PHILIPS

Data handbook

PHILIPS

Electronic components and materials

Components and materials

Part 14 May 1982

Electrolytic and solid capacitors

COMPONENTS AND MATERIALS

PART 14 - MAY 1982

ELECTROLYTIC AND SOLID CAPACITORS

DATA HANDBOOK SYSTEM

Our Data Handbook System is a comprehensive source of information on electronic components, sub-assemblies and materials; it is made up of four series of handbooks each comprising several parts.

ELECTRON TUBES	BLUE
SEMICONDUCTORS	RED
INTEGRATED CIRCUITS	PURPLE
COMPONENTS AND MATERIALS	GREEN

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May 1980

ELECTRON TUBES (BLUE SERIES)

The blue series of data handbooks is comprised of the following parts:

T1 **Tubes for r.f. heating**

T2 **Transmitting tubes for communications**

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ET3 **Special Quality tubes, miscellaneous devices** (will not be reprinted)

T4 **Magnetrons**

T5 **Cathode-ray tubes**
Instrument tubes, monitor and display tubes, C.R. tubes for special applications

T6 **Geiger-Müller tubes**

T7 **Gas-filled tubes**
Segment indicator tubes, indicator tubes, dry reed contact units, thyratrons, industrial rectifying tubes, ignitrons, high-voltage rectifying tubes, associated accessories

T8 **Picture tubes and components**
Colour TV picture tubes, black and white TV picture tubes, colour monitor tubes for data graphic display, monochrome monitor tubes for data graphic display, components for colour television, components for black and white television and monochrome data graphic display

T9 **Photo and electron multipliers**
Photomultiplier tubes, phototubes, single channel electron multipliers, channel electron multiplier plates

T10 **Camera tubes and accessories, image intensifiers**

T11* **Microwave components and assemblies**

* Will become available in the course of 1982.

SEMICONDUCTORS (RED SERIES)

The red series of data handbooks is comprised of the following parts:

S1 **Diodes**
Small-signal germanium diodes, small-signal silicon diodes, voltage regulator diodes(< 1,5 W), voltage reference diodes, tuner diodes, rectifier diodes

S2 **Power diodes, thyristors, triacs**
Rectifier diodes, voltage regulator diodes (> 1,5 W), rectifier stacks, thyristors, triacs

S3 **Small-signal transistors**

S4 **Low-frequency power transistors and hybrid IC modules**

S5 **Field-effect transistors**

S6 **R.F. power transistors and modules**

S7 **Microminiature semiconductors for hybrid circuits**

S8 **Devices for optoelectronics**
Photosensitive diodes and transistors, light-emitting diodes, displays, photocouplers, infrared sensitive devices, photoconductive devices.

S9 Taken into handbook T11 of the blue series

S10 **Wideband transistors and wideband hybrid IC modules**

INTEGRATED CIRCUITS (PURPLE SERIES)

The purple series of data handbooks is comprised of the following parts:

IC1 **Bipolar ICs for radio and audio equipment**

IC2 **Bipolar ICs for video equipment**

IC3* **Digital ICs for radio, audio and video equipment**

IC4 **Digital integrated circuits**
LOCMOS HE4000B family

IC5 **Digital integrated circuits – ECL**
ECL10 000 (GX family), ECL100 000 (HX family), dedicated designs

IC6* **Professional analogue integrated circuits**

IC7 **Signetics bipolar memories**

IC8 **Signetics analogue circuits**

IC9* **Signetics TTL circuits**

* These handbooks will be available in the course of 1982.

COMPONENTS AND MATERIALS (GREEN SERIES)

The green series of data handbooks is comprised of the following parts:

C1 **Assemblies for industrial use**
PLC modules, PC20 modules, HNIL FZ/30 series, NORbits 60-, 61-, 90-series, input devices, hybrid ICs, peripheral devices

C2 **FM tuners, television tuners, video modulators, surface acoustic wave filters**

C3 **Loudspeakers**

C4 **Ferroxcube potcores, square cores and cross cores**

C5 **Ferroxcube for power, audio/video and accelerators**

C6 **Electric motors and accessories**
Permanent magnet synchronous motors, stepping motors, direct current motors

CM7a **Assemblies** (will not be reprinted)
Circuit blocks 40-series and CSA70(L), counter modules 50-series, input/output devices

C8 **Variable mains transformers**

C9 **Piezoelectric quartz devices**
Quartz crystal units, temperature compensated crystal oscillators, compact integrated oscillators, quartz crystal cuts for temperature measurements

C10 **Connectors**

C11 **Non-linear resistors**
Voltage dependent resistors (VDR), light dependent resistors (LDR), negative temperature coefficient thermistors (NTC), positive temperature coefficient thermistors (PTC)

C12 **Variable resistors and test switches**

C13 **Fixed resistors**

C14 **Electrolytic and solid capacitors**

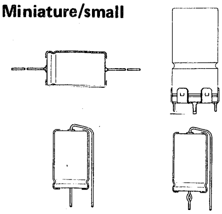
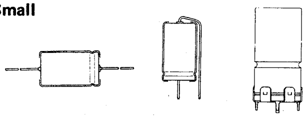
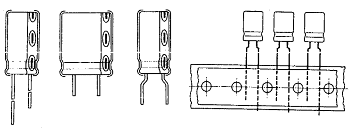
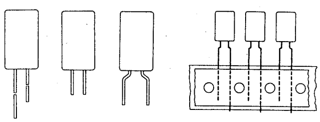
C15 **Film capacitors, ceramic capacitors, variable capacitors**

C16 **Piezoelectric ceramics, permanent magnet materials**

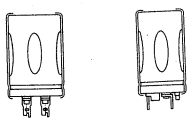
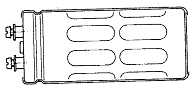
GENERAL

SURVEY

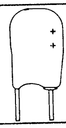
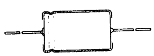
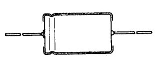
ALUMINIUM ELECTROLYTIC CAPACITORS

type	series number 2222 . . .	application	nominal capacitance μF	rated voltage (U_R) V	page
Miniature/small 	030 031 032 033	long-life, general, industrial	0,33 to 15 000	6,3 to 100	33*
	041 042 043		1 to 220	160 to 385	109*
Small 	021**	long-life general, industrial	220 to 15 000	10 to 63	23
Miniature/small 	035	general	0,22 to 4700	6,3 to 100	77
Miniature 	036	general, industrial	0,22 to 330	6,3 to 63	89
Small 	108	extra long-life, industrial	2,2 to 2200	6,3 to 63	153
Small; bipolar 	039	long-life, general, industrial	1 to 47	U_R (a.c.) = 63 V_p U_R (d.c.) = 63 V	101

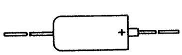
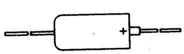
* See also Selection Chart, page 31.
** Development Sample Data; very high CU-product per unit volume.

type	series number 2222 . . .	application	nominal capacitance µF	rated voltage (U_R) V	page
Large 	050 052	long-life industrial	47 to 68 000	10 to 385	129
Large 	114 115	long-life industrial military	150 to 220 000	10 to 385	165
Maintenance types	015 016	long-life, general, industrial	0,47 to 680	4 to 100	277
	071 073	long-life, industrial	680 to 33 000	6,3 to 63	291
	106 107	long-life, military	1500 to 150 000	6,3 to 100	309

SOLID ALUMINIUM CAPACITORS

type	series number 2222 . . .	application	nominal capacitance µF	rated voltage (U_R) V	page
Miniature; resin dipped 	122	long-life, general, industrial	0,1 to 68	6,3 to 40	211
Small  CECC approval pending	123	extra long-life, military, industrial	2,2 to 1000	6,3 to 40	225
Small 	121	long-life, military, industrial	2,2 to 330	6,3 to 50	191

SOLID TANTALUM CAPACITORS

type	series number 2222 . . .	application	nominal capacitance µF	rated voltage (U_R) V	page
Hermetic seal; to MIL-C-39003/01 	141	polarized or d.c. biased circuits	0,1 to 330	6 to 75	235
Hermetic seal 	143	polarized or d.c. biased circuits	0,1 to 330	6 to 50	255

INTRODUCTION

1. INTRODUCTION

Electrolytic and solid capacitors are most commonly used in such circuit functions as filtering, coupling, smoothing and by-passing, and for energy storage, or wherever there is a need for capacitive reactance.

These functions are often applied under specific circumstances and the requirements specified by users have grown steadily. The outcome has been a wide range of electrolytic and solid capacitor programmes to cover the different applications, for example:

General purpose radio, television, and general/industrial applications.

Professional/industrial long life and high reliability – telecommunications equipment, electronic data processing.

high temperature – motor cars.

small size – hybrid circuits, paging systems.

low equivalent series resistance at high frequency – switched-mode power supplies.

2. PRINCIPLES

The essential property of a capacitor is to store electrical charge. The amount of electrical charge (Q) in the capacitor (C) is proportional to the applied voltage (U). The relationship of these parameters is:

$$Q = C . U$$

where Q = charge in coulombs (C)
C = capacitance in farads (F)
U = voltage in volts (V)

The value of capacitance is directly proportional to the (anode) surface area and inversely proportional to the thickness of the dielectric layer, thus:

$$C = \epsilon_r . \epsilon_0 . \frac{A}{d},$$

where ϵ_0 = absolute permittivity (8,85 x 10^{-12} F/m)
ϵ_r = relative dielectric constant (dimensionless)
A = surface area (m^2)
d = thickness of dielectric (oxide) layer (m)

The dielectric layer consists of either aluminium oxide (Al_2O_3) or tantalum oxide (Ta_2O_5) which are formed by an electrochemical oxidizing process from the respective metals. These layers withstand extremely high electrical field strength. During the electrochemical forming process the dielectric layer is exposed to the physical limit of electrical field strength mentioned above. So the thickness of the layer is determined by a voltage U_F, the so-called forming voltage. To avoid changing the thickness of the layer during normal use the operating voltage should always be lower than the forming voltage.
For general purpose electrolytic capacitors the value of U_R/U_F is about 0,8 (U_R being the rated voltage). Types for professional and industrial applications are sometimes rated to 0,6. Solid capacitors are rated to approx. 0,25 due to various reasons.

Table 1

material	relative dielectric constant (dimensionless)	physical limit of electrical field strength (V/m)
Al_2O_3	8	7.10^8
Ta_2O_5	24	5.10^8

3. DESCRIPTION

The above-mentioned dielectric layer is electrically contacted on one side by its base metal (aluminium or tantalum) and on the other side by a conductor, being an electrolyte in the case of an electrolytic capacitor and a solid semiconductor in the case of a solid capacitor. The metal contact electrode is called the anode. To obtain high capacitance values per unit volume the surface of the anode is artificially enlarged by etching (Al) or sintering (Ta) processes.

Aluminium electrolytic capacitors

The containing electrode opposite to the anode is an ionic conductor in the case of an electrolytic capacitor. Because of this ionic conduction the potential of the anode should never be lower than the potential of the electrolyte: if the potential of the anode is lower than that of the electrolyte, positive hydrogen ions will move through the dielectric layer to the anode metal where they are discharged.

The hydrogen gas so formed blows up the dielectric layer, causing a high leakage current or even a short circuit. In the case of the anode being at a positive potential with respect to the electrolyte (this is the case of normal use) the oxidizing ions are driven towards the dielectric layer.

These oxidizing ions are not able to pass through the dielectric layer at field strengths lower than the physical limit mentioned in Table 1. In the case of a defect in the dielectric layer the limiting field strength might be reached even during normal use. In that case the oxidizing ions will pass through the defect to the anode metal where new oxide is formed, which repairs the defect.

It is necessary to make electrical contact to the electrolyte from outside. This is usually done by inserting an etched aluminium electrode into the electrolyte. This electrode, called the cathode, is always covered by a relatively thin oxide layer. To avoid direct mechanical contact between the oxide layers of cathode and anode (which would cause mechanical damage of the dielectric) a soft spacer of porous paper is used which also serves as a sponge for the electrolyte.

The total thickness of the system described is only a fraction of a millimetre. Therefore, during manufacture, long strips of the described system are wound into cylindrical bodies and encased. Figure 1 shows a cross-section of a typical design.

Solid capacitors (Al + Ta)

In a solid capacitor the contacting electrode opposite to the anode is formed by manganese dioxide (MnO_2), a semiconductor, and called the cathode. Therefore, in principle, the potential of the anode with respect to the cathode is allowed to be positive as well as negative. However, due to the absence of oxidizing ions, no self-repairing effect of the dielectric layer by the leakage current is obtained. In practice it is advisable to maintain the anode potential positive with respect to the cathode, because no solid capacitor is absolutely free of moisture, so ionic reactions could take place.

Via the system manganese dioxide – aluminium foil – case – tinned leads, the cathode is electrically connected with the outside in our 121 and 123 series of solid aluminium capacitors (Fig. 1). A glass fibre spacer is used to avoid direct mechanical contact between anode layer and the aluminium contact foil.

In the 122 series of solid aluminium capacitors the cathode is connected to the outside via the system manganese dioxide – graphite – silver – tin solder – tinned leads (Fig. 2).

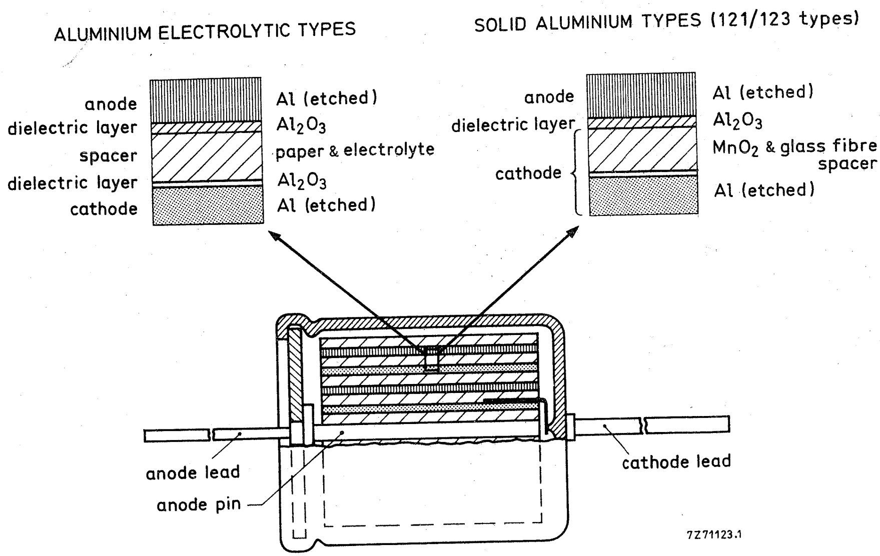


Fig. 1.

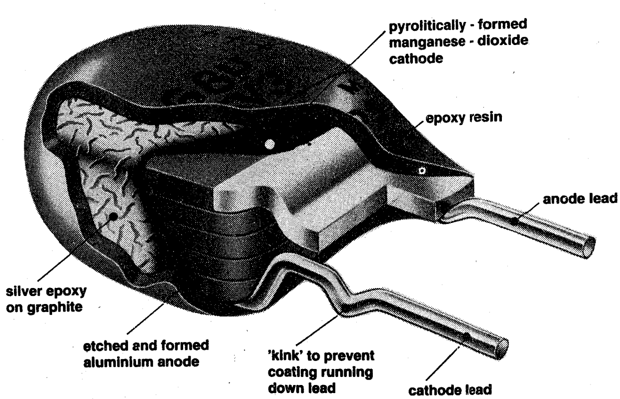


Fig. 2 Solid aluminium type 2222 122.

4. THE ELECTRICAL IMPEDANCE Z OF THE CAPACITOR

The electrical impedance Z of a capacitor in its reference plane (being the connecting points on a printed-wiring board) consists of a real part R, and an imaginary part j. X, thus:

$$Z = R + j.X \quad \text{and} \quad \tan\delta = \frac{R}{X}$$

where R = the equivalent series resistance (ESR) (Ω)
j. X = the imaginary part of the series impedance (Ω)
Z = the complex series impedance (Ω)
tan δ = dissipation factor (dimensionless)

The actual values of R and X depend upon two parameters: the frequency f and the temperature T. It is usual to express X in terms of C_s (equivalent series capacitance) and ω:

$$X = -\frac{1}{\omega C_s} \qquad \omega = 2.\pi.f, \ f \text{ in (Hz)}$$

At high frequencies (> 100 kHz) an inductive part contributes to the impedance, changing X into X = jwL, where L = inductance in H.

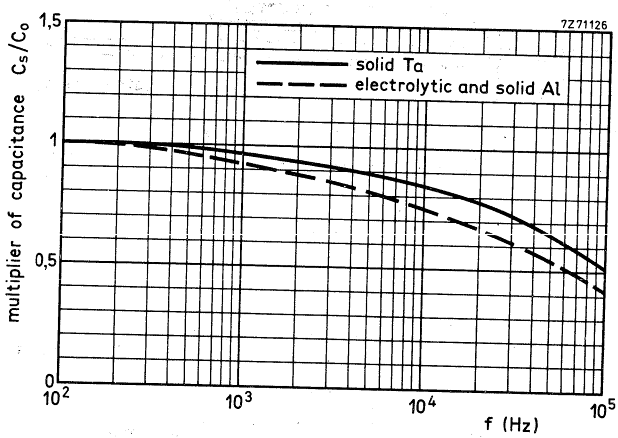


Fig. 3 Typical capacitance as a function of frequency. C_o = capacitance at 25 °C, 100 Hz.

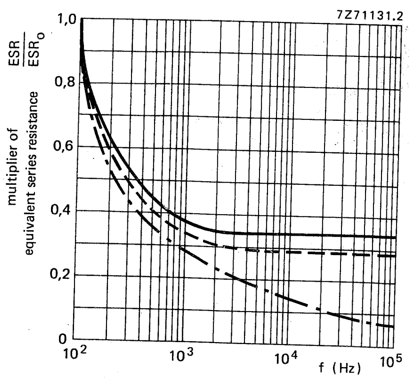


Fig. 4 Typical ESR as a function of frequency; ESR_o = ESR at 25 °C, 100 Hz.
———— Solid tantalum capacitors;
– – – – Aluminium electrolytic capacitors;
–·–·– Solid aluminium capacitors.

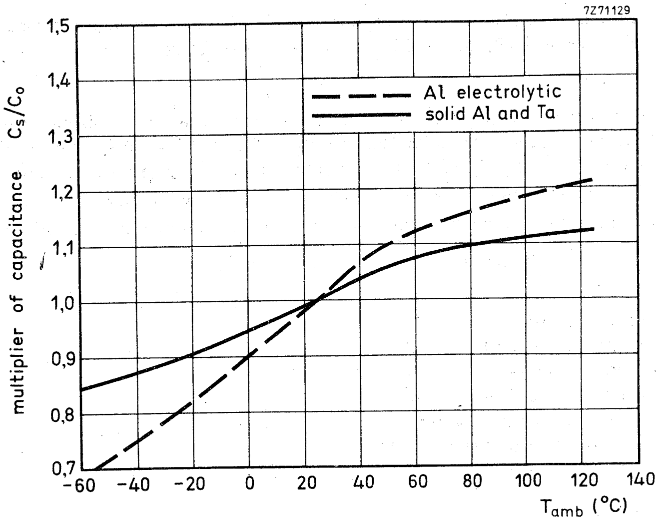


Fig. 5 Typical capacitance as a function of ambient temperature; C_o = capacitance at 25 °C, 100 Hz.

