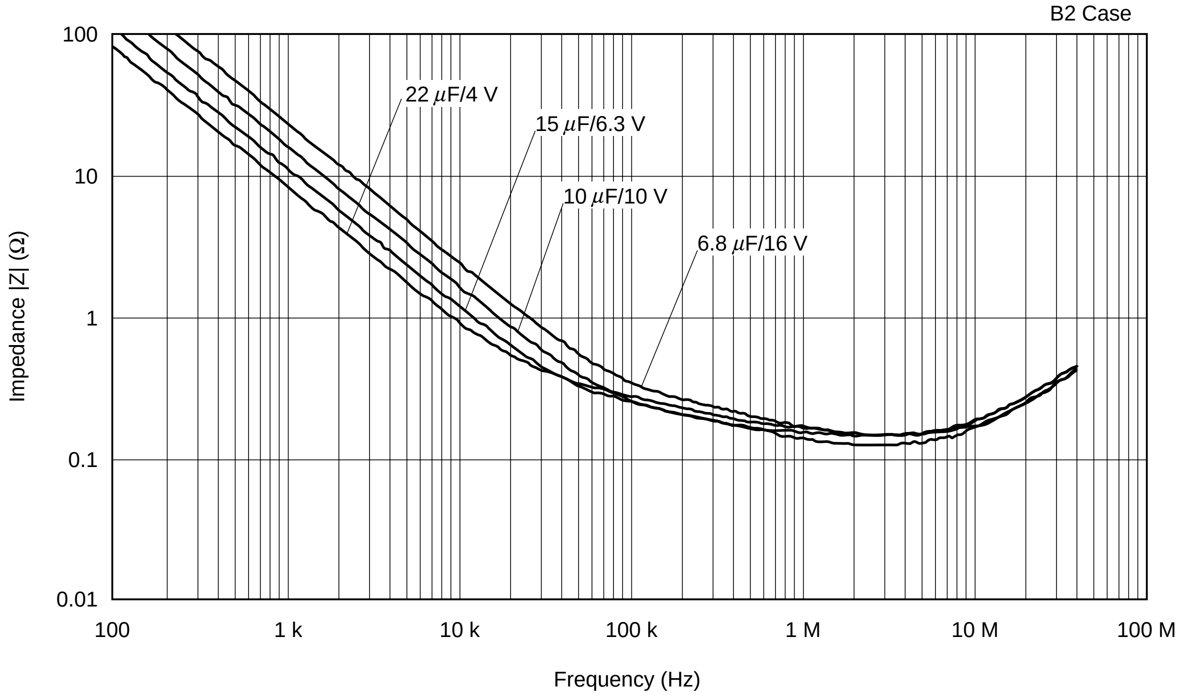
Impedance – Frequency Characteristics



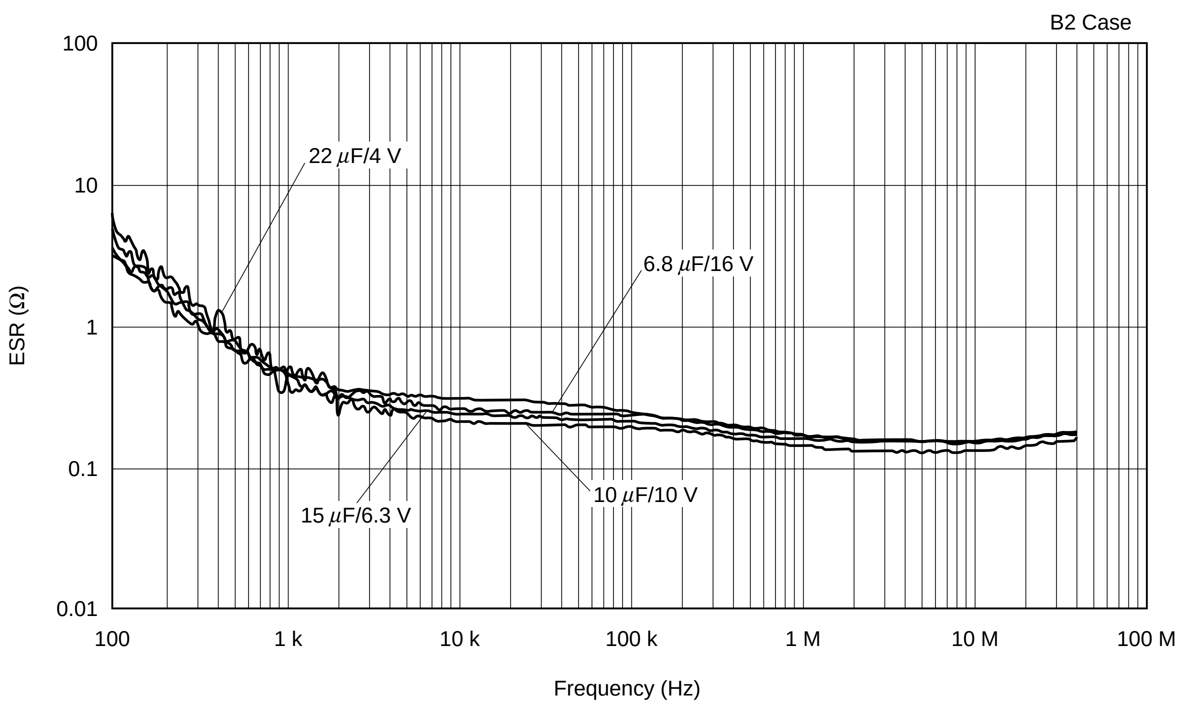
ESR – Frequency Characteristics



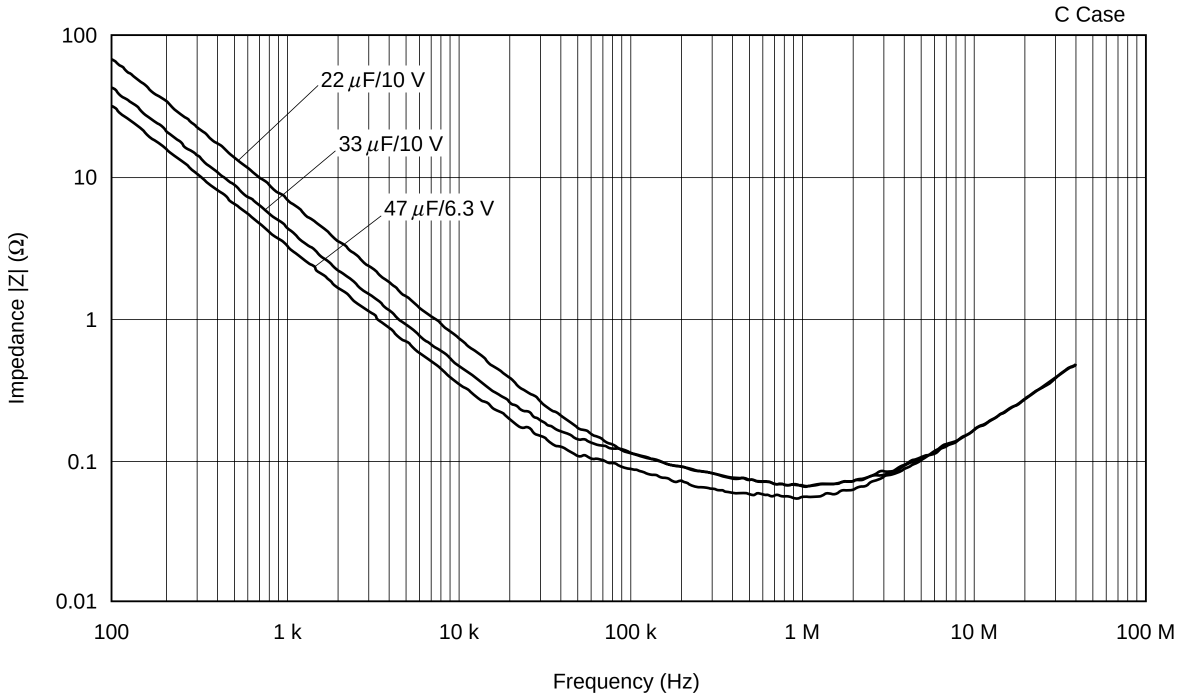
Impedance – Frequency Characteristics



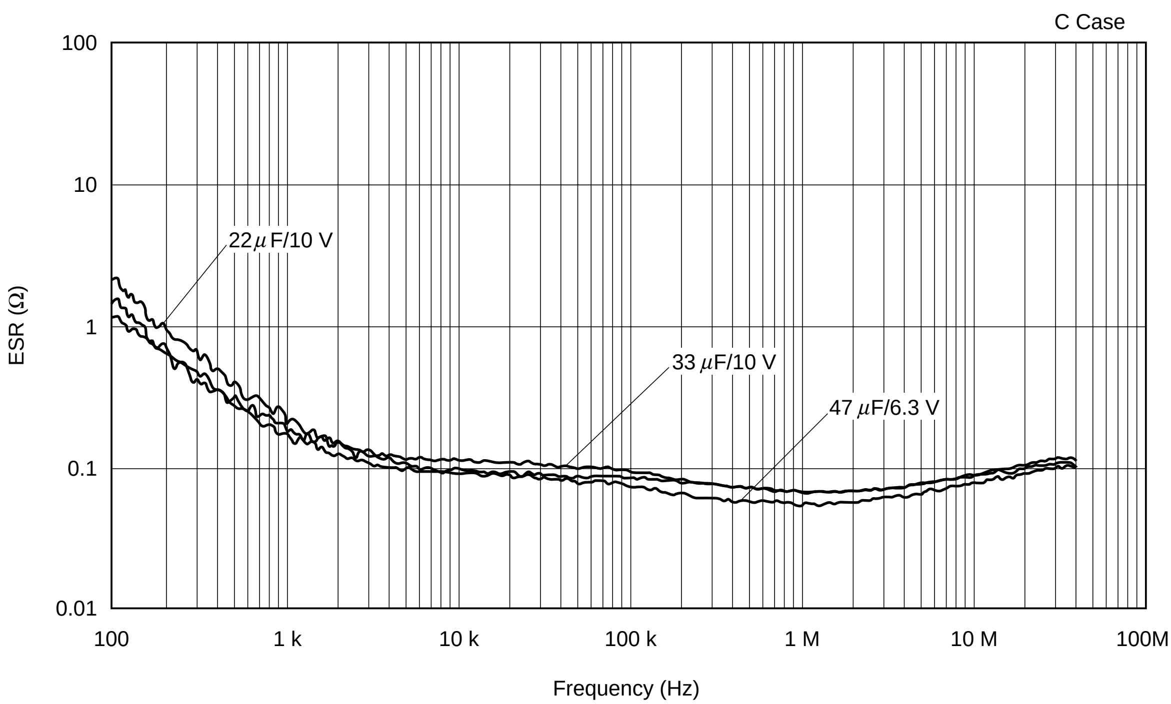
ESR – Frequency Characteristics



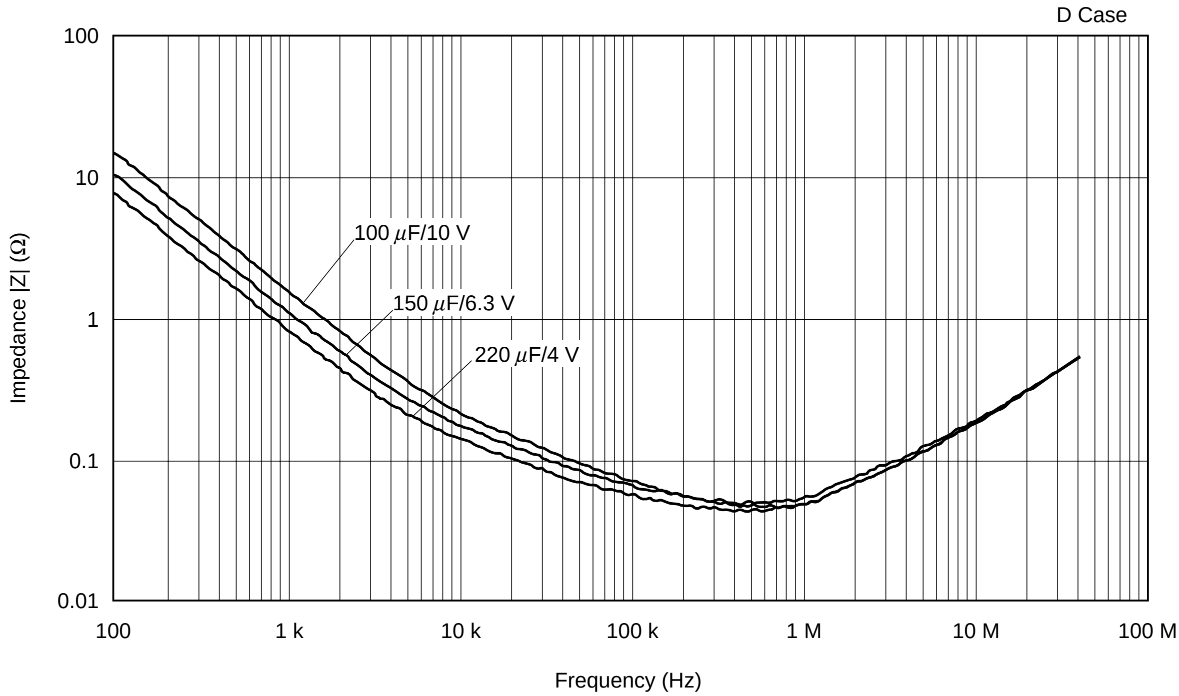
Impedance – Frequency Characteristics