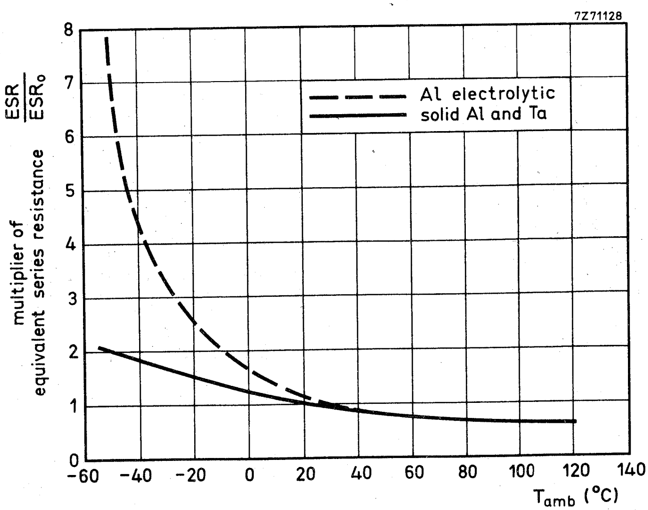


Fig. 6 Typical ESR as a function of ambient temperature. ESR_o = ESR at 100 Hz, at 25 °C.

5. RIPPLE CURRENT

In various applications a considerable amount of ripple current (I_r) passes through the capacitor. Due to the equivalent series resistance (R) power (P) is dissipated in the device:

$$P\ (\text{watt}) = I_r^2 \cdot R$$

The power causes an increase in temperature of the capacitor. Temperature equilibrium is reached when the power (P) passes through the case surface into the ambient. From this it is clear, that the maximum permissible ripple current depends on the maximum permissible temperature of the capacitor, value of the equivalent series resistance, case size and ambient temperature (T_{amb}).

In the data sheets the maximum permissible ripple current is specified under certain conditions.

$$i_r = \sqrt{\frac{P}{R}} = \sqrt{\frac{\alpha \cdot S\,(T_c - T_{amb})}{R}}$$

where I_r = ripple current (A)
R = equivalent series resistance (Ω)
P = heat dissipation (W)
α = heat transfer coefficient (W/m² °C)
S = heat transfer surface area (m²)
T_c = temperature of case surface (°C)
T_{amb} = ambient temperature (°C)

6. LEAKAGE CURRENT

In normal use a small amount of direct current passes through the capacitor. This current is called the leakage current (I_l) and depends on the applied voltage and temperature. The dependency of I_l/I_o (I_o being the leakage current at voltage U_R and 25 °C) on temperature, is shown in Fig. 7 for an aluminium electrolytic capacitor and a solid aluminium capacitor.

The dependency of I_l/I_o as a function of U/U_R is given in Fig. 8 for an aluminium electrolytic capacitor and a solid aluminium capacitor, U being the working voltage.

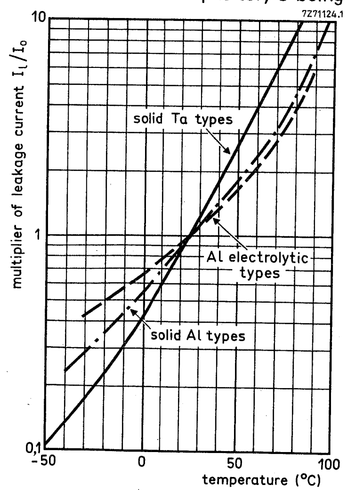


Fig. 7 Typical leakage current as a function of temperature. I_o = leakage current during continuous operation at T_{amb} = 25 °C.

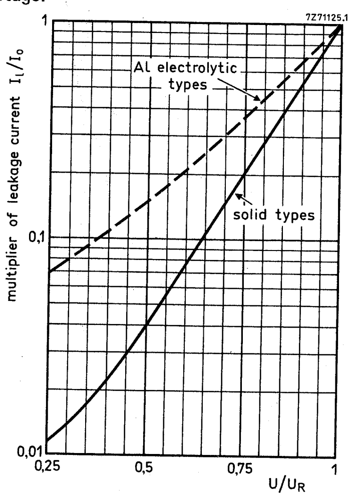


Fig. 8 Typical leakage current as a function of U/U_R. I_o = leakage current at U_R at a discrete constant temperature within category temperature range, U is working voltage.

7. LIFE TIME

Aluminium electrolytic capacitors

The phenomena which determine the life time of an aluminium electrolytic capacitor are, among others, changes of the following parameters exceeding the specified limits:

- capacitance
- dissipation factor
- impedance
- leakage current

Most of them are directly or indirectly caused by a failure mechanism occuring in the electrolyte (drying out, chemical reactions).

Two types of electrolyte can be distinguished:

a. Glycol-electrolyte which is somewhat aggressive to the dielectric layer at higher temperatures. This liquid has a relatively high specific resistance and high temperature coefficient.

b. modern electrolytes (based upon DiMethyl Acetamide) require very good sealing (due to high diffusiveness of the volatile solvent). This liquid has a relatively low specific resistance and a low temperature coefficient, and can generally be used over a wider temperature range than the glycol type of electrolyte.

In general the life time of an aluminium electrolytic capacitor can be increased by a factor of 2 when the temperature is dropped by 10 ^{o}C.

By using the capacitor at a voltage lower than the rated voltage, the leakage current decreases, which means that the process of forming hydrogen gas at the cathode takes place at a lower rate. This also improves the life time of the capacitor.

The typical life time at U_R, as given in the data sheets, is the time during which the number of inoperatives is $\leqslant$ 1%.

Criteria for an inoperative are: $\Delta C/C \geqslant 50\%$;
impedance $\geqslant$ 3 x stated limit;
tan δ (and ESR) $\geqslant$ 3 x stated limit;
leakage current $\geqslant$ 3 x stated limit.

Solid aluminium capacitors

The end of life is determined by gradual degradation of the dielectric oxide layer, resulting in increase of leakage current. The life time can be increased by derating the voltage and, to a less extent, the temperature.

Due to the fact that no electrolyte is used in solid aluminium capacitors the associated failure mechanisms do not occur.

Solid tantalum capacitors

The end of life of solid tantalum capacitors is determined by sudden breakdown failures; sometimes in an early stage of its service life, especially in dynamic applications, e.g. charge and a.c. applications.

An explanation of this lies in the forming of crystalline tantalum oxide beneath the existing amorphous tantalum oxide under conditions of high field strength and high temperature. The growth of this crystalline tantalum oxide eventually breaks through the amorphous oxide layer and, because the newly-formed oxide has a very low specific resistance, a current flow is originated which results in a short-circuit.

The life time of a solid tantalum capacitor can be improved be derating the voltage and ambient temperature.

8. RELIABILITY

In life testing, reliability can be determined by means of a failure rate (F.R.), which is expressed as:

$$\text{Failure rate (F.R.)} = \frac{\text{number of failures during test}}{\text{number of components tested x test duration}}$$

Two types of failures can be found:

— catastrophic failures: short circuits, open circuits.
— degradation failures: parameter drifts outside the specification limits.

With aluminium electrolytic capacitors degradation failures mostly occur, due to factors like:

— agressiveness of the electrolyte.
— diffusion of the electrolyte.
— material impurities and other accidents of production.

The failure rate of solid aluminium and tantalum capacitors is determined by short circuits or open circuits, due to breakdown of the dielectric layer. The electron current does not constitute a repair action in this oxide layer.

The failure rate in solid tantalum capacitors is mostly influenced by a field-crystallization process, described in above. In this case the F.R. can be improved by lowering the temperature and applied voltage or placing a series resistor in the circuitry.

The phenomenon of the formation of a low resistance aluminium oxide does not exist in solid aluminium capacitors, therefore they have greater reliability than solid tantalum types. Under the most severe conditions (maximum category temperature, rated voltage), the catastrophic failure rates (with a 60% confidence level) are:

— electrolytic capacitors 10^{-6}/h
— solid aluminium capacitors 10^{-7}/h
— solid tantalum capacitors 10^{-5}/h

Analysis of failure in the field (under normal operating conditions) shows a far better F.R.: $\approx 10^{-9}$/h for solid aluminium capacitors.

9. TESTS AND REQUIREMENTS

The description of tests and requirements, given in the following tables, is valid for the complete range of aluminium electrolytic capacitors and solid aluminium capacitors. Specific tests for a certain type of capacitor are not included in these tables; those tests are given in the data sheet of the relevant type.

Aluminium electrolytic capacitors

In the description of the procedure and the requirements of the tests, in some case distinction has to be made for the different types of aluminium electrolytic capacitors with respect to their size or with respect to their application fields. In the table this distinction is indicated in the columns 'type' with the indication for size:

- m for miniature types,
- s for small types,
- l for large types,
- lt for large types with screw terminals,

or with the indication for application fields:

1. for long-life grade types,
2. for general-purpose grade types.

If no indication is given in these columns, reference is made to all types.

IEC 384–4 sub clause	IEC 68–2 test method	name of test	procedure (quick reference)		requirements	
			type	description	type	description
–	Ua	Tensile strength of terminations	m s	Loading force 10 N for 10 s.	m s l	No visible damage.
			l	Loading force 20 N for 10 s.		
–	Ub	Bending of terminations	m s	Loading force 5 N, two consecutive bends.	m s	No visible damage
–	Uc	Torsion of terminations	m s	Two successive rotations of 180° in opposite direction, 5 s per rotation.	m s	No visible damage.
–	Ud	Torque on nut (stud)	lt	Torque of 1,76 Nm gradually applied.	lt	No visible damage.
9.8.2	Tb (method 1A)	Resistance to soldering heat	m	Solder bath: 260 °C, 10 s, for capacitors with printed-wiring pins.	m s l	No visible damage, marking legible, $\Delta C/C \leqslant 5\%$.
	Tb (method 1B)		s l	Solder bath 350 °C, 3,5 s for capacitors with solder leads or tags.		
9.8.1	Ta	Solderability	m s l	Solder bath: 235 °C, 2 s for capacitors with printed-wiring pins, 270 °C, 2 s for capacitors with solder leads or tags, immersed up to 2 mm from the body.	m s l	No visible damage, marking legible, good tinning.

IEC 384–4 sub clause	IEC 68–2 test method	name of test	procedure (quick reference) type	procedure (quick reference) description	requirements type	requirements description
9.9	Na	Rapid change of temperature		5 cycles of 3 h at upper and lower category temperature.		No visible damage, no leakage of electrolyte.
9.10	Fc	Vibration	1	10 to 500 Hz, 0,75 mm or 10g (whichever is less), 2 directions, 3 h per direction.		No visible damage, no leakage of electrolyte, marking legible; $\Delta C/C \leqslant 5\%$ with respect to initial measurement.
			2	10 to 55 Hz, 0,75 mm or 10g (whichever is less), 2 directions, 3 h per direction.		
9.11	Eb	Bump	1	40g, 2 directions, 4000 bumps total.		No visible damage, no leakage of electrolyte; $\Delta C/C \leqslant 5\%$ with respect to initial measurement.
			2	40g, 2 directions, 1000 bumps total.		
	Climatic sequence: Ba	Dry heat		16 h at upper category temperature, no voltage applied.		No visible damage, no leakage of electrolyte.
	Climatic sequence: D	Damp heat, cyclic		1 cycle of 24 h at 55 ± 2 °C, R.H. 95 to 100%, no voltage applied.		
	Climatic sequence: Aa	Cold		2 h at lower category temperature, no voltage applied.		No visible damage, no leakage of electrolyte.
9.12.1	Climatic sequence: M	Low air pressure		5 min. at 15 to 35 °C, at atmospheric pressure of 85 mbar, last minute U_R applied.		No visible damage, no evidence of breakdown or flashover.
	Climatic sequence: D	Damp heat, cyclic		5 cycles of 24 h at 55 ± 2 °C, R.H. 95 to 100%, no voltage applied.		
9.12.2	Climatic sequence: Qc	Sealing		1 min. in water at upper category temperature + 5 °C.		No continuous chain of bubbles.
	Climatic sequence			Final measurement		No visible damage, no leakage of electrolyte, marking legible; leakage current $\leqslant$ stated limit; tan $\delta \leqslant 1{,}2$ x stated limit; $\Delta C/C \leqslant 10\%$.

IEC 384–4 sub clause	IEC 68–2 test method	name of test	procedure (quick reference) type	procedure (quick reference) description	requirements type	requirements description
9.13	Ca	Damp heat, steady state		56 days at 40 °C, R.H. 90 to 95%; no voltage applied.		No visible damage, no leakage of electrolyte, marking legible; leakage current $\leqslant$ stated limit, tan $\delta \leqslant 1,2$ x stated limit, insulation resistance $> 100\ M\Omega$, no breakdown or flashover below 1000 V.
					1	$\Delta C/C \leqslant 10\%$.
					2	$\Delta C/C \leqslant 20\%$.
9.14	–	Endurance				No visible damage, no leakage of electrolyte, marking legible; leakage current $\leqslant$ stated limit, insulation resistance $> 100\ M\Omega$, no breakdown or flashover below 1000 V.
			1	2000 h** at upper category temperature, U_R applied.	1	$\Delta C/C \leqslant 15\%$ and $\leqslant -30\%$ for $U_R \leqslant 6,3$ V, $\Delta C/C \leqslant 15\%$ for $6,3\ V < U_R \leqslant 160$ V, $\Delta C/C \leqslant 10\%$ for $U_R > 160$ V; tan $\delta \leqslant 1,3$ x stated limit, impedance at 1 kHz or 10 kHz $\leqslant 2$ x stated limit.*
			2	1000 h at upper category temperature, U_R applied.	2	$\Delta C/C \leqslant 25\%$ and $\leqslant -40\%$ for $U_R \leqslant 6,3$ V. $\Delta C/C \leqslant 30\%$ for $6,3\ V < U_R \leqslant 160$ V, $\Delta C/C \leqslant 15\%$ for $U_R > 160$ V; tan $\delta \leqslant 1,5$ x stated limit or min. 0,40 (whichever is greater), impedance at 1 kHz or 10 kHz $\leqslant 3$ x stated limit.*
9.15	–	Surge		From source of 1,15 x U_R for $U_R \leqslant 315$ V or 1,1 x $U_R > 315$ V, RC = 0,1 ± 0,05 s, 1000 cycles of 30 s on, 330 s off.		No visible damage, no leakage of electrolyte; leakage current $\leqslant$ stated limit, tan $\delta \leqslant$ stated limit, $\Delta C/C \leqslant 15\%$.
			1	At upper category temperature.		
			2	At 25 °C.		

* If stated in the detail specification.

** Capacitors 2222 032, 033, 039, 042, 043, 114, 115 are specified at 5000 h; requirements are as stated under type 1.

IEC 384–4 sub clause	IEC 68–2 test method	name of test	procedure (quick reference)		requirements	
			type	description	type	description
9.16	–	Reverse voltage		1 V in reverse polarity followed by U_R in forward polarity, both for 125 h at upper category temperature.		Leakage current ⩽ stated limit, tan δ ⩽ stated limit, ΔC/C ⩽ 10%.
9.17	–	Pressure relief	I It	D.C. voltage applied in reverse direction producing a current of 1 to 10 A.	I It	Pressure relief opens prior to danger of explosion or fire.
9.18	Ha	Storage at upper category temperature		96 ± 4 h at upper category temperature.		No visible damage, no leakage of electrolyte; leakage current ⩽ 2 x stated limit, tan δ ⩽ 1,2 x stated limit; ΔC/C ⩽ 10%.
9.19	Hb	Storage at low temperature		72 h at a temperature of 15 °C below the lower category temperature.		No visible damage, no leakage of electrolyte; leakage current ⩽ stated limit, tan δ ⩽ stated limit; ΔC/C ⩽ 10%.
9.20		Characteristics at high and low temperature		**Step 1:** reference measurement at 20 °C of capacitance, impedance at 100 Hz and tan δ.		
				Step 2: measurement at lower category temperature.		Impedance at 100 Hz ⩽ 7 x value of step 1 for U_R ⩽ 6,3 V or U_R > 160 V, ⩽ 5 x value of step 1 for 6,3 < U_R ⩽ 16 V, ⩽ 4 x value of step 1 for 16 < U_R ⩽ 160 V.
				Step 3: Measurement at upper category temperature.		Leakage current ⩽ 5 x stated limit at 85 °C, ⩽ 3 x stated limit at 70 °C.
9.21		Charge and discharge		For U_R ⩽ 160 V: 10^6 cycles of 0,5 s charge to U_R (RC = 0,1 s) and 0,5 s discharge (RC = 0,1 s). For U_R > 160 V: under consideration.		No visible damage, no leakage of electrolyte, ΔC/C ⩽ 10%.

Solid aluminium capacitors

In the description of the procedure and the requirements of the tests, in some cases distinction has to be made for the types 2222 121, 2222 122 and 2222 123. In the table this distinction is indicated by 121/123 or 122 in the columns 'type'. If no indication is given in these columns reference is made to all types.

IEC 384–4 sub clause	IEC 68–2 test method	name of test	procedure (quick reference)		requirements	
			type	description	type	description
–	Ua	Tensile strength of terminations		Loading force 10 N for 10 s.		No visible damage.
–	Ub	Bending of terminations		Loading force 5 N, two consecutive bends.		No visible damage.
–	Uc	Torsion of terminations	121/ 123	Two successive rotations of 180° in opposite direction, 5 s per rotation.	121/ 123	No visible damage.
9.8.2	Tb (method 1A)	Resistance to soldering heat	122	Solder bath: 260 °C, 10 s, for capacitors with printed-wiring pins.		No visible damage, marking legible, $\Delta C/C \leqslant 5\%$.
	Tb (method 1B)		121/ 123	Solder bath: 350 °C, 3,5 s, for capacitors with solder leads.		
9.8.1	Ta	Solderability	122	Solder bath: 235 °C, 2 s for capacitors with printed-wiring pins, immersed up to 2 mm from the body.		No visible damage, marking legible, good tinning.
			121/ 123	Solder bath: 270 °C, 2 s for capacitors with solder leads, immersed up to 2 mm from the body.		
9.9	Na	Rapid change of temperature		5 cycles of 30 min at upper and lower category temperature.		Leakage current $\leqslant$ stated limit,* tan $\delta \leqslant$ stated limit.
9.10	Fc	Vibration		10 to 500 Hz, 0,75 mm or 10g (whichever is less), 2 directions, 3 h per direction.		No visible damage, marking legible; $\Delta C/C \leqslant 5\%$ with respect to initial measurement.

* For capacitors 2222 122, leakage current after 1 min.

IEC 384–4 sub clause	IEC 68–2 test method	name of test	procedure (quick reference) type	procedure (quick reference) description	requirements type	requirements description
9.11	Eb	Bump		40g, 2 directions, 4000 bumps total.		No visible damage; $\Delta C/C \leqslant 5\%$ with respect to initial measurement.
	Climatic sequence: Ba	Dry heat		16 h upper category temperature, no voltage applied.		No visible damage.
	Climatic sequence: D	Damp heat, cyclic		1 cycle of 24 h at 55 ± 2 °C, R.H. 95 to 100%, no voltage applied.		
	Climatic sequence: Aa	Cold		2 h at lower category temperature, no voltage applied.		No visible damage.
9.12.1	Climatic sequence: M	Low air pressure		5 min. at 15 to 35 °C, at atmospheric pressure of 85 mbar, last minute U_R applied.		No visible damage, no evidence of breakdown or flashover below 1000 V.
	Climatic sequence: D	Damp heat, cyclic		5 cycles of 24 h at 55 ± 2 °C, R.H. 95 to 100%, no voltage applied.		
				Final measurement.		No visible damage, marking legible; leakage current ⩽ stated limit,* tan $\delta \leqslant$ 1,2 x stated limit.
					121/ 123	$\Delta C/C \leqslant 5\%$.
					122	$\Delta C/C \leqslant 10\%$.
9.13	Ca	Damp heat, steady state		56 days at 40 °C, R.H. 90 to 95%; no voltage applied.		No visible damage, marking legible; leakage current ⩽ stated limit;* tan $\delta \leqslant$ 1,2 x stated limit, insulation resistance > 100 MΩ, no breakdown or flashover below 1000 V.
					121/ 123	$\Delta C/C \leqslant 5\%$.
					122	$\Delta C/C \leqslant 15\%$.

* For capacitors 2222 122, leakage current after 1 min.

IEC 384–4 sub clause	IEC 68–2 test method	name of test	procedure (quick reference) type	procedure (quick reference) description	requirements type	requirements description
9.14	–	Endurance	122	2000 h at 125 °C, U_R* applied.		No visible damage, marking legible; leakage current ⩽ stated limit, tan δ ⩽ 1,2 x stated limit, insulation resistance > 100 MΩ, no breakdown or flashover below 1000 V, ΔC/C ⩽ 10%.
			121/ 123	5000 h at 125 °C, U_R** applied.		
				5000 h at 85 °C, U_R applied.		
9.15	–	Surge		From source of 1,15 x U_R at 85 °C or 1,15 x derated voltage at 125 °C, 1000 cycles of 30 s on, 330 s off.		No visible damage; leakage current ⩽ stated limit, tan δ ⩽ stated limit.
					121/ 123	ΔC/C ⩽ 5%.
					122	ΔC/C ⩽ 10%.
9.16	–	Reverse voltage		0,30 x U_R in reverse polarity at 85 °C for 125 h, followed by U_R in forward polarity at 85 °C for 125 h.		Leakafe current ⩽ stated limit, tan δ ⩽ stated limit, ΔC/C ⩽ 10%.
			121/ 123	0,15 x U_R** in reverse polarity at 125 °C for 125 h, followed by U_R** in forward polarity at 125 °C for 125 h.		
			122	0,30 x U_R* in reverse polarity at 125 °C for 125 h, followed by U_R* in forward polarity at 125 °C for 125 h.		
9.18	Ha	Storage at upper category tempera- ture		96 ± 4 h at upper category temperature.		No visible damage; leakage current ⩽ stated limit,*** tan δ ⩽ stated limit.
					121/ 123	ΔC/C ⩽ 5%.
					122	ΔC/C ⩽ 10%.

* 25 V for 40 V versions.
** 40 V for 50 V versions.
*** For capacitors 2222 122, leakage current after 1 min.

IEC 384–4 sub clause	IEC 68–2 test method	name of test	procedure (quick reference)		requirements	
			type	description	type	description
9.20		Characteristics at high and low temperature		**Step 1:** reference measurement at 20 °C of capacitance, impedance at 100 Hz and tan δ.		
				Step 2: measurement at lower category temperature.		Tan $\delta \leqslant 2$ x stated limit, impedance ratio $\leqslant 2$, $\Delta C/C \leqslant 20\%$.
				Step 3: measurement at upper category temperature.		Leakage current $\leqslant 10$ x stated limit,* tan $\delta \leqslant$ stated limit, $\Delta C/C \leqslant 20\%$.
9.21		Charge and discharge		10^6 cycles of 0,5 s charge to U_R and 0,5 s discharge.		No visible damage, $\Delta C/C \leqslant 5\%$.

* For capacitors 2222 122, leakage current after 1 min.

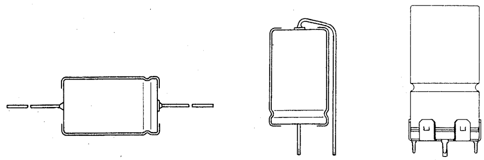
ALUMINIUM ELECTROLYTIC CAPACITORS

DEVELOPMENT SAMPLE DATA

This information is derived from development samples made available for evaluation. It does not necessarily imply that the device will go into regular production.

ALUMINIUM ELECTROLYTIC CAPACITORS

- **Small type**
- **Axial leads or single ended**
- **Long life**
- **General and industrial applications**



QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	220 to 15000 μF
Tolerance on nominal capacitance	± 20%
Rated voltage range, U_R (R5 series)	10 to 63 V
Category temperature range	−55 to +85 °C
Basis specifications	IEC 384-4, long-life grade DIN 41316
Climatic category	
IEC 68	55/085/56
DIN 40040	FPF

Selection chart for C_{nom}-U_R and relevant case sizes.

C_{nom} μF	U_R (V) 10	16	25	40	63
220					00
330					01
470				00	01
680			00	01	02
1000		00	01	01	03
1500	00	01	01	02	04
2200	01	01	02	03	05
3300	01	02	03	04	
4700	02	03	04	05	
6800	03	04	05		
10000	04	05			
15000	05				

case size	nominal dimensions (mm)
00	ϕ 10 x 30
01	ϕ 12,5 x 30
02	ϕ 15 x 30
03	ϕ 18 x 30
04	ϕ 18 x 40
05	ϕ 21 x 40

APPLICATION

These capacitors have extremely high CU-product per unit volume, which render them very suitable for applications, where high requirements are imposed on size and mass, e.g. portable and mobile equipment. They are mainly used for smoothing, coupling and decoupling purposes in consumer applications, such as audio and video circuits, and in other applications such as measuring, regulating, timing and delay circuits.

DESCRIPTION

The capacitors are available in 3 styles, all with aluminium case, and soldered-copper leads.

Style 1: axial leads; case insulated with a blue plastic sleeve.

Style 2: single ended; with mounting ring with printed-wiring pins; especially for use in applications with severe shocks and vibrations; case sizes 03, 04 and 05.

Style 3: single ended; case insulated with a blue plastic sleeve; case sizes 00, 01 and 02.

MECHANICAL DATA

Dimensions in mm

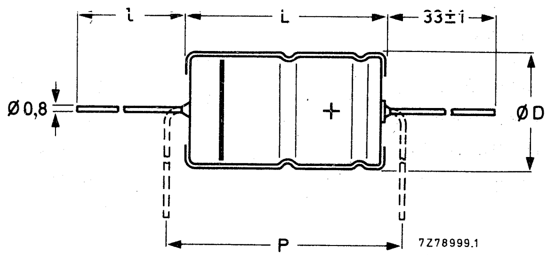


Fig. 1 Style 1; see Table 1a for dimensions D. L, I and P.

Table 1a

case size	style 1					
	D_{nom}	L_{nom}	D_{max}	L_{max}	l	P_{min}
00	10,0	30,0	10,5	30,5	55 ± 1	35,0
01	12,5	30,0	13,0	30,5	55 ± 1	35,0
02	15,0	30,0	15,5	30,5	55 ± 1	35,0
03	18,0	30,0	18,5	30,5	55 ± 1	35,0
04	18,0	40,0	18,5	41,5	34 ± 1	45,0
05	21,0	40,0	21,5	41,5	34 ± 1	45,0

DEVELOPMENT SAMPLE DATA

Table 1b

case size	style 2				
	d	D1	$D2_{max}$	D3	L
03	0,8	18,0	20,5	18,5 ± 0,2	31 ± 1
04	1,0	18,0	20,5	18,5 ± 0,2	42 ± 1
05	1,0	21,0	23,5	21,5 ± 0,2	42 ± 1

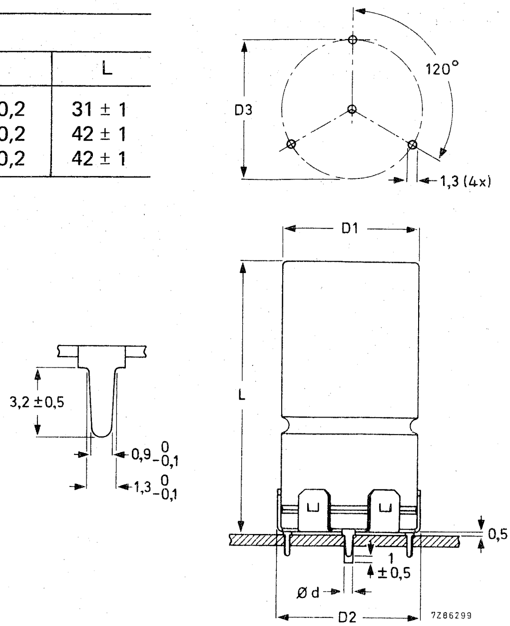


Fig. 2 Style 2; Table 1b for dimensions d, D1, D2, D3 and L.

Table 1c

case size	style 3			
	d	D_{max}	L_{max}	P
00	0,8	10,5	34,0	7,5-12,5
01	0,8	13,0	34,0	7,5-12,5
02	0,8	15,5	34,0	10,0-15,0

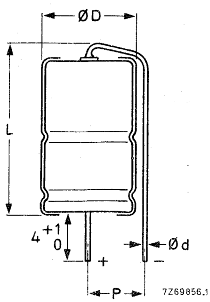


Fig. 3 Style 3; see Table 1c for dimensions d, D, L and P.

Marking

The capacitors are marked with:

nominal capacitance; tolerance on nominal capacitance; rated voltage; group number 021; code of origin; name of manufacturer; date code (year and month) according to IEC 62; band to identify the negative terminal.

Mounting

The diameter of the mounting holes in the printed-wiring board is 1 + 0,1 mm for style 1 and style 3 capacitors, and 1,3 + 0,1 mm for style 2 capacitors. (The diameter of the centre hole for the anode lead of style 2 capacitors, case size 03, is 1 + 0,1 mm.)

Minimum atmospheric pressure 8,5 kPa

ELECTRICAL DATA

Table 2

Unless otherwise specified all electrical values in Table 2 apply at an ambient temperature of 20 to 25 °C, a frequency of 100 Hz, an atmospheric pressure of 86 to 106 kPa and a relative humidity of 45 to 75%. (See also the relevant paragraphs.)

U_R V	nom. cap. µF	max. r.m.s. ripple current at T_{amb} = 85 °C mA	max. leakage current at U_R after 1 min µA	max. ESR Ω	case size	catalogue number*
10	1500	570	94	0,245	00	2222 021 . 4152
	2200	740	136	0,177	01	. 4222
	3300	920	202	0,128	01	. 4332
	4700	1150	286	0,100	02	. 4472
	6800	1460	412	0,079	03	. 4682
	10000	1840	604	0,064	04	. 4103
	15000	2200	904	0,054	05	. 4153
16	1000	530	100	0,260	00	. 5102
	1500	680	148	0,205	01	. 5152
	2200	880	216	0,150	01	. 5222
	3300	1120	321	0,111	02	. 5332
	4700	1390	455	0,087	03	. 5472
	6800	1760	656	0,070	04	. 5682
	10000	2100	964	0,058	05	. 5103
25	680	480	106	0,323	00	. 6681
	1000	630	154	0,220	01	. 6102
	1500	780	229	0,179	01	. 6152
	2200	1020	334	0,132	02	. 6222
	3300	1240	499	0,099	03	. 6332
	4700	1650	709	0,079	04	. 6472
	6800	2000	1024	0,064	05	. 6682

* Replace dot in catalogue number by:
1 for style 1,
4 for style 2 (case sizes 03, 04, 05),
8 for style 3 (case sizes 00, 01, 02).

U_R V	nom. cap. μF	max. r.m.s. ripple current at T_{amb} = 85 °C mA	max. leakage current at U_R after 1 min μA	max. ESR Ω	case size	catalogue number*
40	470	440	117	0,404	00	2222 021 . 7471
	680	580	167	0,279	01	. 7681
	1000	730	244	0,190	01	. 7102
	1500	815	364	0,159	02	. 7152
	2200	1170	532	0,118	03	. 7222
	3300	1500	796	0,090	04	. 7332
	4700	1815	1132	0,072	05	. 7472
63	220	350	88	0,614	00	. 8221
	330	480	129	0,409	01	. 8331
	470	570	182	0,287	01	. 8471
	680	770	261	0,199	02	. 8681
	1000	1035	382	0,135	03	. 8102
	1500	1330	571	0,122	04	. 8152
	2200	1740	836	0,099	05	. 8222

DEVELOPMENT SAMPLE DATA

Capacitance

Nominal capacitance at 100 Hz and T_{amb} = 25 °C — see Table 2

Tolerance on nominal capacitance at 100 Hz — ± 20%

Voltage

	< 50 °C	50 to 85 °C
Rated voltage = max. permissible voltage	1,1 x U_R	U_R
Ripple voltage** = max. permissible a.c. voltage providing the following three conditions are met:		
a) max. (d.c. + peak a.c.) voltage	1,1 x U_R	U_R
b) max. peak a.c. voltage without d.c. voltage applied	2 V	
c) momentary value of applied voltage	between U_R and −2 V	
Surge voltage = max. permissible voltage for short periods	1,2 x U_R	1,15 x U_R
Reverse voltage = max. d.c. voltage applied in the reverse polarity at the maximum category temperature for short periods	2 V	

* Replace dot in catalogue number by:
1 for style 1,
4 for style 2 (case sizes 03, 04, 05),
8 for style 3 (case sizes 00, 01, 02).

** Ripple voltages are not applicable if the maximum permissible ripple current is exceeded. In that case the ripple current is decisive.

Ripple current*

Maximum permissible r.m.s. ripple current at 100 Hz and T_{amb} = 85 °C — see Table 2

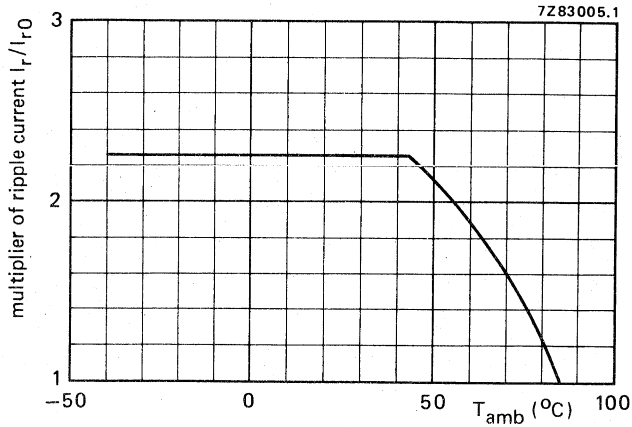


Fig. 4 Typical ripple current as a function of ambient temperature; I_{r0} = ripple current at 85 °C.

Non-sinusoidal ripple currents have to be analyzed into a number of sinusoidal currents and the following requirements shall then be satisfied:

$$\sum_n \frac{I_n^2}{r_n} \leqslant I_{r\,max}^2$$

$I_{r\,max}$ = maximum ripple current at 100 Hz and applicable ambient temperature;

I_n = ripple current at a certain frequency;

$r_n = I_r/I_{r0}$ = multiplying factor at a same frequency.

Charge and discharge current

The capacitors may be charged from a source without internal resistance and they may be discharged by short-circuiting. If the capacitors are charged and discharged continuously at a rate of several times per minute, the charge and discharge currents have to be considered as ripple currents flowing through the capacitors. The r.m.s. value of these currents should be determined and the value thus found must not exceed the applicable limit.

* Ripple currents are not applicable if the maximum permissible ripple voltage is exceeded. In that case the ripple voltage is decisive.

Leakage current

Maximum leakage current 1 min after application of the rated voltage at T_{amb} = 25 °C	see Table 2 (0,006 CU + 4 μA)
Leakage current during continuous operation at U_R, at T_{amb} = 25 °C	approx. 0,01 x values stated in Table 2
at T_{amb} = 85 °C	≤ values stated in Table 2

If the leakage current is too high, owing to prolonged storage and/or storage at an excessive temperature (> 40 °C), application of the rated voltage for some hours will cause the leakage current to fall to a value lower than specified in Table 2.

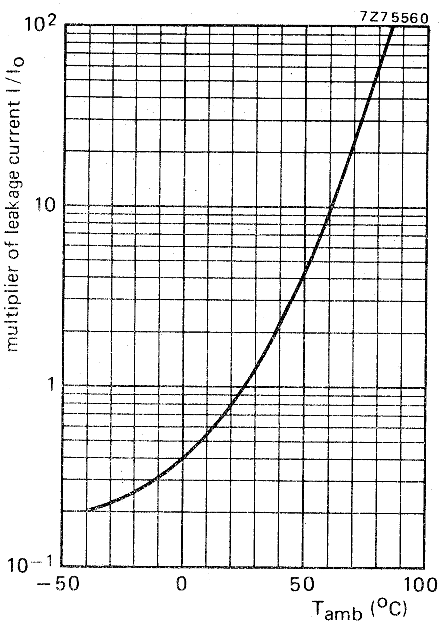


Fig. 5 Typical leakage current as a function of ambient temperature; I_0 = leakage current during continuous operation at 25 °C and U_R.

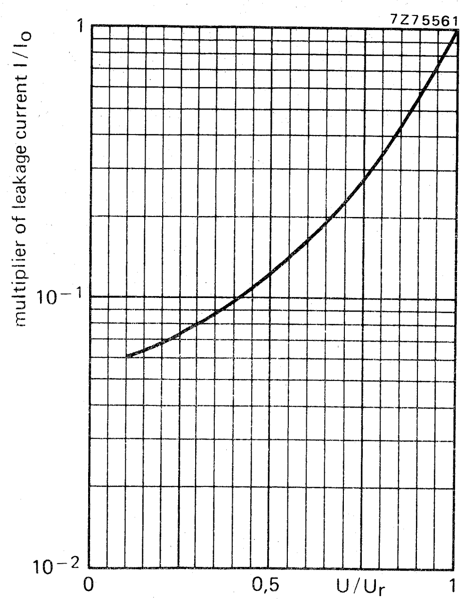


Fig. 6 Typical leakage current as a function of U/U_R; I_0 = leakage current during continuous operation at 25 °C and U_R.