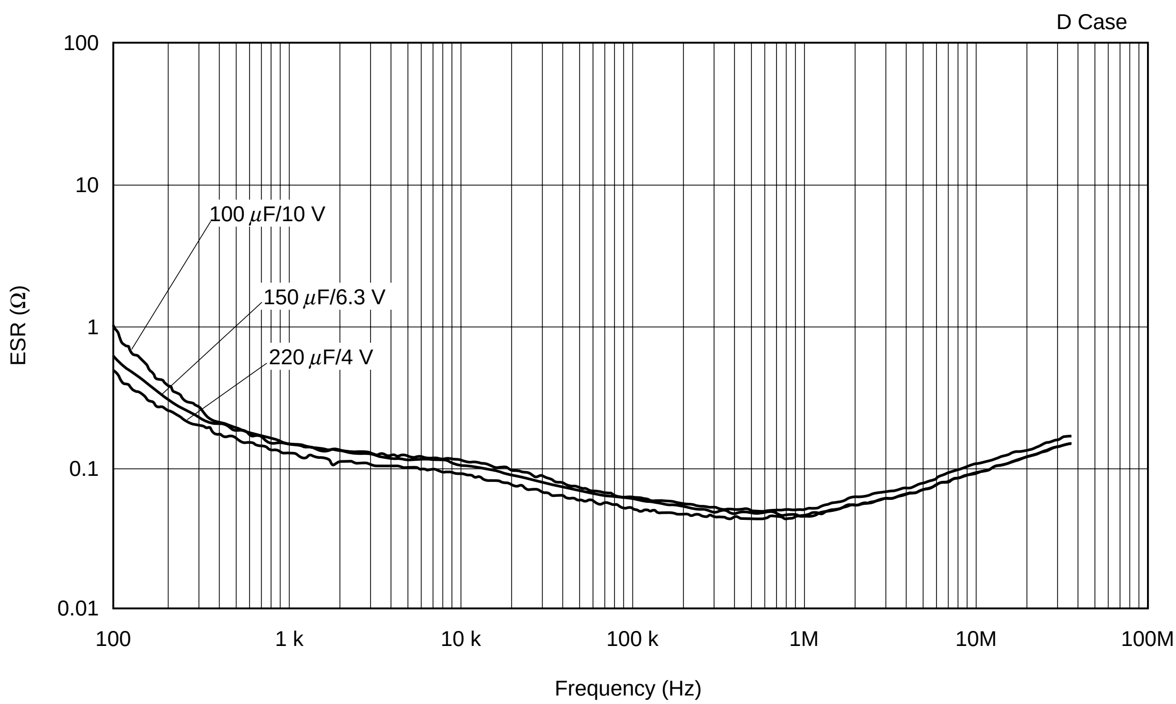
ESR – Frequency Characteristics



Impedance – Frequency Characteristics



ESR – Frequency Characteristics



PSM SERIES

NEC's PSM series have lower impedance than conventional tantalum capacitor using manganese dioxided (MnO_2).

These capcitors are suitable for noise reduction in a high-frequency application with its low ESR.

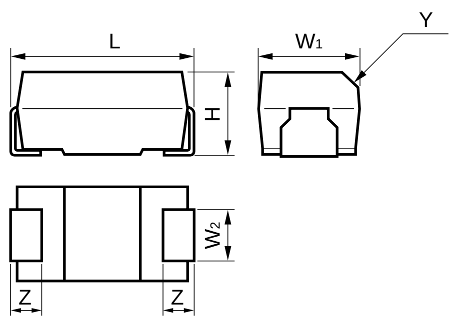
FEATURES

- Low impedance/low ESR
- Wide operating temperature (–55 to 105˚C)
- High ripple current

APPLICATIONS

- D/D converter
- Suppression of oscillation for general purpose regulator

OUTLINE DRAWINGS AND DIMENSIONS



[D case]

Unit: mm (inch)

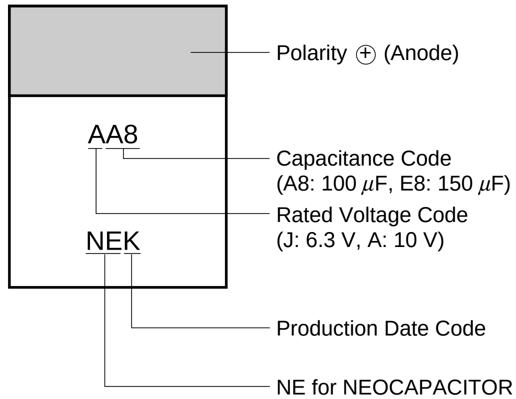
Case Size	EIA Code	L	W_1	W_2	H	Z	Y
D	7343	7.3±0.3 (0.287±0.012)	4.3±0.3 (0.169±0.012)	2.4±0.1 (0.094±0.004)	2.8±0.3 (0.110±0.012)	1.3±0.3 (0.051±0.012)	0.5C (0.020)

PRODUCT LINE-UP AND CASE SIZE

Capacitance (μF) \ Rated Voltage (V dc)	4	6.3	10	16
68				
100			D	
150		D		
220				

MARKING

[D case]



[Capacitance Code]

Alphabetical Code	A	E	J	N	S	W		Numerical Code	5	6	7	8
Number	1.0	1.5	2.2	3.3	4.7	6.8		Multiplier	10^5	10^6	10^7	10^8

Example A8: $1.0 \times 10^8 = 10^8$ pF = 100 μF

[Marking of Production Date Code]

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1998	N	P	Q	R	S	T	U	V	W	X	Y	Z
1999	a	b	c	d	e	f	g	h	j	k	l	m
2000	n	p	q	r	s	t	u	v	w	x	y	z
2001	A	B	C	D	E	F	G	H	J	K	L	M

Date code will resume beginning in 2002.

PART NUMBERING SYSTEM

– Bulk –

PSM D 0J 157 M

- M — Capacitance Tolerance (±20 %)
- 157 — Capacitance in pF: First two digits represent significant figures and third digit specifies number of zeros to follow.
- 0J — Rated Voltage (0J: 6.3 V, 1A: 10 V)
- D — Case Size
- PSM — Series

– Tape and Reel –

TE PSMD0J157 12 R

- R — Packing Orientation [R: Cathode on the side of sprocket hole]
- 12 — Tape Width (12: 12 mm)
- PSMD0J157 — Same as Bulk (see left)
- TE — Tape and Reel

PERFORMANCE CHARACTERISTICS

Item		Specification			Test Method
Operating Temperature Range		–55 to +105°C			
Rated Voltage		6.3	10	Vdc	Temperature: 85°C
Surge Voltage		8	13	Vdc	Temperature: 85°C
Category Voltage		5	8	Vdc	Temperature: 105°C (*1)
Capacitance Range		100 μF, 150 μF			Frequency: 1 kHz
Capacitance Tolerance		±20%			
Leakage Current (L.C.)		0.1 CV (μA) or 3 μA whichever is greater			5 min, after rated voltage applied
Tangent of Loss Angle (tan δ)		0.30 max.			Frequency: 1 kHz
Equivalent Series Resistance (ESR)		80 mΩ max.			Frequency: 100 kHz
Surge Voltage Test		ΔC/C : ±20% tan δ : Initial Requirement L.C. : Initial Requirement			Temperature: 85°C Surge Voltage for 30 sec. Series Resistance: 1 kΩ Discharge Voltage for 5 min. 30 sec. 1000 cycles
Characteristics at High and Low Temperature	Temp.	–55°C	+105°C		Step 1: 20°C Step 2: –55°C Step 3: 20°C Step 4: 105°C Step 5: 20°C
	ΔC/C	0, –20%	+50, 0%		
	tan δ	Initial Requirement	Initial Requirement × 1.5		
	L.C.	–	Initial Requirement × 10		
Rapid Change of Temperature		ΔC/C : ±20% tan δ : Initial Requirement L.C. : Initial Requirement			–55 to +105°C 5 cycles
Resistance to Soldering		ΔC/C : ±20% tan δ : Initial Requirement L.C. : Initial Requirement			Reflow soldering, 240°C, 10 sec.
Damp Heat, Steady State		Capacitance: +30% to –20% of Rated voltage tan δ : Initial Requirement × 1.5 L.C. : Initial Requirement			Temperature: 40°C 90 to 95% RH 500 hours
Endurance		ΔC/C : ±20% tan δ : Initial Requirement × 1.5 L.C. : Initial Requirement			Temperature: 85°C Rated Voltage applied Temperature: 105°C Category Voltage Applied 1000 hours
Failure Rate		λ_0 = 1%/1000H			
Permissible Ripple Current		1.5 Arms, 2.5 Ap-p			Frequency: 1 MHz

LEGEND
CV : Product of capacitance in μF and voltage in V
ΔC/C : Capacitance Change Ratio

*1: Category voltage at 85°C or more is calculated by following expression.

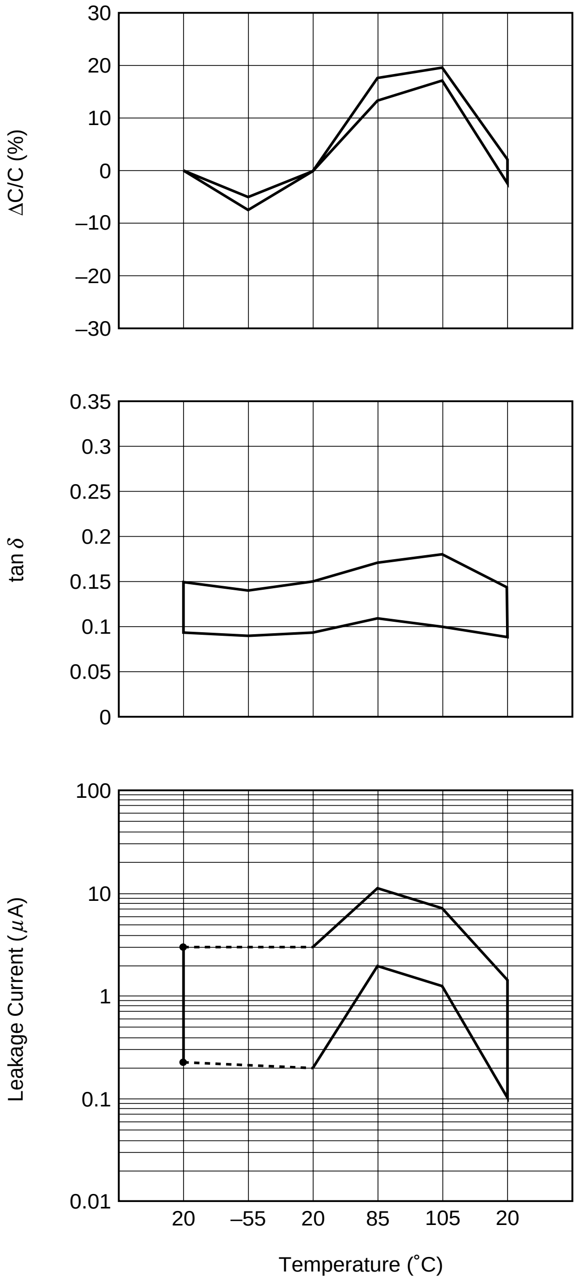
$$U_T = U_R - \frac{U_R - U_C}{20} (T - 85)$$