Equivalent series resistance (ESR)

Maximum ESR at 100 Hz and T_{amb} = 25 °C, measured by means of a four-terminal circuit (Thomson Circuit)	see Table 2

Tan δ (dissipation factor)

Tan δ = ESR x ωC

Equivalent series inductance (ESL)

Case sizes 00 and 01	50 nH	typical values
Case size 02	55 nH	
Case sizes 03, 04 and 05	60 nH	

OPERATIONAL DATA

Category temperature range for rated voltage	−55 to +85 °C

PACKING

The capacitors are packed in boxes of 200 (case sizes 00 to 03) or 100 (case sizes 04, 05).

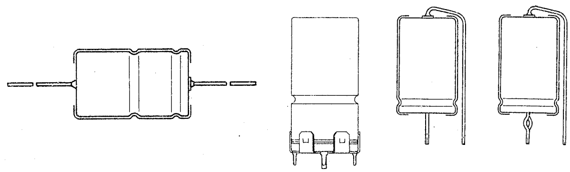
TESTS AND REQUIREMENTS

See Introduction, section 9, under aluminium electrolytic capacitors.

Note: Capacitors 2222 021 are small types, long-life grade.

ALUMINIUM ELECTROLYTIC CAPACITORS

- Miniature and small types
- Axial leads or single ended
- Long life
- General and industrial applications



Selection chart for C_{nom}-U_R and relevant case sizes

C_{nom} µF	U_R(V) 6,3	10	16	25	40	63	100	160	250	350	385
0,33						2					
0,47						2					
0,68						2					
1						2	2				4
1,5						2					
2,2					1	2	2		4		5
3,3				1		2	2				
4,7			1			2	3	4	5	6	7
6,8		1			2	2	3			00	00
10	1			2	2	3	4/5a	5	7/00	01	01
15			2		2	3			01	01	02
22		2		2	3	4/5a	5	7/00	01	02	03
33	2		2		3		6	01	02	03	04
47		2		3	4/5a	5	7	02	03	04	04
68	2		3			6	00	02	04	05	05
100		3		4/5a	5	7	01	03	05		
150	3		4/5a	5	6	00	02	04			
220		4/5a	5	6	7/00	01	03	05			
330		5	6	7	01	02	04				
470	5	6	7	00	01	02	05				
680	6	7	00	01	02	03	05				
1 000	7	00	01	02	03	05					
1 500	00	01	02	03	04	05					
2 200	01	02	03	04	05						
3 300	02	03	04	05	05						
4 700	03	04	05	05							
6 800	04	05	05								
10 000	05	05									
15 000	05										
2222 030; 031; 032; 033 see pages 33 to 75								2222 041; 042; 043 see pages 109 to 127			

Miniature types

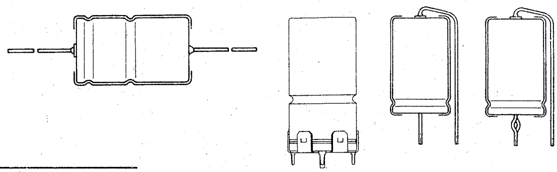
case size	nominal dimensions mm	series number
1	Ø 3,3 x 10	030
2	Ø 4,5 x 10	
3	Ø 6 x 10	
5a	Ø 8 x 11	
4	Ø 6,5 x 18	031 041
5	Ø 8 x 18	
6	Ø 10 x 18	
7	Ø 10 x 25	

Small types

case size	nominal dimensions mm	series number
00	Ø 10 x 30	032 042
01	Ø 12,5 x 30	
02	Ø 15 x 30	
03	Ø 18 x 30	
04	Ø 18 x 40	033
05	Ø 21 x 40	043

ALUMINIUM ELECTROLYTIC CAPACITORS

- Miniature and small types
- Axial leads or single ended
- Long life
- General and industrial applications



QUICK REFERENCE DATA

Nominal capacitance range (E6 series):	0,33 to 15 000 μF
Tolerance on nominal capacitance:	−10 to +50%
Rated voltage range, U_R (R5 series):	6,3 to 100 V
Category temperature range:	−40 to +85 °C
Endurance test at 85 °C	
case size 1:	1000 h
case sizes 2 to 7:	2000 h
case sizes 00 to 05:	5000 h
Basic specifications:	
IEC 384-4, long-life grade	
DIN 41316 (6,3 to 63 V versions)	
DIN 41332 (100 V version)	
Climatic category	
IEC 68:	40/085/56
DIN 40040:	GPF

case size	nominal dimensions (mm)	series number	
1	Ø 3,3 x 10	030	miniature
2	Ø 4,5 x 10	030	miniature
3	Ø 6 x 10	030	miniature
5a	Ø 8 x 11	030	miniature
4	Ø 6,5 x 18	031	miniature
5	Ø 8 x 18	031	miniature
6	Ø 10 x 18	031	miniature
7	Ø 10 x 25	031	miniature
00	Ø 10 x 30	032	small
01	Ø 12,5 x 30	032	small
02	Ø 15 x 30	032	small
03	Ø 18 x 30	032	small
04	Ø 18 x 40	033	small
05	Ø 21 x 40	033	small

Selection chart for C_{nom}-U_R and relevant case sizes.

C_{nom} μF	U_R (V) 6,3	10	16	25	40	63	100
0,33						2	
0,47						2	
0,68						2	
1						2	2
1,5						2	
2,2					1	2	2
3,3				1		2	2
4,7			1			2	3
6,8		1			2	2	3
10	1			2	2	3	4/5a
15			2		2	3	
22		2		2	3	4/5a	5
33	2		2		3		6
47		2		3	4/5a	5	7
68	2		3			6	00
100		3		4/5a	5	7	01
150	3		4/5a	5	6	00	02
220		4/5a	5	6	7/00	01	03
330		5	6	7	01	02	04
470	5	6	7	00	01	02	05
680	6	7	00	01	02	03	05
1 000	7	00	01	02	03	05	
1 500	00	01	02	03	04	05	
2 200	01	02	03	04	05		
3 300	02	03	04	05	05		
4 700	03	04	05	05			
6 800	04	05	05				
10 000	05	05					
15 000	05						

APPLICATION

These capacitors with high CU-product per unit volume are mainly used for smoothing, coupling and decoupling purposes in consumer applications, such as audio and television circuits, and in industrial applications, such as measuring and regulating circuits. Other applications are in timing and delay circuits. The taped versions are extremely suitable for automatic insertion and for cutting and forming equipment.

DESCRIPTION

The capacitors have etched aluminium foil electrodes rolled up with a paper strip impregnated with an electrolyte. The capacitors are in an aluminium case, which is insulated with a blue plastic sleeve.

The capacitors are available in 4 styles, all with soldered-copper leads.

Style 1: axial leads; case sizes 1 to 7 are supplied on bandoliers.
Style 2: single ended; with mounting ring with printed-wiring pins; especially for use in applications with severe shocks and vibrations; case sizes 03, 04 and 05.
Style 3: single ended; case sizes 1 to 7 and 00 to 03;
Style 4: single ended with self-locking lead; case sizes 4 to 7; non-preferred.

MECHANICAL DATA

Dimensions in mm

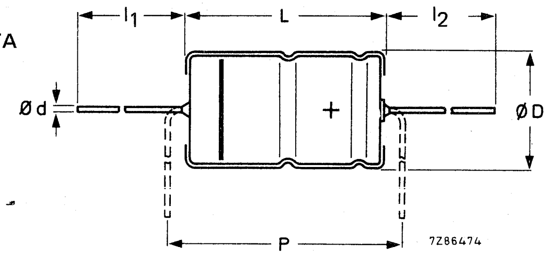


Fig. 1 Style 1; see Table 1a for dimensions d, D, L, l_1 and P.
l_2 = 33 ± 1 mm for case sizes 00 to 05.

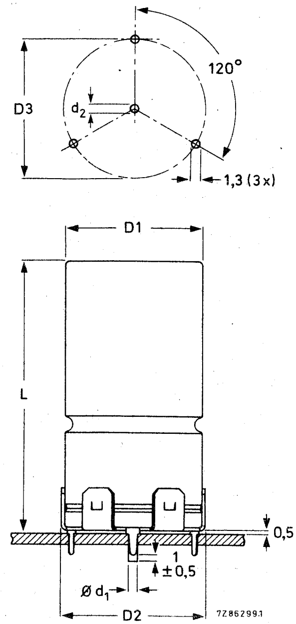
Table 1a

case size	d	l_1	style 1 D_{nom}	L_{nom}	D_{max}	L_{max}	P_{min}	mass approx. g
1	0,6	*	3,3	10,0	3,5	11,0	15	0,35
2	0,6	*	4,5	10,0	5,0	10,5	15	0,50
3	0,6	*	6,0	10,0	6,3	10,5	15	0,70
5a	0,6	*	8,0	11,0	8,5	11,5	15	1,1
4	0,8	*	6,5	18,0	6,9	18,5	25	1,3
5	0,8	*	8,0	18,0	8,5	18,5	25	1,7
6	0,8	*	10,0	18,0	10,5	18,5	25	2,5
7	0,8	*	10,0	25,0	10,5	25,0	30	3,3
00	0,8	55 ± 1	10,0	30,0	10,5	30,5	35,0	4
01	0,8	55 ± 1	12,5	30,0	13,0	30,5	35,0	6,3
02	0,8	55 ± 1	15,0	30,0	15,5	30,5	35,0	8,2
03	0,8	55 ± 1	18,0	30,0	18,5	30,5	35,0	10,9
04	0,8	34 ± 1	18,0	40,0	18,5	41,5	45,0	14
05	0,8	34 ± 1	21,0	40,0	21,5	41,5	45,0	19

* Case sizes 1 to 7 are supplied on bandoliers in boxes or on reels (see PACKING).

Table 1b

case size	style 2						mass approx. g
	d_1	d_2	D1	$D2_{max}$	D3	L	
03	0,8	1 + 0,1	18,0	20,5	18,5 ± 0,2	31 ± 1	11,5
04	1,0	1,3 + 0,1	18,0	20,5	18,5 ± 0,2	42 ± 1	15
05	1,0	1,3 + 0,1	21,0	23,5	21,5 ± 0,2	42 ± 1	20



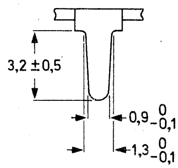


Fig. 2 Style 2; see Table 1b for dimensions d_1, d_2, D1, D2, D3 and L.

Table 1c

case size	d	style 3			mass approx. g
		D_{max}	L_{max}	P	
1	0,6	3,5	13,0	2,5– 5	0,25
2	0,6	5,0	12,5	2,5– 5	0,40
3	0,6	6,3	12,5	3,5– 7,5	0,55
5a	0,6	8,5	13,0	5 –10	1,0
4	0,8	6,9	21,5	5 –10	1,2
5	0,8	8,5	21,5	5 –10	1,6
6	0,8	10,5	21,5	7,5–12,5	2,3
7	0,8	10,5	28,0	7,5–12,5	3,1
00	0,8	10,5	34,0	7,5–12,5	3,8
01	0,8	13,0	34,0	7,5–12,5	6,1
02	0,8	15,5	34,0	10,0–15,0	8,0
03	0,8	18,5	34,0	10,0–15,0	10,7

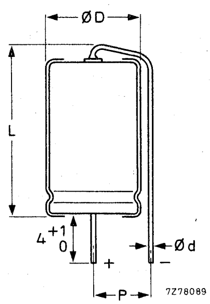


Fig. 3 Style 3 see Table 1c for dimensions d, D, L and P.

Table 1d

case size	d	style 4			mass approx g
		D_{max}	L_{max}	P	
4	0,8	6,9	21,5	5 –10	1,2
5	0,8	8,5	21,5	5 –10	1,6
6	0,8	10,5	21,5	7,5–12,5	2,3
7	0,8	10,5	28,0	7,5–12,5	3,1

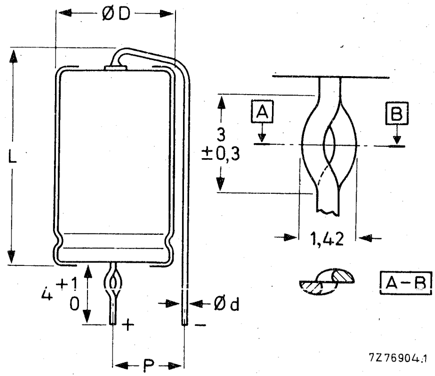


Fig. 4 Style 4; non-preferred; see Table 1d for dimensions d, D, L and P.

Marking

The capacitors are marked with:
- nominal capacitance;
- tolerance on nominal capacitance (not for case size 1);
- rated voltage;
- group number; code of origin;
- name of manufacturer;
- date code (year and month) according to IEC 62;
- band to identify the negative terminal;
- + signs to identify the positive terminal (not for case sizes 1 to 5a).

Mounting

The capacitors are suitable for mounting on printed-wiring boards; the required hole diameters are shown in Table 1e.

Table 1e

style	lead/pin diameter	required hole diameter
1 and 3	0,6 mm lead 0,8 mm lead	0,8 + 0,1 mm 1,0 + 0,1 mm
2	0,8 mm anode pin 1,0 mm anode pin cathode pins	1 + 0,1 mm 1,3 + 0,1 mm 1,3 + 0,1 mm
4	anode lead 0,8 mm cathode lead	1,3 + 0,1 mm 1,0 + 0,1 mm

Minimum atmospheric pressure

8,5 kPa

ELECTRICAL DATA

Table 2 (footnote is at the end of the table).

Unless otherwise specified all electrical values in Table 2 apply at an ambient temperature of 20 to 25 °C, a frequency of 100 Hz, an atmospheric pressure of 86 to 106 kPa and a relative humidity of 45 to 75%.

U_R V	nom. cap. µF	max. r.m.s. ripple current at 85 °C mA	max. leakage current at U_R after 1 min. µA	max. tan δ	max. ESR Ω	max. impedance Ω at 10 kHz	max. impedance Ω at 1 kHz	case size	catalogue number * 2222 followed by
6,3	10	14	5	0,30	47,8	20		1	030 .3109
6,3	33	42	11	0,25	12,1	6,1		2	030 .3339
6,3	68	53	22	0,25	5,86	2,9		2	030 .3689
6,3	150	87	10	0,25	2,66	1,3		3	030 .3151
6,3	470	220	22	0,25	0,85	0,43		5	031 .3471
6,3	680	350	30	0,25	0,59	0,29		6	031 .3681
6,3	1000	480	42	0,25	0,40	0,20		7	031 .3102
6,3	1500	450	61	0,28	0,30		0,23	00	032 .3152
6,3	2200	610	88	0,29	0,21		0,16	01	032 .3222
6,3	3300	790	129	0,32	0,15		0,11	02	032 .3332
6,3	4700	1000	182	0,34	0,12		0,07	03	032 .3472
6,3	6800	1280	261	0,39	0,09		0,05	04	033 .3682
6,3	10000	1570	382	0,45	0,07		0,05	05	033 .3103
6,3	15000	1600	571	0,67	0,07		0,05	05	033 .3153
10	6,8	14	5	0,25	58,6	24		1	030 .4688
10	22	42	11	0,20	14,5	7,3		2	030 .4229
10	47	53	24	0,20	6,78	3,4		2	030 .4479
10	100	87	10	0,20	3,19	1,6		3	030 .4101
10	220	150	18	0,20	1,45	0,73		5a	030 .4221
10	220	150	18	0,20	1,45	0,73		4	031 .4221
10	330	220	24	0,20	0,97	0,48		5	031 .4331
10	470	350	33	0,20	0,68	0,34		6	031 .4471
10	680	480	45	0,20	0,47	0,24		7	031 .4681
10	1000	430	64	0,20	0,32	0,20		00	032 .4102
10	1500	570	94	0,23	0,25		0,20	01	032 .4152
10	2200	740	136	0,24	0,18		0,14	02	032 .4222
10	3300	950	202	0,27	0,13		0,09	03	032 .4332
10	4700	1220	286	0,29	0,10		0,06	04	033 .4472
10	6800	1500	412	0,34	0,08		0,04	05	033 .4682
10	10000	1520	604	0,49	0,08		0,05	05	033 .4103

U_R V	nom. cap. µF	max. r.m.s. ripple current at 85 °C mA	max. leakage current at U_R after 1 min. µA	max. tan δ	max. ESR Ω	max. impedance Ω at 10 kHz	max. impedance Ω at 1 kHz	case size	catalogue number * 2222 followed by
16	4,7	14	5	0,20	67,8	26		1	030 .5478
16	15	42	12	0,16	17,0	8		2	030 .5159
16	33	53	27	0,16	7,72	3,6		2	030 .5339
16	68	87	11	0,16	3,75	1,8		3	030 .5689
16	150	150	19	0,16	1,70	0,80		5a	030 .5151
16	150	150	19	0,16	1,70	0,80		4	031 .5151
16	220	220	26	0,16	1,16	0,55		5	031 .5221
16	330	350	36	0,16	0,78	0,36		6	031 .5331
16	470	480	49	0,16	0,55	0,26		7	031 .5471
16	680	400	70	0,16	0,38	0,18		00	032 .5681
16	1000	550	100	0,16	0,26	0,12		01	032 .5102
16	1500	680	148	0,19	0,21		0,17	02	032 .5152
16	2200	880	216	0,20	0,15		0,13	03	032 .5222
16	3300	1160	321	0,23	0,11		0,08	04	033 .5332
16	4700	1430	455	0,25	0,09		0,06	05	033 .5472
16	6800	1460	657	0,36	0,08		0,06	05	033 .5682
25	3,3	13	5	0,18	86,9	27		1	030 .6338
25	10	36	13	0,14	22,3	9		2	030 .6109
25	22	43	28	0,14	10,2	4,1		2	030 .6229
25	47	83	12	0,14	4,80	1,9		3	030 .6479
25	100	120	19	0,14	2,23	0,90		5a	030 .6101
25	100	120	19	0,14	2,23	0,90		4	031 .6101
25	150	190	27	0,14	1,49	0,60		5	031 .6151
25	220	280	37	0,14	1,02	0,41		6	031 .6221
25	330	350	54	0,14	0,68	0,27		7	031 .6331
25	470	360	75	0,14	0,47	0,19		00	032 .6471
25	680	500	106	0,14	0,32	0,13		01	032 .6681
25	1000	660	154	0,14	0,22	0,09		02	032 .6102
25	1500	810	229	0,17	0,18		0,15	03	032 .6152
25	2200	1060	334	0,18	0,13		0,10	04	033 .6222
25	3300	1340	499	0,21	0,10		0,07	05	033 .6332
25	4700	1370	709	0,28	0,10		0,06	05	033 .6472