U_R : Rated Voltage
U_C : Category Voltage at 105°C

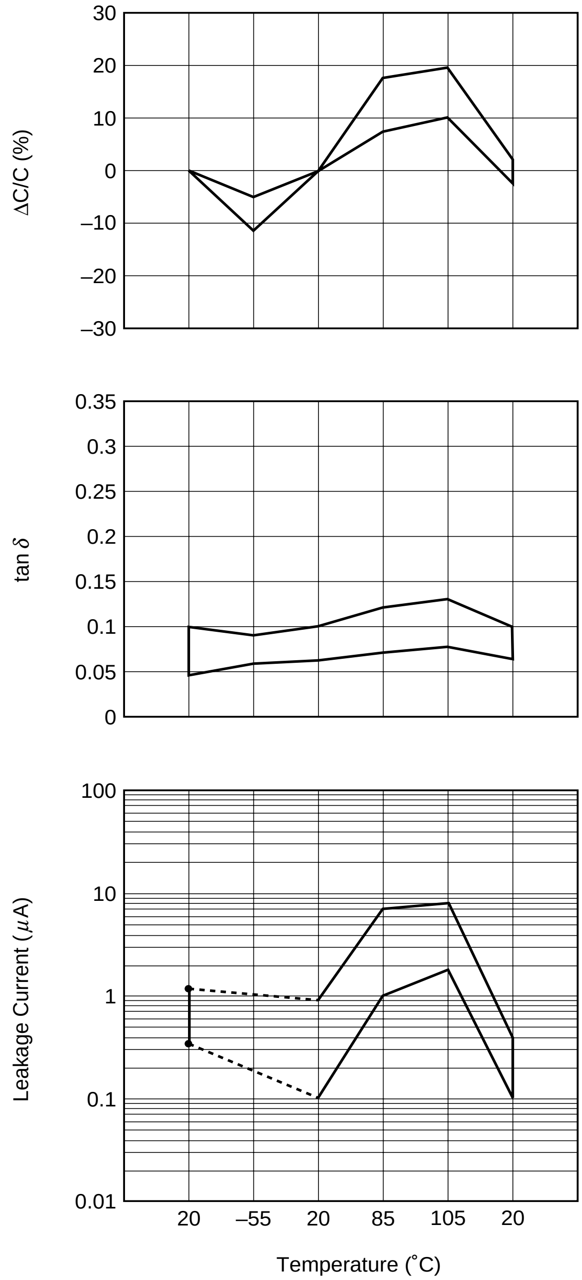
DC Rated Voltage @85˚C (105˚C) Vdc	Capacitance @20˚C, 1 kHz μF	Case Size	Part Number	Leakage Current @20˚C μA Max.	tan δ @20˚C, 1 kHz % Max.	ESR @20˚C, 100 kHz mΩ Max.	Ripple Current @20˚C, 1 MHz Ap-p Max.
6.3 (5)	150	D	PSMD0J157M	94.5	30	80	2.5
10 (8)	100	D	PSMD1A107M	100	30	80	2.5

- **PSM Series**

Characteristics at High and Low Temperature



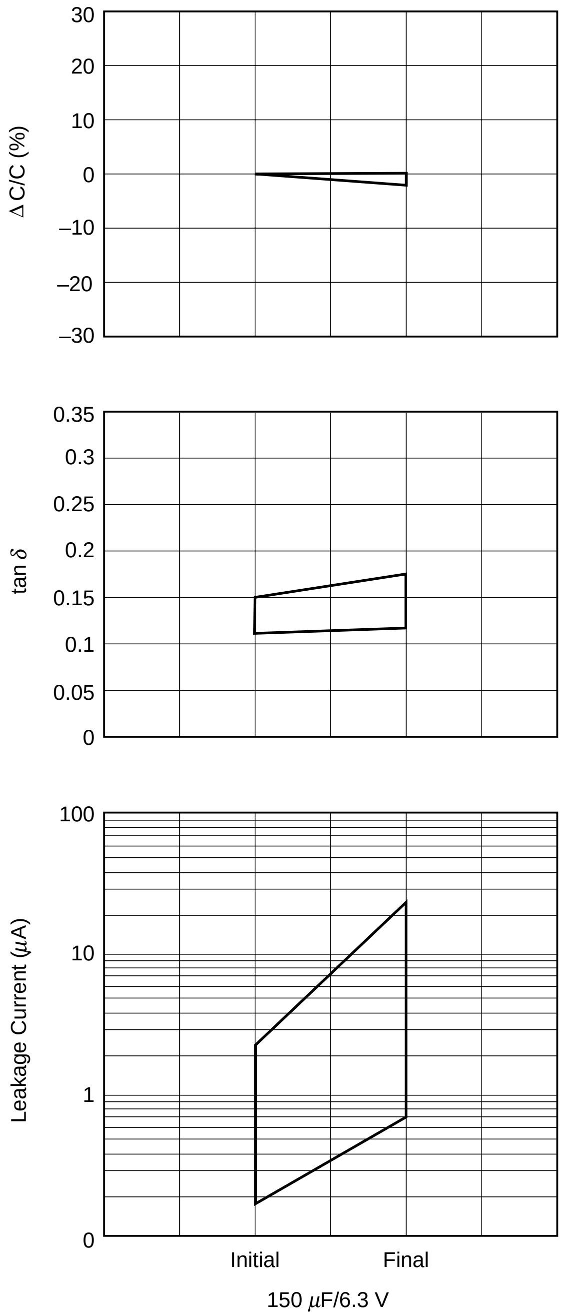
150 μF/6.3 V

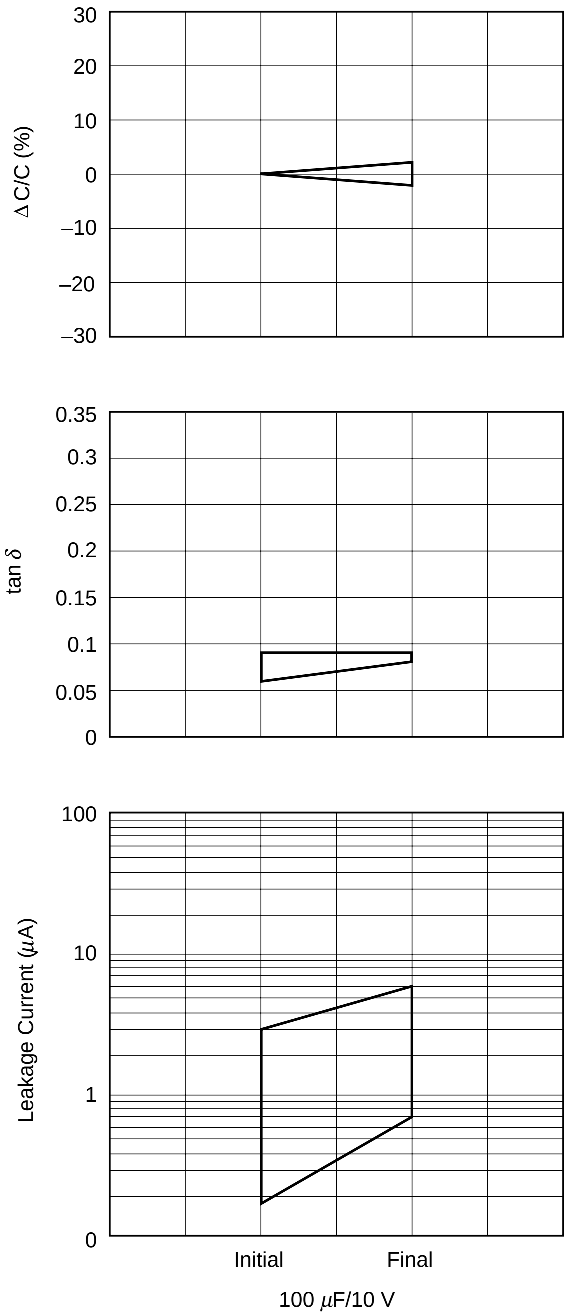


100 μF/10 V

- **PSM Series**

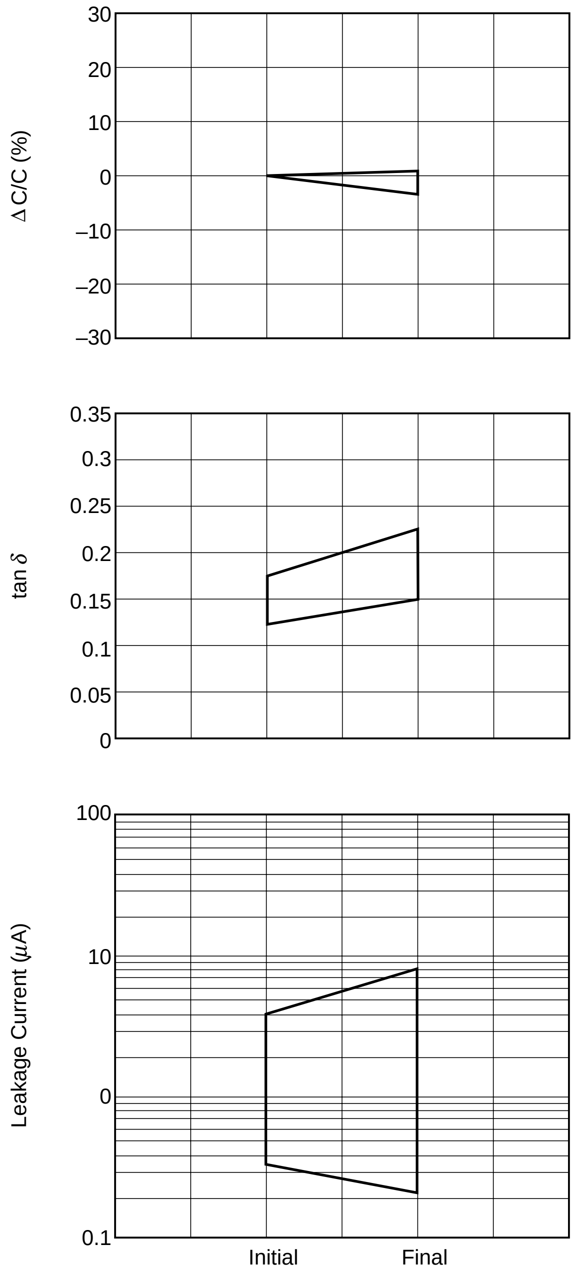
Damp Heat, Steady State (40˚C, 90 to 95%RH)



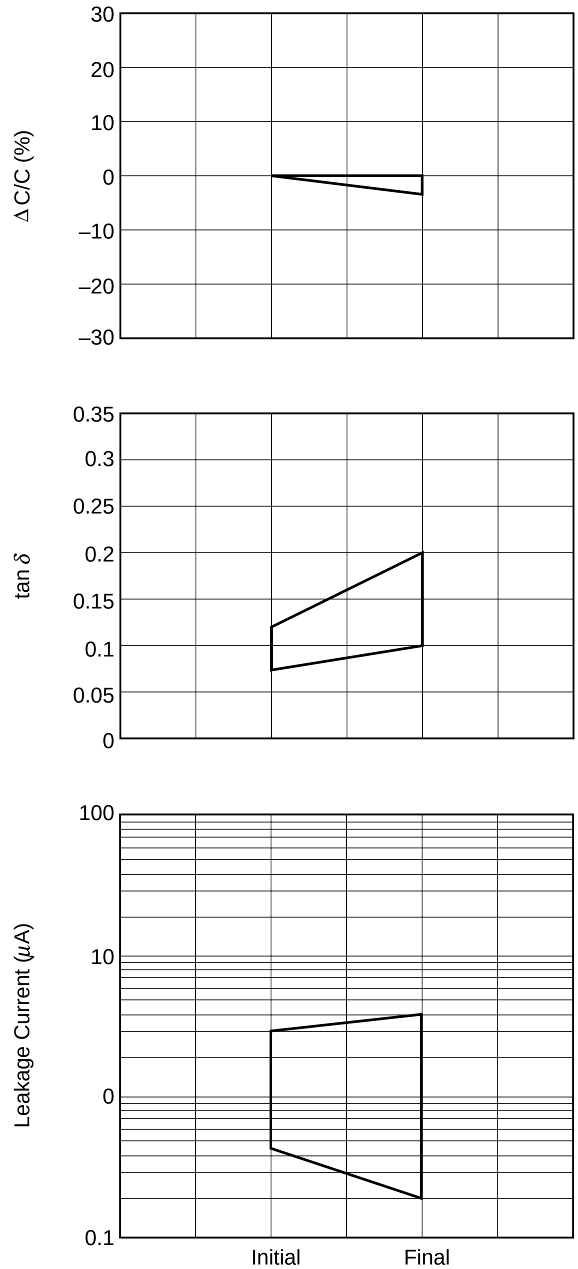


- **PSM Series**

Surge Voltage (85˚C, rated voltage × 1.3, charge for 30 seconds, discharge for 6 minutes, 1000 cycles)



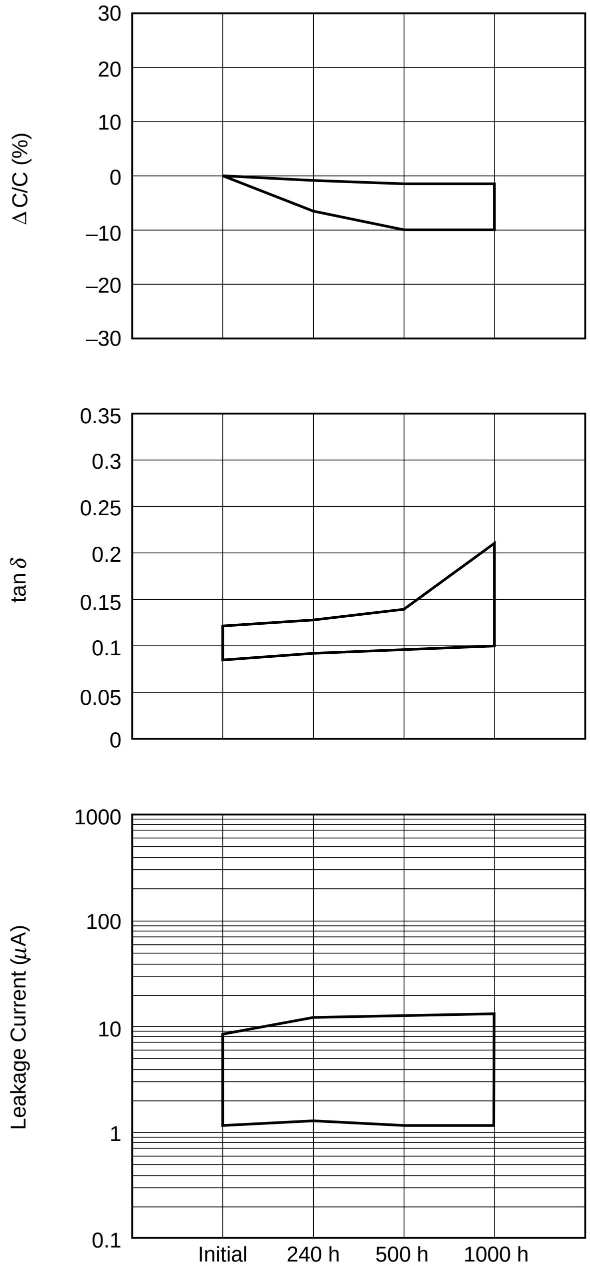
150 μF/6.3 V



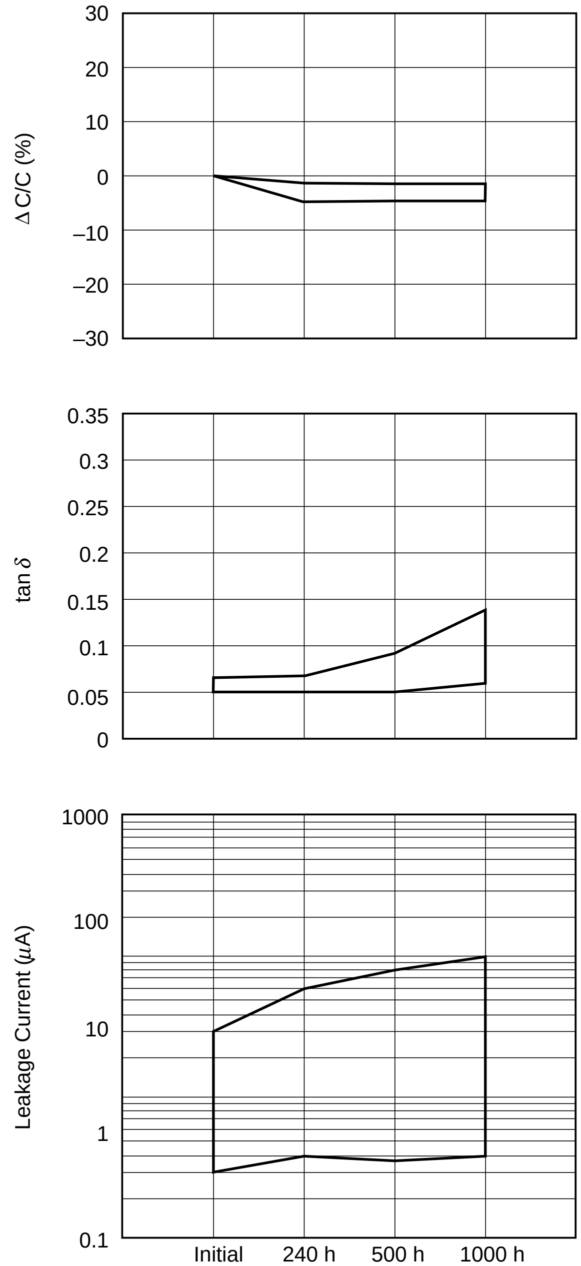
100 μF/10 V

- **PSM Series**

Endurance (105˚C, Rated Voltage)