U_R V	nom. cap. µF	max. r.m.s. ripple current at 85 °C mA	max. leakage current at U_R after 1 min. µA	max. tan δ	max. ESR Ω	max. impedance Ω at 10 kHz	max. impedance Ω at 1 kHz	case size	catalogue number * 2222 followed by
40	2,2	13	5	0,15	109	32		1	030 .7228
40	6,8	36	14	0,11	25,8	10		2	030 .7688
40	10	38	20	0,11	17,6	7		2	030 .7109
40	15	43	30	0,11	11,7	4,7		2	030 .7159
40	22	61	9	0,11	8,0	3,2		3	030 .7229
40	33	83	12	0,11	5,31	2,1		3	030 .7339
40	47	120	16	0,11	3,73	1,5		5a	030 .7479
40	47	120	16	0,11	3,73	1,5		4	031 .7479
40	100	190	28	0,11	1,75	0,70		5	031 .7101
40	150	280	40	0,11	1,17	0,47		6	031 .7151
40	220	430	57	0,11	0,80	0,32		7	031 .7221
40	220	260	57	0,12	0,86	0,32		00	032 .7221
40	330	370	84	0,12	0,58	0,21		01	032 .7331
40	470	440	117	0,12	0,40	0,15		01	032 .7471
40	680	580	167	0,12	0,28	0,10		02	032 .7681
40	1000	780	244	0,12	0,19	0,07		03	032 .7102
40	1500	970	364	0,15	0,16		0,13	04	033 .7152
40	2200	1220	532	0,16	0,12		0,09	05	033 .7222
40	3300	1284	796	0,24	0,11		0,07	05	033 .7332
63	0,33	5	5	0,09	435	167		2	030 .8337
63	0,47	8	5	0,09	305	117		2	030 .8477
63	0,68	10	5	0,09	211	81		2	030 .8687
63	1,0	12	5	0,09	143	55		2	030 .8108
63	1,5	12	5	0,09	95,6	37		2	030 .8158
63	2,2	21	7	0,09	65,2	25		2	030 .8228
63	3,3	25	11	0,09	46,5	17		2	030 .8338
63	4,7	31	15	0,09	30,5	12		2	030 .8478
63	6,8	35	22	0,09	21,1	8,1		2	030 .8688
63	10	51	7	0,08	12,8	5,5		3	030 .8109
63	15	61	10	0,08	8,5	3,7		3	030 .8159
63	22	90	13	0,08	5,79	2,5		5a	030 .8229
63	22	90	13	0,08	5,79	2,5		4	031 .8229
63	47	120	22	0,08	2,71	1,2		5	031 .8479
63	68	200	30	0,08	1,88	0,81		6	031 .8689
63	100	260	42	0,08	1,28	0,55		7	031 .8101
63	150	260	61	0,08	0,90	0,37		00	032 .8151
63	220	350	88	0,08	0,61	0,25		01	032 .8221
63	330	480	129	0,08	0,41	0,17		02	032 .8331
63	470	570	182	0,08	0,29	0,15		02	032 .8471
63	680	770	261	0,08	0,20	0,08		03	032 .8681
63	1000	1140	382	0,08	0,14	0,06		05	033 .8102
63	1500	1110	571	0,12	0,15		0,15	05	033 .8152

U_R	nom. cap.	max. r.m.s. ripple current at 85 °C	max. leakage current at U_R after 1 min.	max. tan δ	max. ESR	max. impedance Ω		case size	catalogue number * 2222 followed by
						at 10 kHz	at 1 kHz		
V	µF	mA	µA		Ω				
100	1,0	14	5	0,08	128	45		2	030 .9108
100	2,2	25	11	0,08	57,9	21		2	030 .9228
100	3,3	35	17	0,08	38,6	14		2	030 .9338
100	4,7	38	22	0,07	23,7	9,6		3	030 .9478
100	6,8	61	34	0,07	16,4	6,6		3	030 .9688
~~100~~	~~10~~	~~90~~	~~50~~	~~0,07~~	~~11,2~~	~~4,5~~		~~5a~~	~~030 .9109~~
100	10	90	50	0,07	11,2	4,5		4	031 .9109
100	22	120	80	0,07	5,07	2,1		5	031 .9229
100	33	200	119	0,07	3,38	1,4		6	031 .9339
100	47	260	33	0,07	2,37	0,96		7	031 .9479
100	68	130	45	0,15	3,53	2,0		00	032 .9689
100	100	190	64	0,15	2,40	1,2		01	032 .9101
100	150	250	94	0,15	1,60	0,85		02	032 .9151
100	220	330	136	0,15	1,09	0,60		03	032 .9221
100	330	460	202	0,15	0,73	0,50		04	033 .9331
100	470	600	286	0,15	0,51	0,35		05	033 .9471
100	680	650	412	0,15	0,42	0,35		05	033 .9681

* Replace dot in catalogue number by:
1 for style 1, case sizes 00 to 05, supplied in box;
2 for style 1 on bandoliers on reel (preferred for case sizes 1 to 4) } case sizes 1 to 7
3 for style 1 on bandoliers in box (preferred for case sizes 5a to 7) } case sizes 1 to 7
4 for style 2;
8 for style 3;
7 for style 4.

Capacitance

Nominal capacitance at 100 Hz and T_{amb} = 20 °C	see Table 2
Tolerance on nominal capacitance at 100 Hz	−10 to +50%

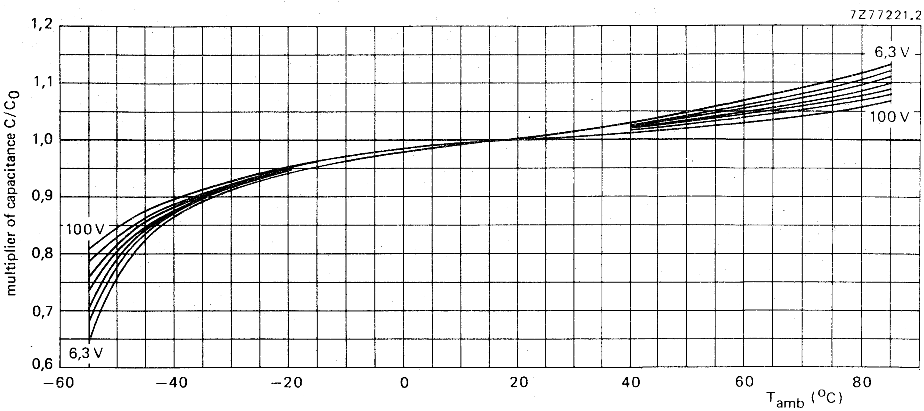


Fig. 5 Multiplier of capacitance as a function of ambient temperature; **case sizes 1 to 7;** C_0 = capacitance at 20 °C, 100 Hz.

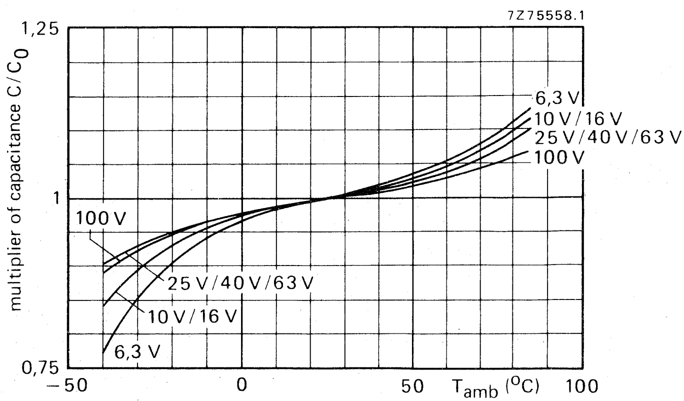


Fig. 6 Multiplier of capacitance as a function of ambient temperature; **case sizes 00 to 05;** C_0 = capacitance at 25 °C, 100 Hz.

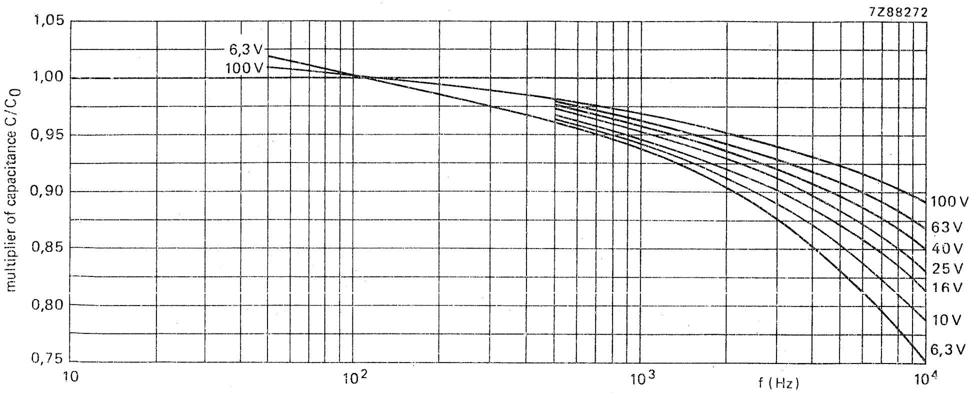


Fig. 7 Multiplier of capacitance as a function of frequency; **case sizes 1 to 7**; C_0 = capacitance at 20 °C, 100 Hz.

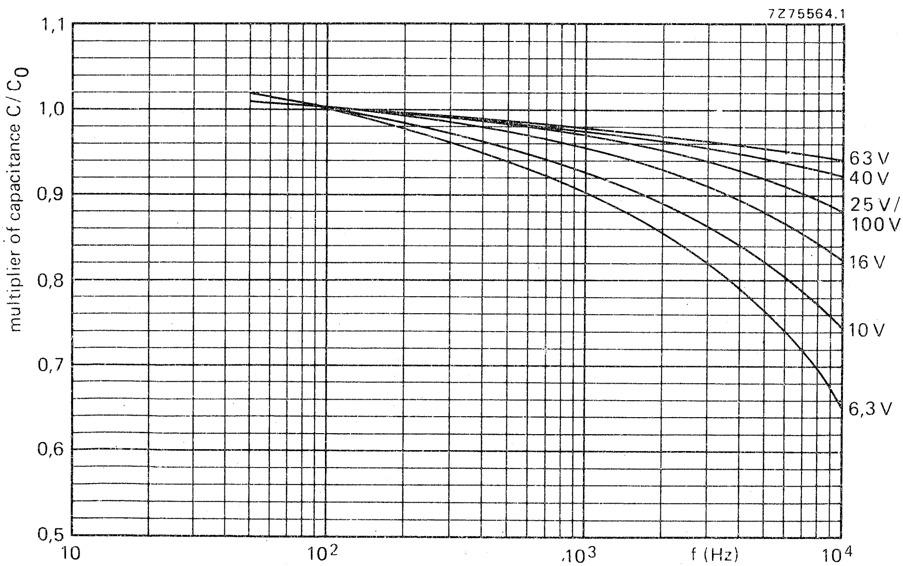


Fig. 8 Multiplier of capacitance as a function of frequency; **case sizes 00 to 05**; C_0 = capacitance at 25 °C, 100 Hz.

Voltage

	< 40 °C	40 to 85 °C
Rated voltage = max. permissible voltage	1,1 x U_R	U_R
Ripple voltage* = max. permissible a.c. voltage providing the following three conditions are met:		
a) max. (d.c. + peak a.c.) voltage	⩽ 1,1 x U_R	⩽ U_R
b) max. peak a.c. voltage with d.c. voltage applied	⩽ applied d.c. voltage + 1 V	
c) max. peak a.c. voltage without d.c. voltage applied	1 V	
Surge voltage = max. permissible voltage for short periods	1,15 x U_R	
Reverse voltage = max. d.c. voltage applied in the reverse polarity at the maximum category temperature for short periods	1 V	

Ripple current **

Maximum permissible r.m.s. ripple current at

100 Hz and T_{amb} = 85 °C	see Table 2
100 Hz and T_{amb} = 40 °C	2,24 x values stated in Table 2

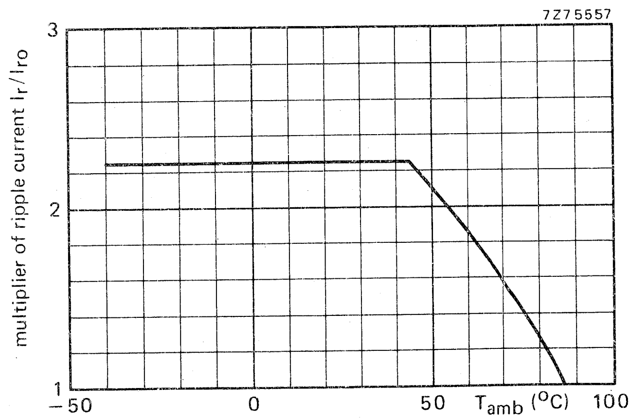


Fig. 9 Multiplier of ripple current as a function of ambient temperature; I_{r0} = ripple current at 85 °C, 100 Hz.

* Ripple voltages are not applicable if the maximum permissible ripple current is exceeded. In that case the ripple current is decisive.

** Ripple currents are not applicable if the maximum permissible ripple voltage is exceeded. In that case the ripple voltage is decisive.

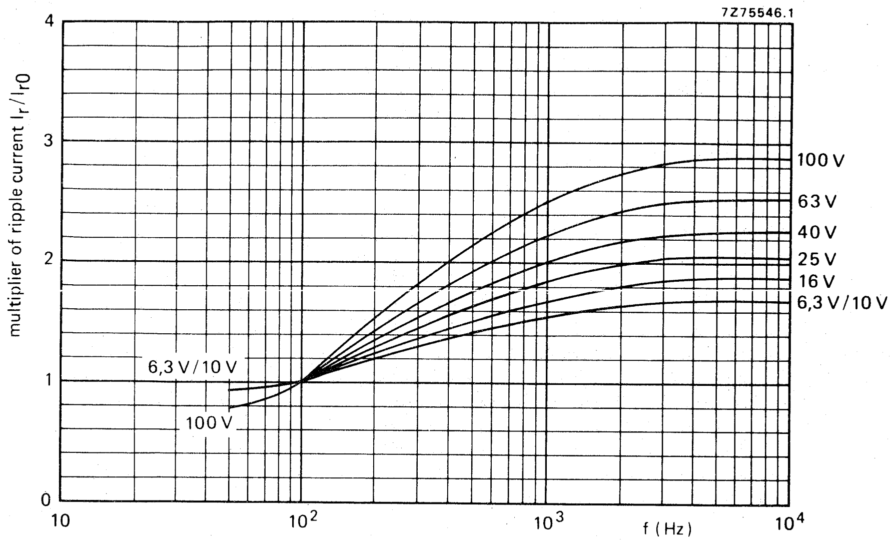


Fig. 10 Multiplier of ripple current as a function of frequency, **case sizes 1 to 7;** I_{r0} = ripple current at 100 Hz and upper category temperature.

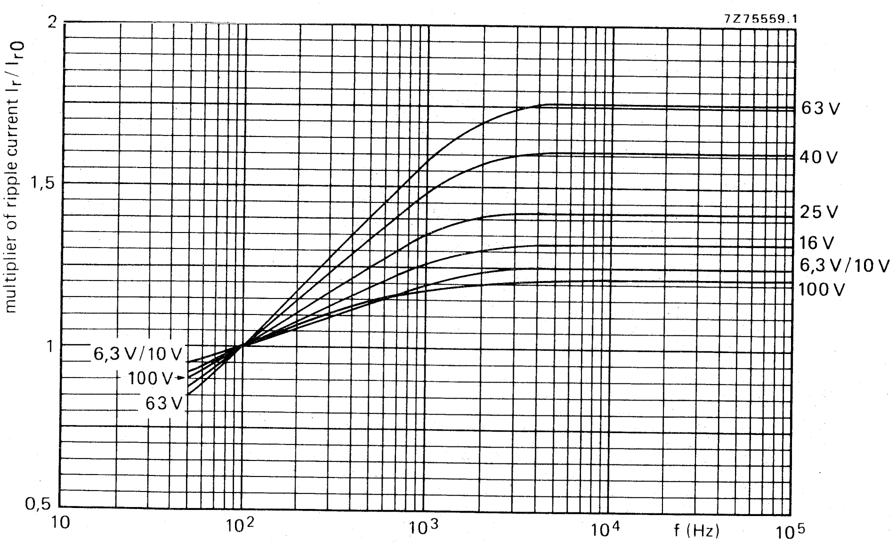


Fig. 11 Multiplier of ripple current as a function of frequency, **case sizes 00 to 03;** I_{r0} = ripple current at 85 °C, 100 Hz.

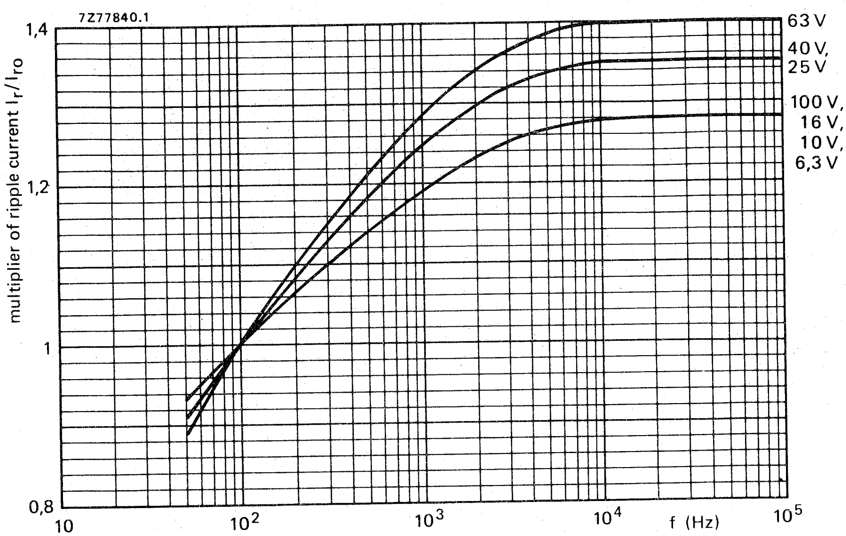


Fig. 12 Multiplier of ripple current as a function of frequency, **case sizes 04 and 05;** I_{r0} = ripple current at 85 °C, 100 Hz.

Non-sinusoidal ripple currents have to be analyzed into a number of sinusoidal currents and the following requirements shall then be satisfied:

$$\sum_n \frac{I_n^2}{r_n} \leq I_{r\,max}^2$$

$I_{r\,max}$ = maximum ripple current at 100 Hz and applicable ambient temperature;

I_n = ripple current at a certain frequency;

$\sqrt{r_n} = I_r/I_{r0}$ = multiplying factor at a same frequency.

Charge and discharge current

The capacitors may be charged from a source without internal resistance and they may be discharged by short-circuitring. If the capacitors are charged and discharged continuously at a rate of several times per minute, the charge and discharge currents have to be considered as ripple currents flowing through the capacitor. The r.m.s. value of these currents should be determined and the value thus found must not exceed the applicable limit.

Leakage current

Maximum leakage current 1 min after application of U_R, at T_{amb} = 20 °C.	
case sizes 1 and 2	see Table 2 (0,05 CU or 5 μA, whichever is greater)
case sizes 3 to 7 and 00 to 05	see Table 2 (0,006 CU + 4 μA for CU > 1000 μC; 0,01 CU or 1 μA, whichever is greater for CU ⩽ 1000 μC)
Leakage current during continuous operation at U_R,	
at T_{amb} = 20 °C, case sizes 1 to 7	approx. 0,1 x values of Table 2
at T_{amb} = 20 °C, case sizes 00 to 05	approx. 0,01 x values of Table 2
at T_{amb} = 85 °C	⩽ values of Table 2

If owing to prolonged storage and/or storage at an excessive temperature (> 40 °C) the leakage current is too high, application of the rated voltage for some hours will cause the leakage current to fall to a value lower than specified in Table 2.