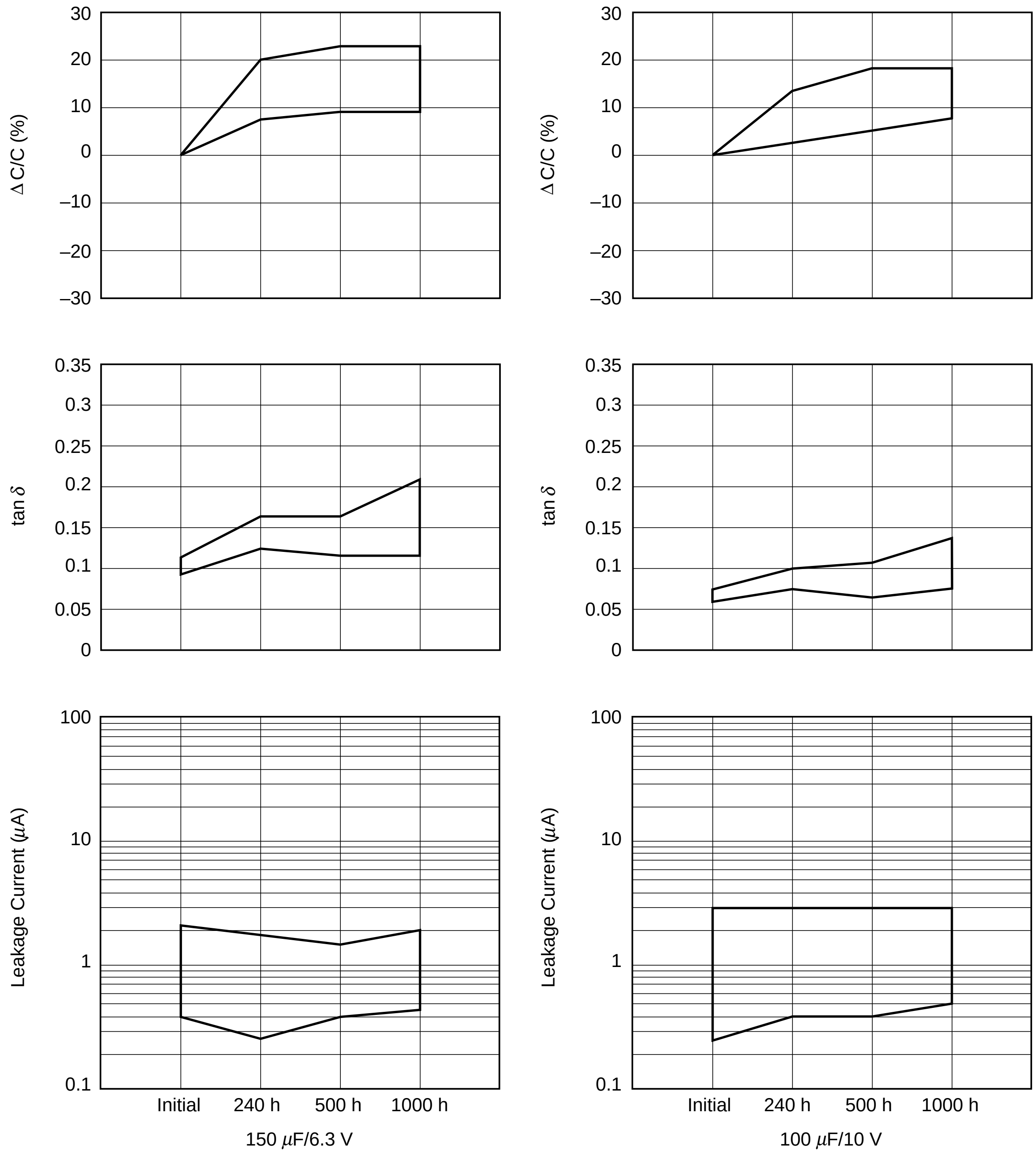
150 µF/6.3 V



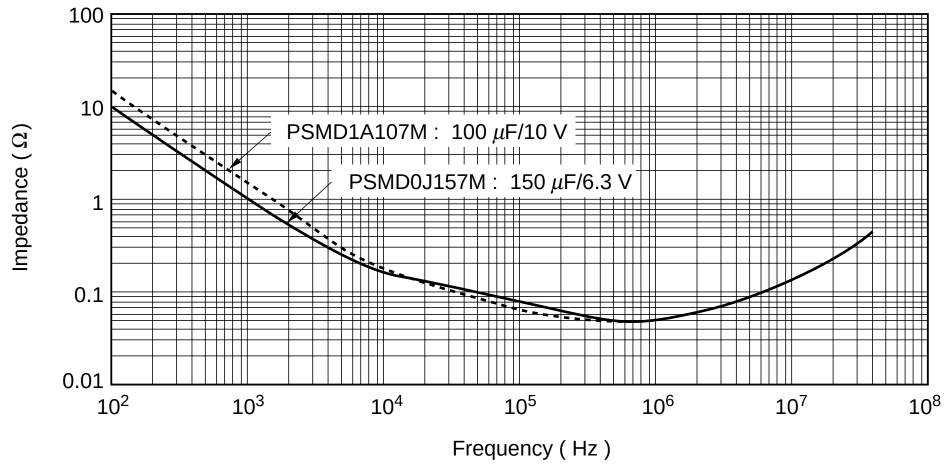
100 µF/10 V

- **PSM Series**

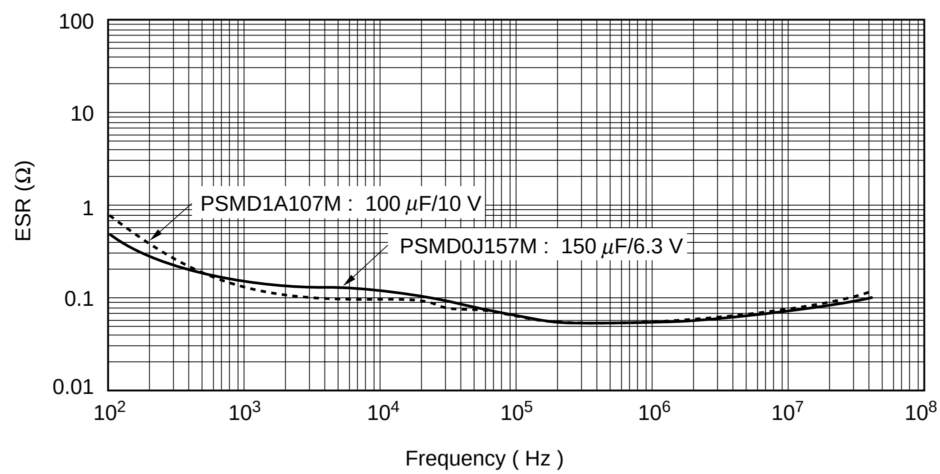
Damp Heat, Steady State (40˚C, 90 to 95%RH)



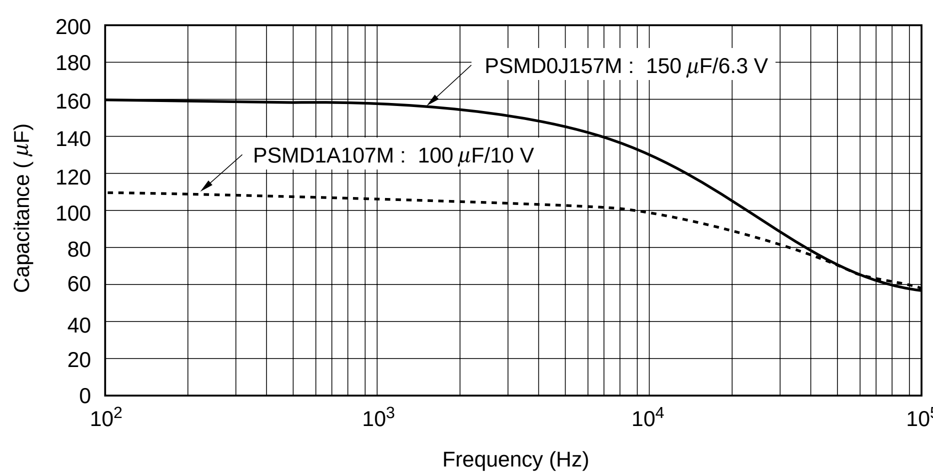
- **Impedance – Frequency Characteristics (Reference Date)**