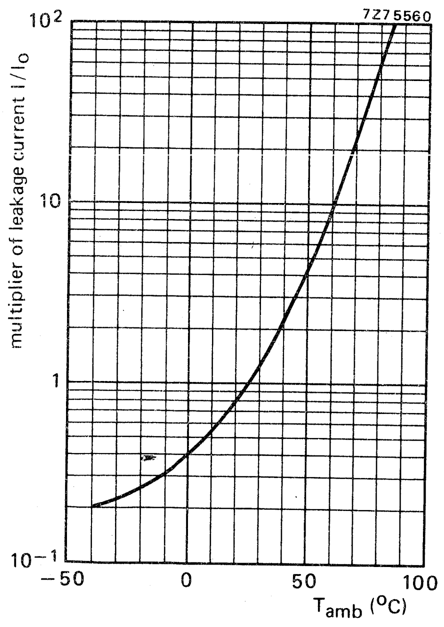


Fig. 13 Multiplier of leakage current as a function of ambient temperature, **case sizes 00 to 05;** I_o = leakage current during continuous operation at 25 °C and U_R.

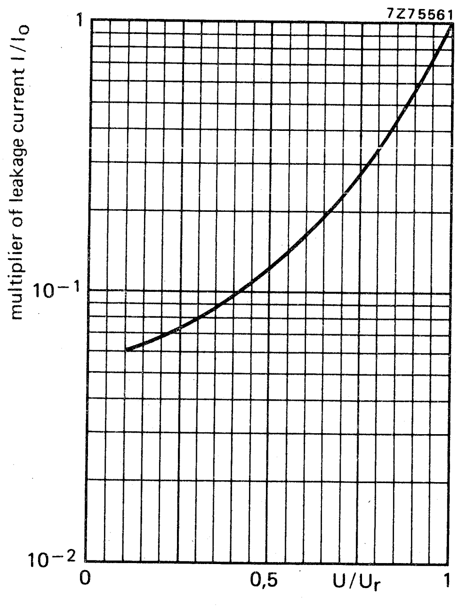


Fig. 14 Multiplier of leakage current as a function of U/U_R, **case sizes 00 to 05;** I_o = leakage current during continuous operation at 25 °C and U_R.

Tan δ

Maximum tan δ at 100 Hz and T_{amb} = 25 °C see Table 2

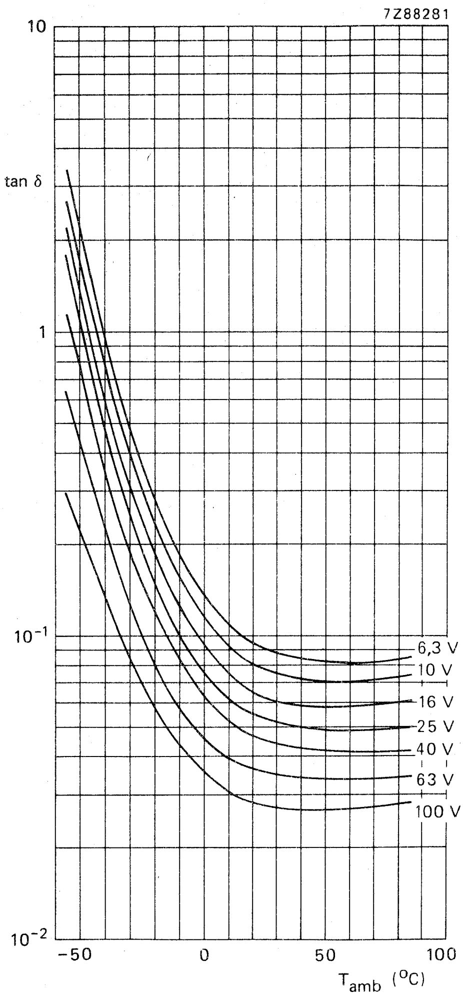


Fig. 15 Typical tan δ as a function of ambient temperature at 100 Hz; **case sizes 1 to 7.**

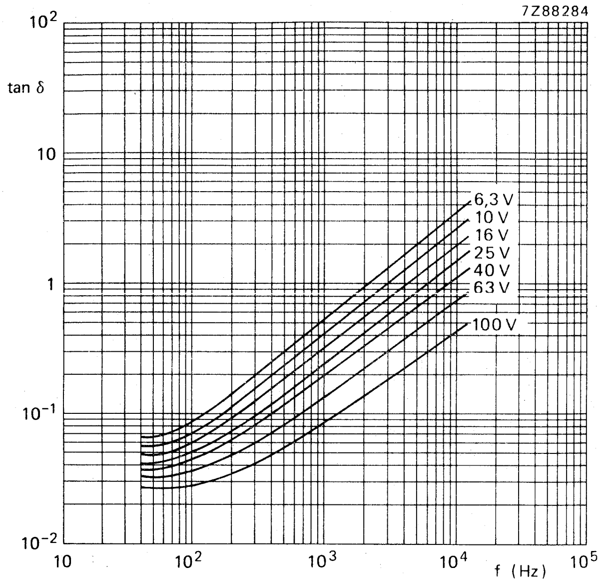


Fig. 16 Typical tan δ as a function of frequency at 25 °C, **case sizes 1 to 7.**

Equivalent series resistance (ESR)

Maximum ESR at 100 Hz and T_{amb} = 25 °C, measured by means of a four-terminal circuit (Thomson Circuit) (ESR = tan $\delta/\omega C$) see Table 2

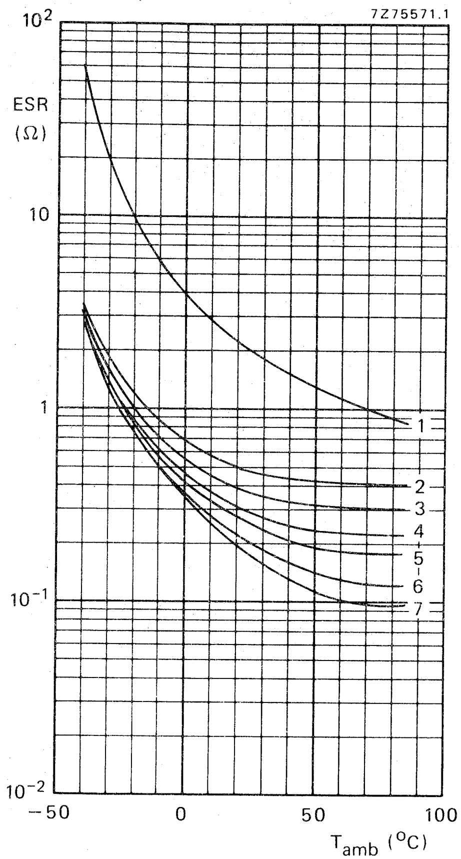


Fig. 17 Typical ESR as a function of ambient temperature at 100 Hz.

Case size 00:
curve 1 = 68 μF, 100 V;
curve 2 = 150 μF, 63 V;
curve 3 = 220 μF, 40 V;
curve 4 = 470 μF, 25 V;
curve 5 = 680 μF, 16 V;
curve 6 = 1000 μF, 10 V;
curve 7 = 1500 μF, 6,3 V.

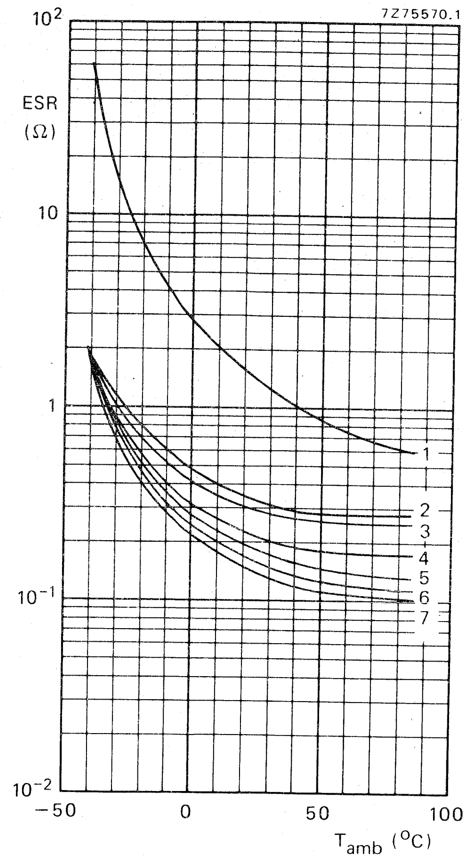


Fig. 18 Typical ESR as a function of ambient temperature at 100 Hz.

Case size 01:
curve 1 = 100 μF, 100 V;
curve 2 = 220 μF, 63 V;
curve 3 = 330 μF, 40 V;
curve 4 = 470 μF, 40 V;
curve 5 = 680 μF, 25 V;
curve 6 = 1000 μF, 16 V;
curve 7 = 1500 μF, 10 V and 2200 μF, 6,3 V.

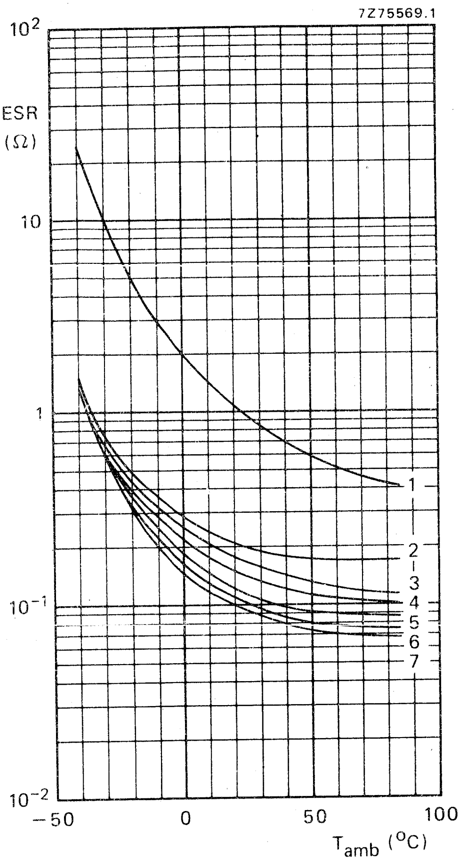


Fig. 19 Typical ESR as a function of ambient temperature at 100 Hz.

Case size 02:
curve 1 = 150 μF, 100 V;
curve 2 = 330 μF, 63 V;
curve 3 = 470 μF, 63 V;
curve 4 = 680 μF, 40 V;
curve 5 = 1000 μF, 25 V;
curve 6 = 1500 μF, 16 V;
curve 7 = 2200 μF, 10 V and 3300 μF, 6,3 V.

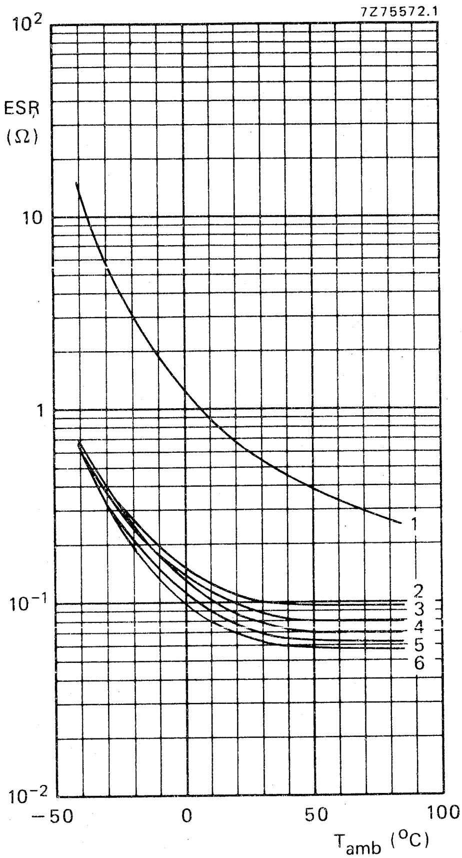


Fig. 20 Typical ESR as a function of ambient temperature at 100 Hz.

Case size 03:
curve 1 = 220 μF, 100 V;
curve 2 = 680 μF, 63 V;
curve 3 = 1000 μF, 40 V;
curve 4 = 1500 μF, 25 V;
curve 5 = 2200 μF, 16 V;
curve 6 = 3300 μF, 10 V and 4700 μF, 6,3 V.

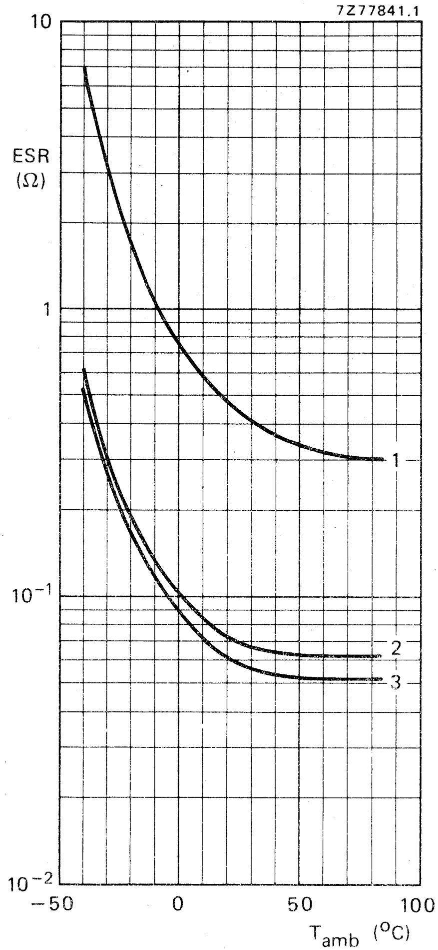


Fig. 21 Typical ESR as a function of ambient temperature at 100 Hz.

Case size 04:
curve 1 = 330 μF, 100 V;
curve 2 = 1500 μF, 40 V and 2200 μF, 25 V;
curve 3 = 3300 μF, 16 V, 4700 μF, 10 V and 6800 μF, 6,3 V.

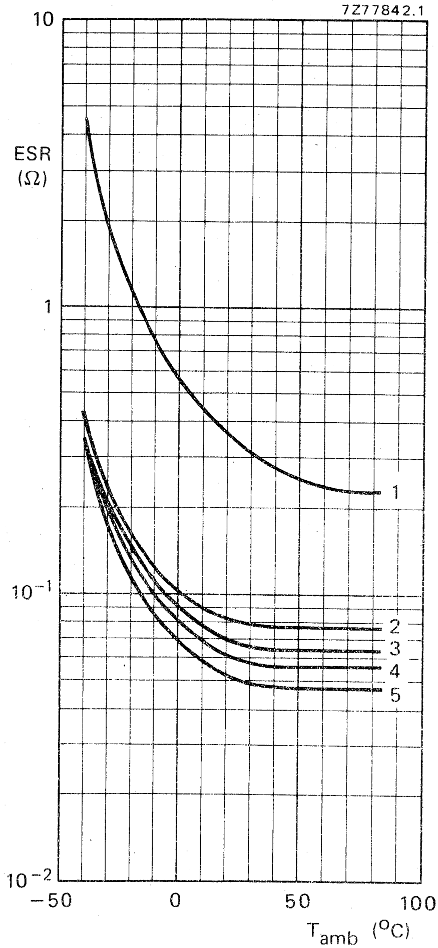


Fig. 22 Typical ESR as a function of ambient temperature at 100 Hz.

case size 05:
curve 1 = 470 μF, 100 V and 680 μF, 100 V;
curve 2 = 1000 μF, 63 V;
curve 3 = 1500 μF, 63 V;
curve 4 = 2200 μF, 40 V and 3300 μF, 25 V;
curve 5 = 4700 μF, 16 V, 6800 μF, 10 V, 10 000 μF, 6,3 V and 15 000 μF, 6,3 V.

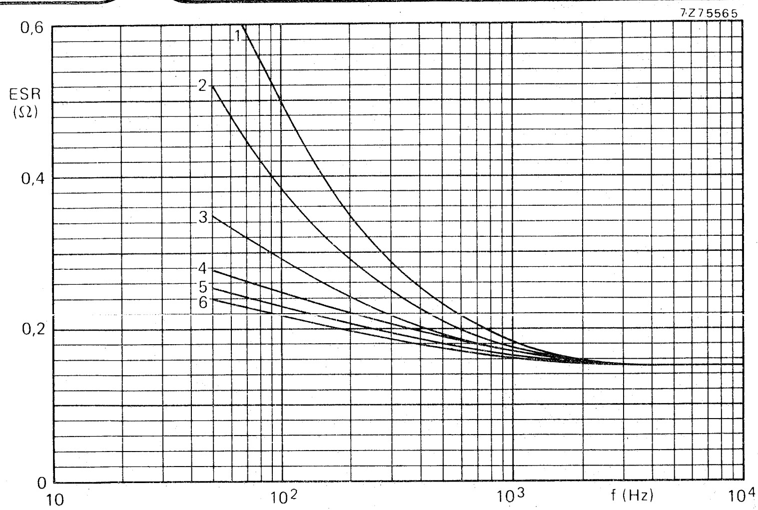


Fig. 23 Typical ESR as a function of frequency at 25 °C. 6,3 to 63 V versions, **case size 00:**

curve 1 = 150 μF, 63 V;
curve 2 = 220 μF, 40 V;
curve 3 = 470 μF, 25 V;
curve 4 = 680 μF, 16 V;
curve 5 = 1000 μF, 10 V;
curve 6 = 1500 μF, 6,3 V.

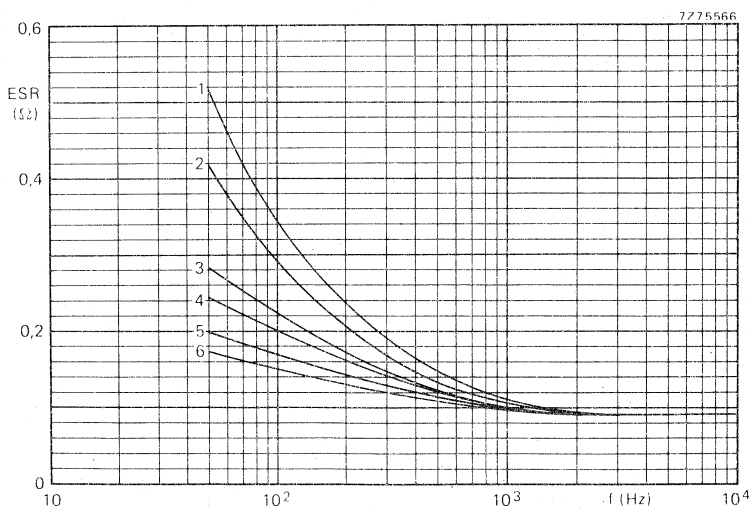


Fig. 24 Typical ESR as a function of frequency at 25 °C. 6,3 to 63 V versions, **case size 01:**

curve 1 = 220 μF, 63 V;
curve 2 = 330 μF, 40 V;
curve 3 = 470 μF, 40 V;
curve 4 = 680 μF, 25 V;
curve 5 = 1000 μF, 16 V;
curve 6 = 1500 μF, 10 V; and 2200 μF, 6,3 V.

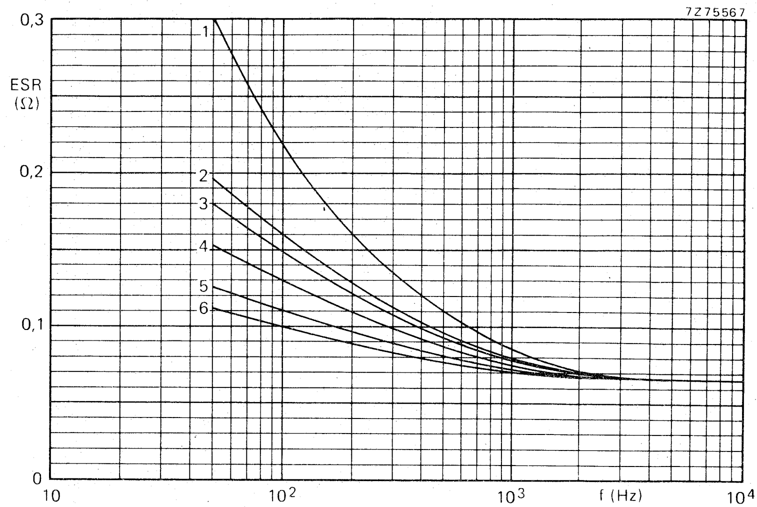


Fig. 25 Typical ESR as a function of frequency at 25 °C. 6,3 to 63 V versions, **case size 02:**

curve 1 = 330 μF, 63 V;
curve 2 = 470 μF, 63 V;
curve 3 = 680 μF, 40 V;
curve 4 = 1000 μF, 25 V;
curve 5 = 1500 μF, 16 V;
curve 6 = 2200 μF, 10 V;
and 3300 μF, 6,3 V.

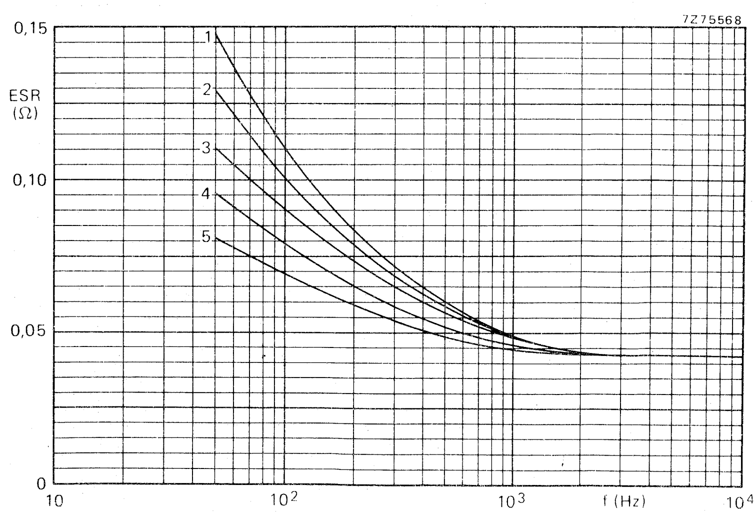


Fig. 26 Typical ESR as a function of frequency at 25 °C. 6,3 to 63 V versions, **case size 03:**

curve 1 = 680 μF, 63 V;
curve 2 = 1000 μF, 40 V;
curve 3 = 1500 μF, 25 V;
curve 4 = 2200 μF, 16 V;
curve 5 = 3300 μF, 10 V;
and 4700 μF, 6,3 V.

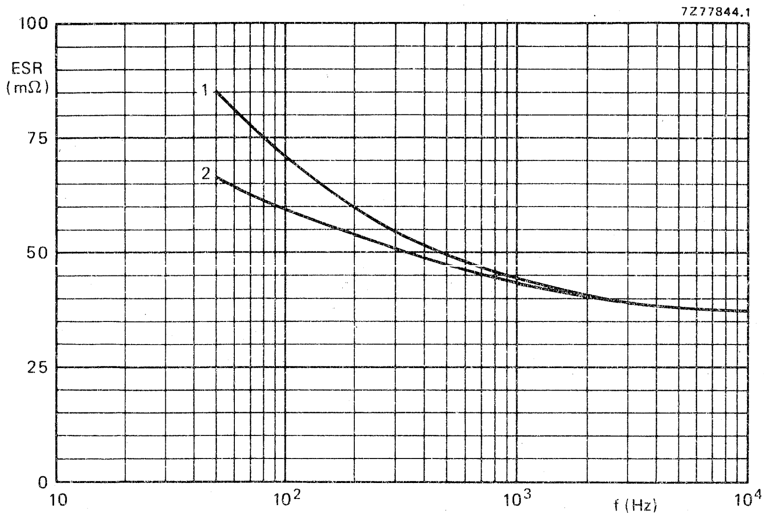


Fig. 27 Typical ESR as a function of frequency at 25 °C. **Case size 04**: curve 1 = 1500 μF, 40 V and 2200 μF, 25 V; curve 2 = 3300 μF, 16 V, 4700 μF, 10 V and 6800 μF, 6,3 V.

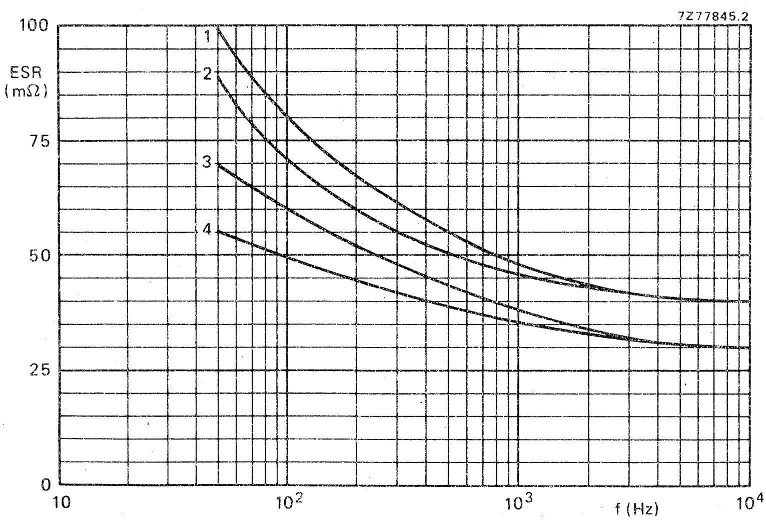


Fig. 28 Typical ESR as a function of frequency at 25 °C. **Case size 05**: curve 1 = 1000 μF, 63 V; curve 2 = 1500 μF, 63 V; curve 3 = 2200 μF, 40 V and 3300 μF, 25 V; curve 4 = 4700 μF, 16 V, 6800 μF, 10 V, 10 000 μF and 15 000 μF, 6,3 V.

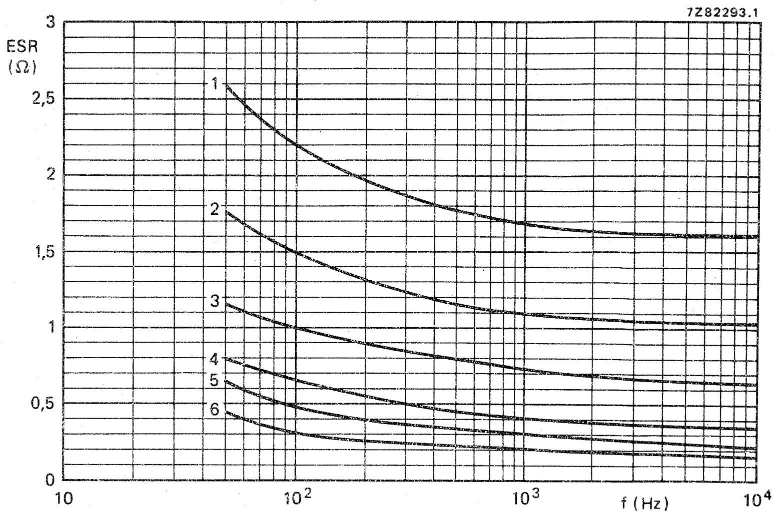


Fig. 29 Typical ESR as a function of frequency at 25 °C. 100 V version:
curve 1 = 68 μF, case size 00;
curve 2 = 100 μF, case size 01;
curve 3 = 150 μF, case size 02;
curve 4 = 220 μF, case size 03;
curve 5 = 330 μF, case size 04;
curve 6 = 470 μF and 680 μF, case size 05.

Impedance (Z)

Maximum impedance at T_{amb} = 20 °C and 1 kHz or 10 kHz, measured by means of a four-terminal circuit (Thomson circuit)	see Table 2
$z = Z \times C_{nom}$, at 10 kHz	see Table 3
$z = Z \times C_{nom}$, at 1 kHz	see Table 4

Table 3

T_{amb}	$z = Z \times C_{nom}$ (Ω μF) at U_R; at 10 kHz						
	6,3 V	10 V	16 V	25 V	40 V	63 V	100 V
+20 °C	⩽ 200	⩽ 160	⩽ 120	⩽ 90	⩽ 70	⩽ 55	⩽ 45
−25 °C	⩽ 1200	⩽ 750	⩽ 560	⩽ 400	⩽ 300	⩽ 180	⩽ 130
−40 °C	⩽ 3200	⩽ 2000	⩽ 1500	⩽ 1100	⩽ 900	⩽ 500	⩽ 350

Table 4

T_{amb}	$z = Z \times C_{nom}$ (Ω μF) at U_R; at 1 kHz						
	6,3 V	10 V	16 V	25 V	40 V	63 V	100 V
+20 °C	⩽ 350	⩽ 300	⩽ 250	⩽ 220	⩽ 200	⩽ 180	⩽ 175
−25 °C	⩽ 1700	⩽ 1100	⩽ 800	⩽ 570	⩽ 430	⩽ 330	⩽ 300
−40 °C	⩽ 4500	⩽ 2800	⩽ 2000	⩽ 1400	⩽ 1100	⩽ 800	—

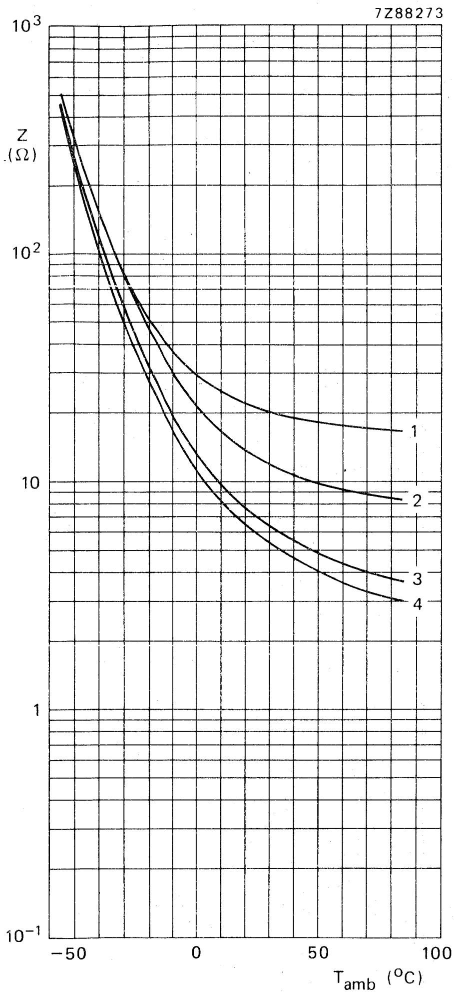


Fig. 30 Typical impedance as a function of ambient temperature at 10 kHz; **case size 1:**

curve 1 = 1 μF, 63 V;
curve 2 = 2,2 μF, 40 V;
curve 3 = 4,7 μF, 16 V;
curve 4 = 10 μF, 6,3 V.

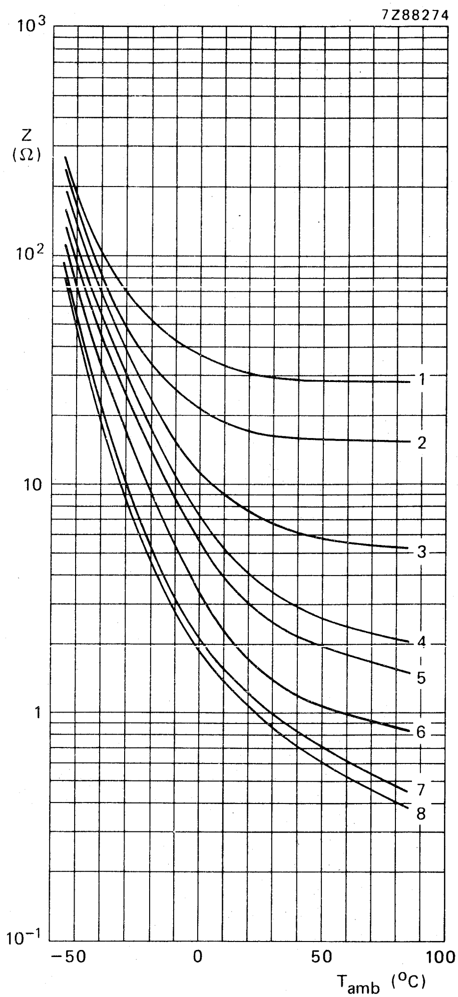


Fig. 31 Typical impedance as a function of ambient temperature at 10 kHz; **case size 2:**

curve 1 = 0,47 μF, 63 V;
curve 2 = 1 μF, 63 V;
curve 3 = 3,3 μF, 63 V;
curve 4 = 6,8 μF, 63 V;
curve 5 = 10 μF, 25 V;
curve 6 = 22 μF, 25 V;
curve 7 = 47 μF, 10 V;
curve 8 = 68 μF, 6,3 V.

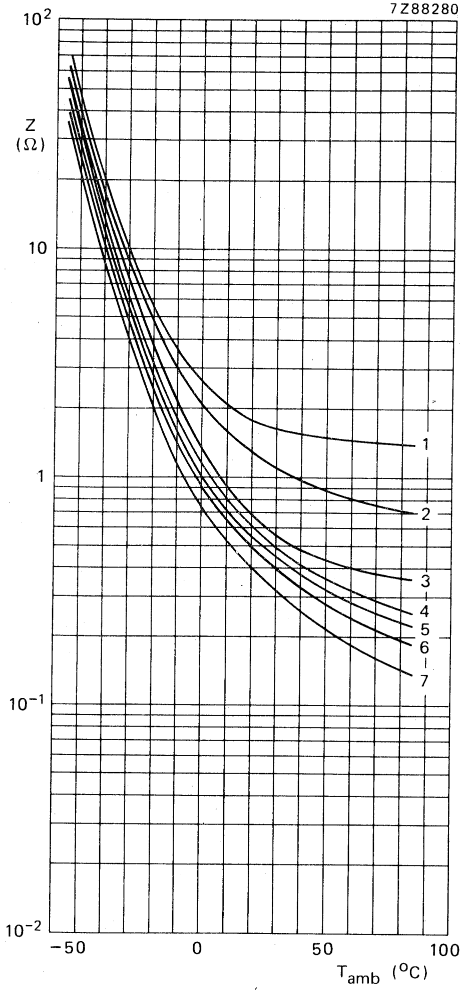


Fig. 32 Typical impedance as a function of ambient temperature at 10 kHz; **case size 3:**

curve 1 = 4,7 μF, 100 V;
curve 2 = 10 μF, 63 V;
curve 3 = 22 μF, 40 V;
curve 4 = 47 μF, 25 V;
curve 5 = 68 μF, 16 V;
curve 6 = 100 μF, 10 V;
curve 7 = 150 μF, 6,3 V.

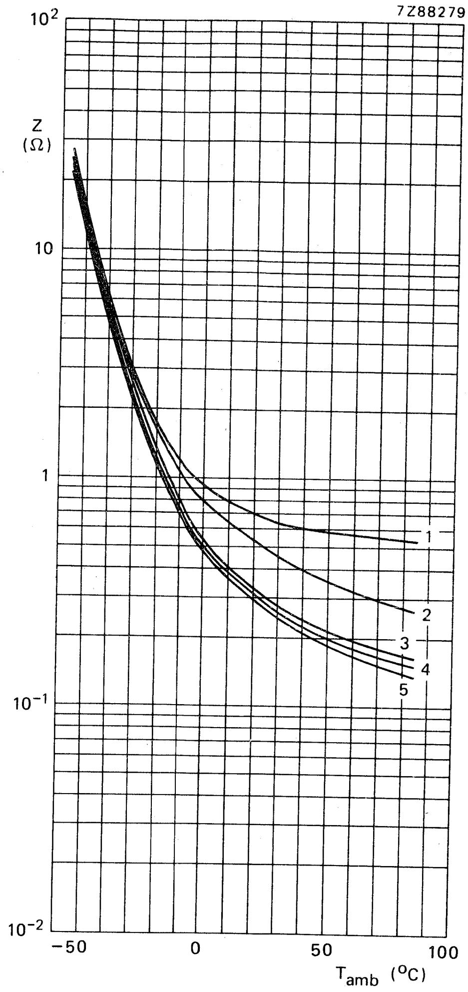


Fig. 33 Typical impedance as a function of ambient temperature at 10 kHz; **case size 5a:**

curve 1 = 22 μF, 63 V;
curve 2 = 47 μF, 40 V;
curve 3 = 100 μF, 25 V;
curve 4 = 150 μF, 16 V;
curve 5 = 220 μF, 10 V.

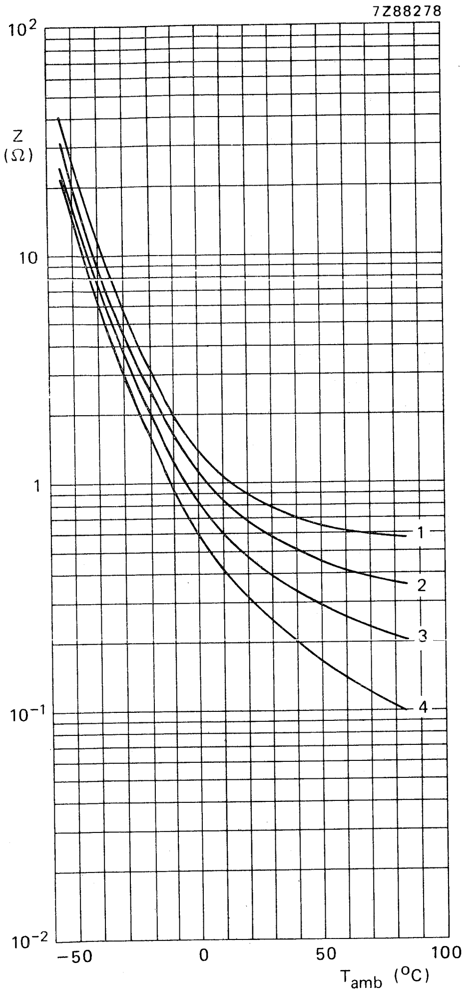


Fig. 34 Typical impedance as a function of ambient temperature at 10 kHz; **case size 4:**

curve 1 = 22 μF, 63 V;
curve 2 = 47 μF, 40 V;
curve 3 = 100 μF, 25 V;
curve 4 = 220 μF, 10 V.