- **ESR – Frequency Characteristics (Reference Date)**

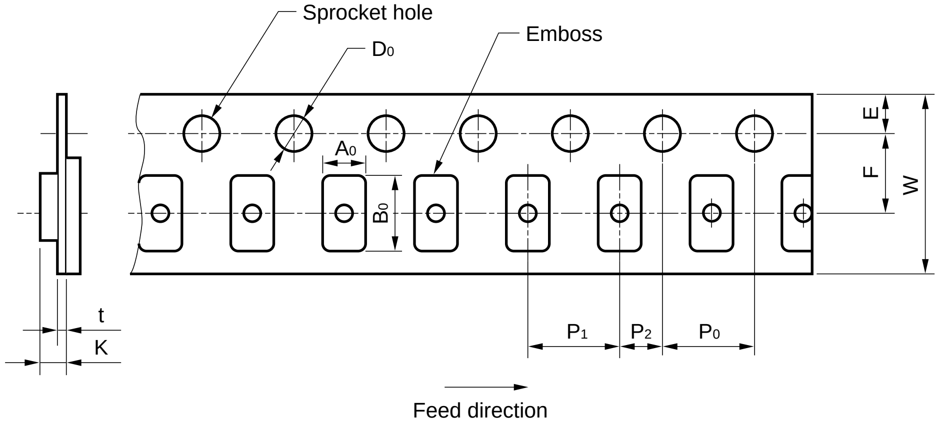


- **Capacitance – Frequency Characteristics (Reference Date)**



Tape and reel specifications

Plastic Tape Carrier

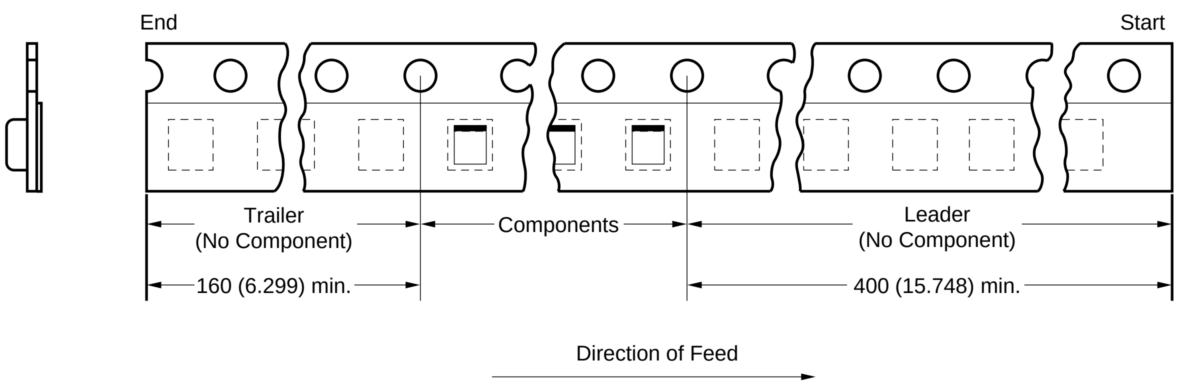


Unit: mm (inch)

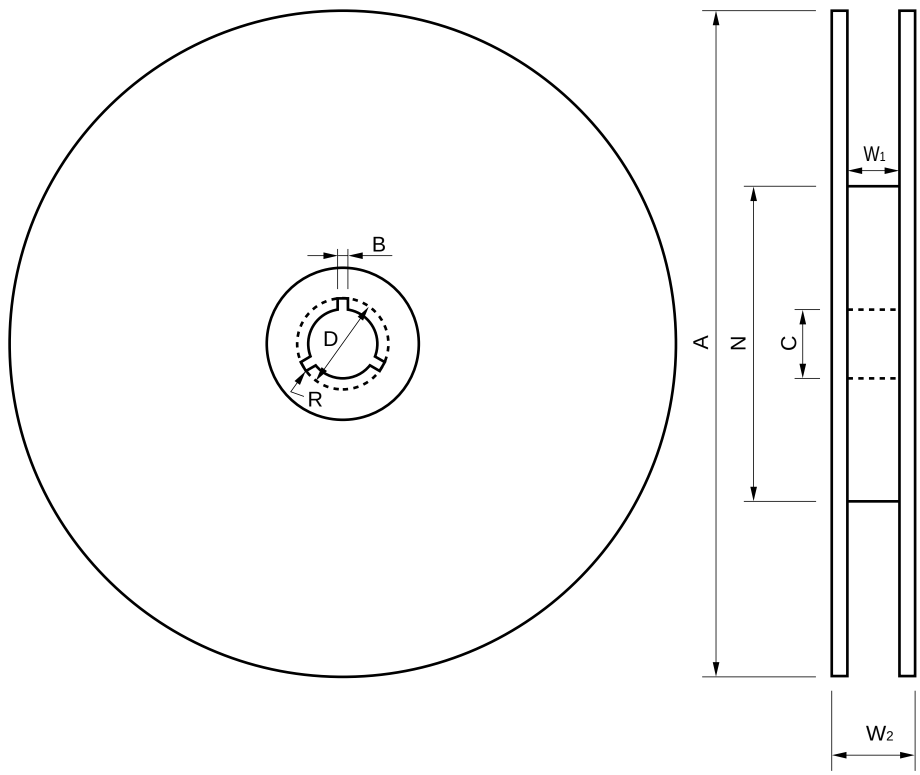
Case Size	EIA Code	W±0.3 (±0.012)	F±0.05 (±0.002)	E±0.1 (±0.004)	P_1±0.1 (±0.004)	P_2±0.1 (±0.002)	P_0±0.1 (+0.004)	$D_0{}^{+0.1}_{0}$ ($^{+0.004}_{0}$)	t	A_0±0.2 (±0.008)	B_0±0.2 (±0.008)	K±0.2 (±0.008)
A	3216H	8 (0.315)	3.5 (0.138)	1.75 (0.069)	4 (0.157)	2 (0.079)	4 (0.157)	ϕ1.5 (0.059)	0.2 (0.008)	1.9 (0.075)	3.5 (0.138)	1.9 (0.075)
B2	3528									3.3 (0.130)	3.8 (0.150)	2.1 (0.083)
C	6032	12 (0.472)	5.5 (0.217)		8 (0.315)				0.3 (0.012)	3.7 (0.146)	6.4 (0.252)	3.0 (0.118)
D	7343									4.8 (0.189)	7.7 (0.303)	3.3 (0.130)

Leader and Trailer

Unit: mm (inch)



Reel



Unit: mm (inch)

Tape Width	A ±2 (±0.079)	N min.	C±0.5 (±0.020)	D±0.5 (±0.020)	B±0.5 (±0.020)	W_1±1.0 (±0.039)	W_2 max.	R
8 mm	ϕ178 (7)	ϕ50 (1.969)	ϕ13 (0.512)	ϕ21 (0.827)	2 (0.079)	10 (0.394)	14.5 (0.571)	1 (0.039)
12 mm						14.5 (0.571)	18.5 (0.728)	

[QUANTITY PER REEL]

Case Size	ϕ178 mm
A	2,000
B2	2,000
C	500
D	500

Notes on Correct Use

Most NEOCAPACITOR failures are the result of large leakage current or short circuit.
It is reommended the following be taken into consideration when designing the circuit.

1. Circuit design

(1) Failure rate

The failure rate NEOCAPACITORS depends on applied voltage and operating temperature. Use the following formula for estimating field failure rate.

$$\lambda = \lambda_0 (V/V_0)^3 \times 2^{(T-T_0)/10}$$

λ : Maximum filed faulure rate
λ_0 : Basic failure rate (1% per 1000 h)
T : Operating temperature
V : Applied voltage of actural use
T_0 : 85˚C
V_0 : Rated voltage

(2) Permissible ripple current

Permissible ripple current shall be derated as follows

a. Temperature
–55 to +85˚C Rating value (PSN series)
–55 to +105˚C Rating value (PSM series)

b. Frequency

1 MHz	Rating value
500 kHz	0.9 times rating value
100 kHz	0.75 times rating value

(3) Reverse voltage

Do not apply reverse voltage since the capacitors are polarized.

(4) Derating

Apply appropriate voltage to the capacitors according to the failure rate estimation.
It is recommended that the applied voltage be less than 50% of the rated voltage.

2. Mounting

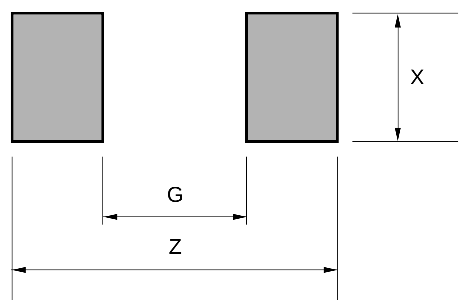
This capacitor is designed to be surface-mounted by means of reflow soldering.

(The conditions under which the capacitor should be soldered with a soldering iron are explained in (2) Using a soldering iron. Because the capacitor is not designed to be soldered by means of laser beam soldering, VPS, or flow soldering, the conditions for these soldering methods are not explained in this document. For the conditions for flow soldering, cantact NEC.)

(1) Reflow soldering

keep in mind the following points when soldering the capacitor in a soldering oven with a hot plate:

(a) Pattern design (in accordance with IEC1188)

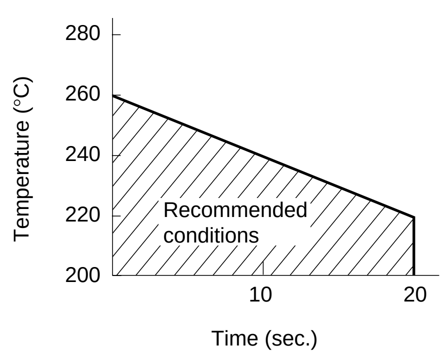


Case	G max.	Z min.	X min.
A	1.1	3.8	1.5
B2	1.4	4.1	2.7
C	2.9	6.9	2.7
D	4.1	8.2	2.9

The above dimensions are recommended. Note that if the pattern is too big, the component may not be mounted in place.

(b) Temperature and time

Keep the peak temperature and time to within the following conditions.



Whenever possible, perform preheating (at 150˚C max.) for smooth temperature profile. To maintain the reliability, mount the capacitor at a low temperature and in a short time whenever possible. The peak temperature and time shown above are applicable when the capacitor is to be soldered in a soldering oven or with a hot plate. When the capacitor is soldered by means of infrared reflow soldering, the internal temperature of the capacitor may rise beyond the surface temperature.

(2) Using soldering iron

When soldering the capacitor with a soldering iron, controlling the temperature at the tip of the soldering iron is very difficult. However, it is recommended that the following temperature and time be sbserved to maintain the reliability of the capacitor:

Iron temperature .... 300 ˚C max.
Time....................... 3 seconds max.
Iron power .... 30 W max.

3. Cleaning

Generally, several organic solvents are used for flux cleaning of an electronic component after soldering. Many cleaning methods, such as immersion cleaning, rinse cleaning, brush cleaning, shower cleaning, vapor cleaning, and ultrasonic cleaning, are available, and one of these cleaning methods may be used alone or two or more may be used in combination. The temperature of the organic solvent may vary from room temperature to several 10˚C, depending on the desired effect. If cleaning is carried out with emphasis placed only on cleaning effect, however, the marking on the electronic component cleaned may be erased, the appearance of the component may be damaged, and in the worst case, the component may be functionally damaged. It is therefore recommended that the NEOCAPACITOR be cleaned under the following conditions:

[Recommended conditions of flux cleaning]

(1) Cleaning solvent .... Isopropyl alcohol
(2) Cleaning method.......... Shower cleaning, rinse cleaning, vapor cleaning
(3) Cleaning time .... 5 minutes max.

<u>*Ultasonic cleaning</u>

This cleaning method is extremely effective for eliminating dust that has been generated as result of mechanical processes, but may pose a problem depending on the condition. As a result of an experiment conducted by NEC, it was confirmed that the external terminals of the capacitor were cut when it was cleaned with some ultrasonic cleaning machines. The cause of this phenomenon is considered metal fatigue of the capacitor terminals that occurred due to ultrasonic cleaning. To prevent the terminal from being cut, decreasing the output power of the ultrasonic cleaning machine or shortening the cleaning time may be a possible solution. However, it is difficult to specify the safe cleaning conditions because there are many factors involved such as the conversion efficiency of the ultrasonic oscillator, transfer efficiency of the cleaning bath, difference in cleaning effect depending on the location in the cleaning bath, the size and quantity of the printed circuit boards to be cleaned, and the securing states of the components on the boards. It is therefore recommended that ultrasonic cleaning be avoided as much as possible.

If ultrasonic cleaning is essential, make sure through experiments that no abnormality occur as a result to the cleaning. For further information, consult NEC.

4. Others

(1) Do not apply excessive vibration and shock to the capacitor.
(2) The solderability of the capacitor may be degraded by humidity. Store the capacitor at (–5 to +40˚C) room temperature and (40 to 60% RH) humidity.
(3) Exercise care that no external force is applied to the tape packaged products (if the packaging material is deformed, the capacitor may not be automatically mounted by a chip mounter).

On the Internet at http://www.ic.nec.co.jp/compo/index_e.html

For further information, please contact:

NEC Corporation
NEC Building
7-1, Shiba 5-chome, Minato-ku
Tokyo 108-8001, Japan
Tel: 03-3454-1111
Fax: 03-3798-6059

[North & South America]

NEC Electronics Inc.
2880 Scott Blvd.
Santa Clara, CA 95050-2554, U.S.A
Tel: 408-588-6000
800-366-9782
Fax: 408-588-6130
800-729-9288

[Regional Sales Offices]

Central Region
Greenpoint Tower
2800 West Higgins
Road Suite 765
Hoffman Estates,
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Tel: 847-839-6300
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3033 Scott Blvd.
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Eastern Region
901 N. Lake Destiny Drive
Suite 320
Maitland, FL 32751, U.S.A.
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Fax: 407-875-0962

Western Region
One Embassy Centre
9020 S.W. Washington
Square Road
Suite 400
Tigard, OR 97223
Tel: 503-671-0177
Fax: 503-643-5911

NEC do Brasil S.A.
Rodovia Presidente Dutra, KM 2 18
CEP 07210-902-Jd. Postal 161
Cumbica-Guarulhos-SP, Brasil
CEP 07210-902
Tel: 011-6465-6810
Fax: 011-6465-6829

[Europe]

NEC Electronics (Germany) GmbH
Kanzlerstr. 2,
40472 Düsseldorf 30
Germany
Tel: 0211-650302
Tlx: 859960
Fax: 0211-6503490

NEC Electronics (Benelux)
Boschdijik 187A
5612 HB Eindhoven
Netherlands
Tel: 040-2445845
Tlx: 50923
Fax: 040-2444580

NEC Electronics (Scandinavia)
P.O. Box 134
S-18322 Taeby, Sweden
Tel: 08-6380820
Tlx: 13839 NECSCAN S
Fax: 08-6380388

NEC Electronics (France) S.A.
9, rue Paul Dautier-BP 187
79142 Velizy-Villacoublay Cedex
France
Tel: 01-30-67-58-00
Tlx: 699499
Fax: 01-30-67-58-99

Madried Office
Juan Esplandiu, 75
28007 Madirid, Spain
Tel: 01-504-2787
Tlx: 1-41316
Fax: 01-504-2860

NEC Electronics Italiana s.r.l
Via Fabio Filizi 25/A
20124 Milano, Italy
Tel: 02-667541
Tlx: 315355
Fax: 02-66754299

NEC Electronics (UK) Limited
Cygnus House, Sunrise Park Way,
Milton Keynes, MK14 6NP, U.K.
Tel: 01908-691-133
Tlx: 826791
Fax: 01908-670-290

Dubin Office
34/35, South Eillam Street
Dubilin 2 Ireland
Tel: 01-6794200
Tlx: 90847
Fax: 01-6794081

[Asia & Oceania]

NEC Electronics Hong Kong Limited
12/F., Cityplaza 4, 12
Taikoo Wan Road, Hong Kong
Tel: 2886-9318
Fax: 2886-9022, 2886-9044

Seoul Branch
10F, ILSONG Bldg., 157-37,
Samsung-Dong, Kangnam-Ku
Seoul, the Republic of Korea
Tel: 02-528-0303
Fax: 02-528-4411

Shen-zhen Office
31st, Floor, Shen-zhen International
Financial
Bldg. 23 Jian Sha Road, Shenzhen PRC
Tel: 755-2227077

Australia Representative Office
303-313 Burwood Highway
Burwood East, VIC3151, Australia
Tel: 03-98878012/98878013
Fax: 03-98878014

NEC Electronics Taiwan Ltd.
7F, No. 363 Fu Shing North Road
Taipei, Taiwan, R. O. C.
Tel: 02-2719-2377
Tlx: 22372
Fax: 02-2719-5951/5936

NEC Electronics Singapore Pte. Ltd.
101 Thomson Road #04-02/05
United Square, Singapore 307591
Tel: 65-253-8311
Fax: 65-250-3583

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