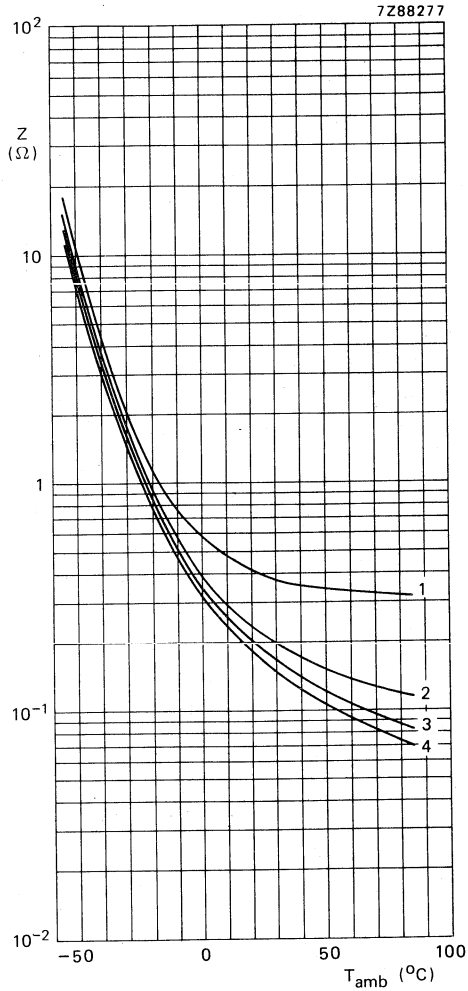


Fig. 35 Typical impedance as a function of ambient temperature at 10 kHz; **case size 5:**

curve 1 = 47 μF, 63 V;
curve 2 = 150 μF, 25 V;
curve 3 = 330 μF, 10 V;
curve 4 = 470 μF, 6,3 V.

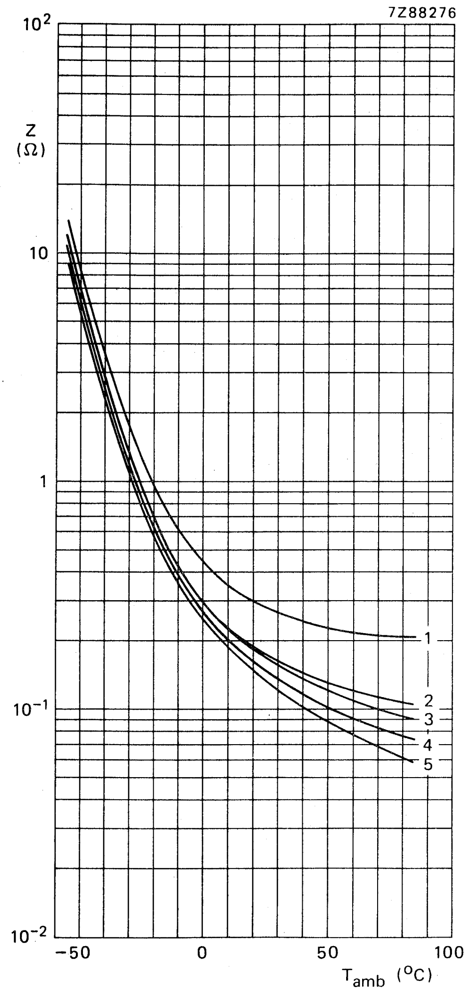


Fig. 36 Typical impedance as a function of ambient temperature at 10 kHz; **case size 6:**

curve 1 = 68 μF, 63 V;
curve 2 = 150 μF, 40 V;
curve 3 = 220 μF, 25 V;
curve 4 = 330 μF, 16 V;
curve 5 = 680 μF, 6,3 V.

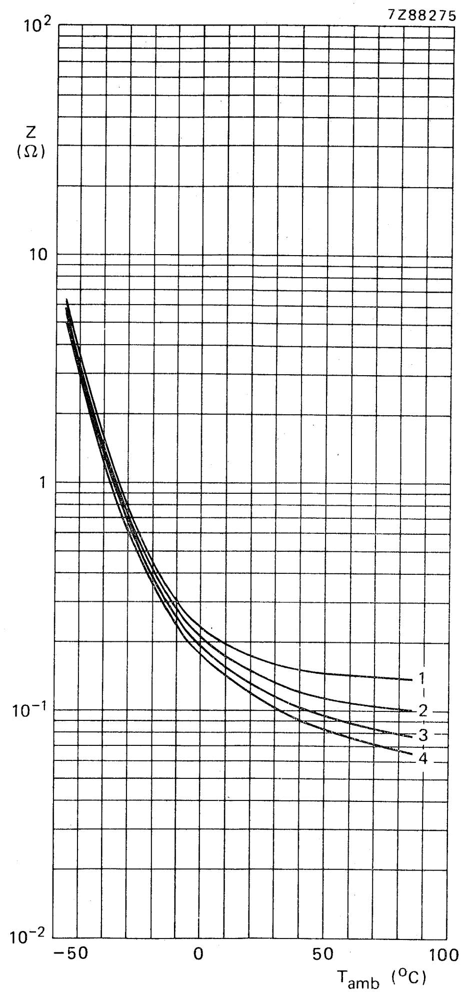


Fig. 37 Typical impedance as a function of ambient temperature at 10 kHz; **case size 7:**

curve 1 = 100 μF, 63 V;
curve 2 = 220 μF, 40 V;
curve 3 = 470 μF, 16 V;
curve 4 = 1000 μF, 6,3 V.

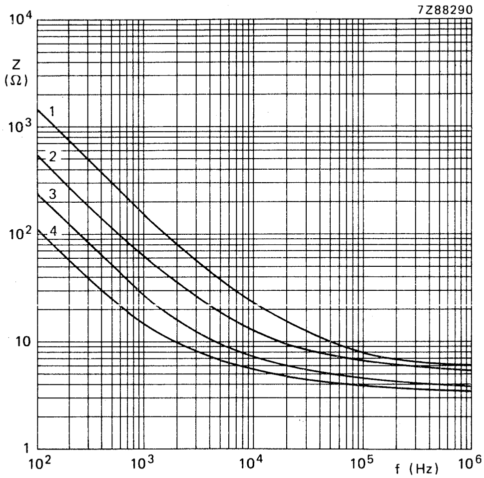


Fig. 38 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 1:**
curve 1 = 1 μF, 63 V;
curve 2 = 2,2 μF, 40 V;
curve 3 = 4,7 μF, 16 V;
curve 4 = 10 μF, 6,3 V.

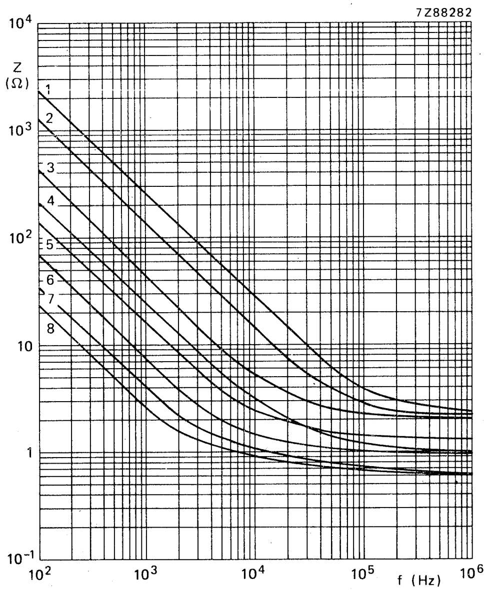


Fig. 39 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 2:**
curve 1 = 0,47 μF, 63 V;
curve 2 = 1 μF, 63 V/100 V;
curve 3 = 3,3 μF, 63 V/100 V;
curve 4 = 6,8 μF, 63 V;
curve 5 = 10 μF, 25 V;
curve 6 = 22 μF, 25 V;
curve 7 = 47 μF, 10 V;
curve 8 = 68 μF, 6,3 V.

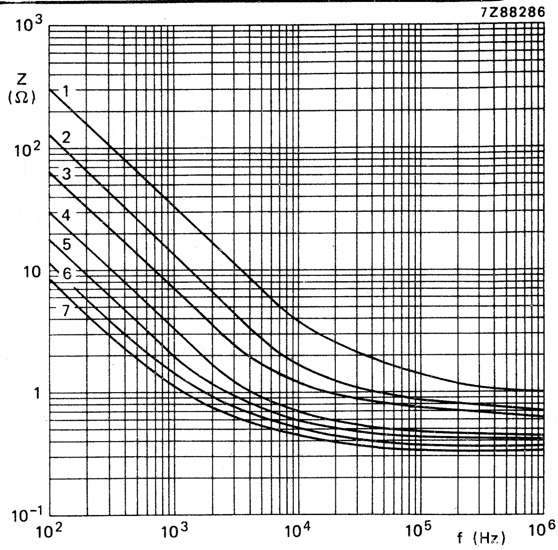


Fig. 40 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 3:**
curve 1 = 4,7 μF, 100 V;
curve 2 = 10 μF, 63 V;
curve 3 = 22 μF, 40 V;
curve 4 = 47 μF, 25 V;
curve 5 = 68 μF, 16 V;
curve 6 = 100 μF, 10 V;
curve 7 = 150 μF, 6,3 V.

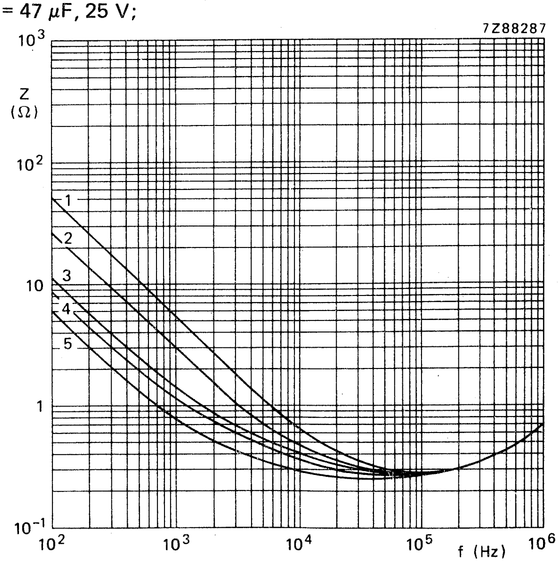


Fig. 41 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 5a:**
curve 1 = 22 μF, 63 V;
curve 2 = 47 μF, 40 V;
curve 3 = 100 μF, 25 V;
curve 4 = 150 μF, 16 V;
curve 5 = 220 μF, 10 V.

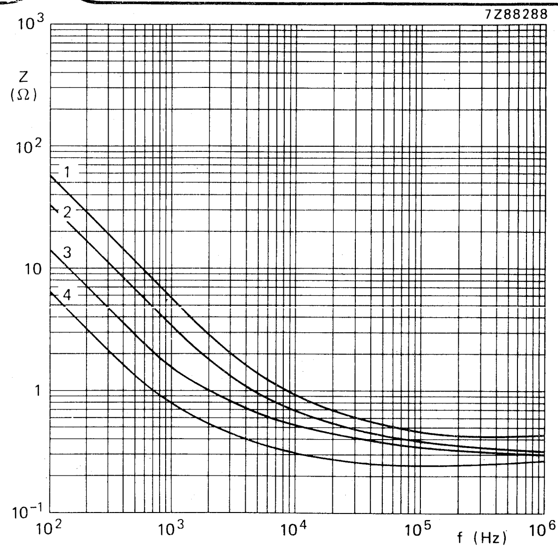


Fig. 42 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 4:**
curve 1 = 22 μF, 63 V;
curve 2 = 47 μF, 40 V;
curve 3 = 100 μF, 25 V;
curve 4 = 220 μF, 10 V.

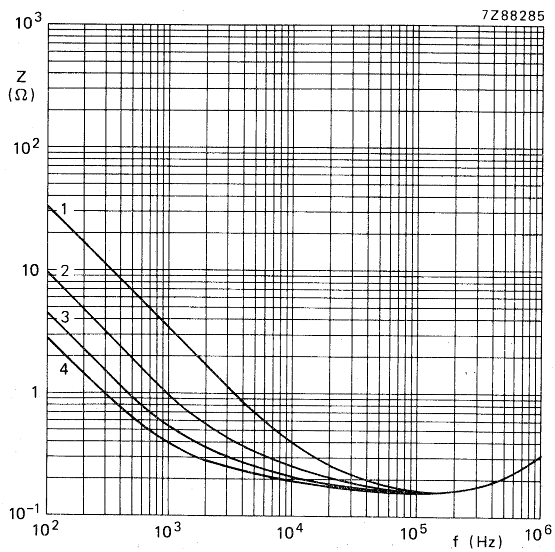


Fig. 43 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 5:**
curve 1 = 47 μF, 63 V;
curve 2 = 150 μF, 25 V;
curve 3 = 330 μF, 10 V;
curve 4 = 470 μF, 6,3 V.

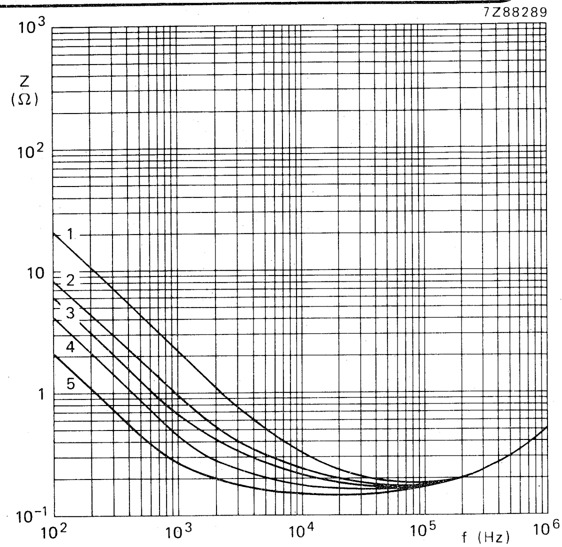


Fig. 44 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 6:**
curve 1 = 68 μF, 63 V;
curve 2 = 150 μF, 40 V;
curve 3 = 220 μF, 25 V;
curve 4 = 330 μF, 16 V;
curve 5 = 680 μF, 6,3 V.

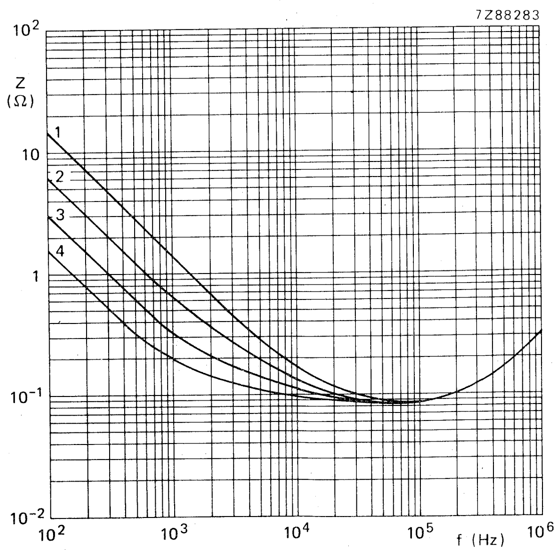


Fig. 45 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 7:**
curve 1 = 100 μF, 63 V;
curve 2 = 220 μF, 40 V;
curve 3 = 470 μF, 16 V;
curve 4 = 1000 μF, 6,3 V.

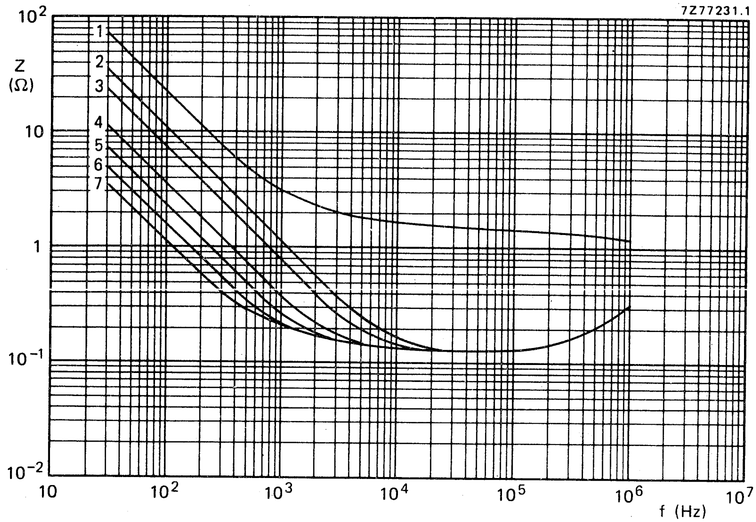


Fig. 46 Typical impedance as a function of frequency at 20 °C. **Case size 00:**
curve 1 = 68 μF, 100 V;
curve 2 = 150 μF, 63 V;
curve 3 = 220 μF, 40 V;
curve 4 = 470 μF, 25 V;
curve 5 = 680 μF, 16 V;
curve 6 = 1000 μF, 10 V;
curve 7 = 1500 μF, 6,3 V.

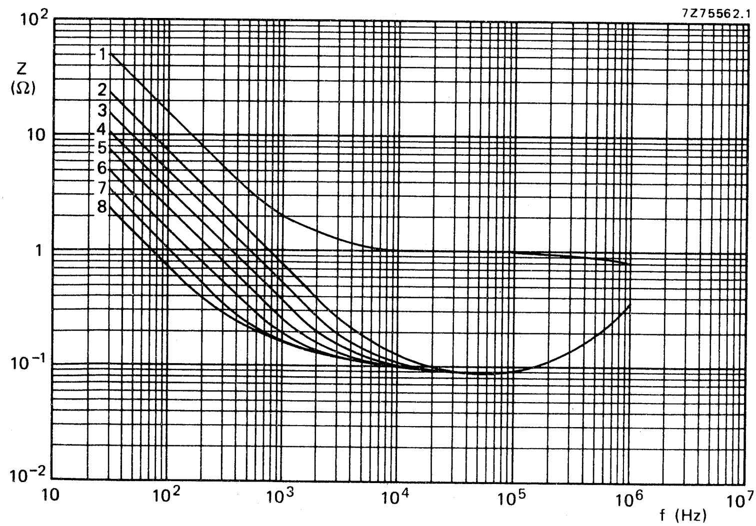


Fig. 47 Typical impedance as a function of frequency at 20 °C. **Case size 01:**
curve 1 = 100 μF, 100 V;
curve 2 = 220 μF, 63 V;
curve 3 = 330 μF, 40 V;
curve 4 = 470 μF, 40 V;
curve 5 = 680 μF, 25 V;
curve 6 = 1000 μF, 16 V;
curve 7 = 1500 μF, 10 V;
curve 8 = 2200 μF, 6,3 V.

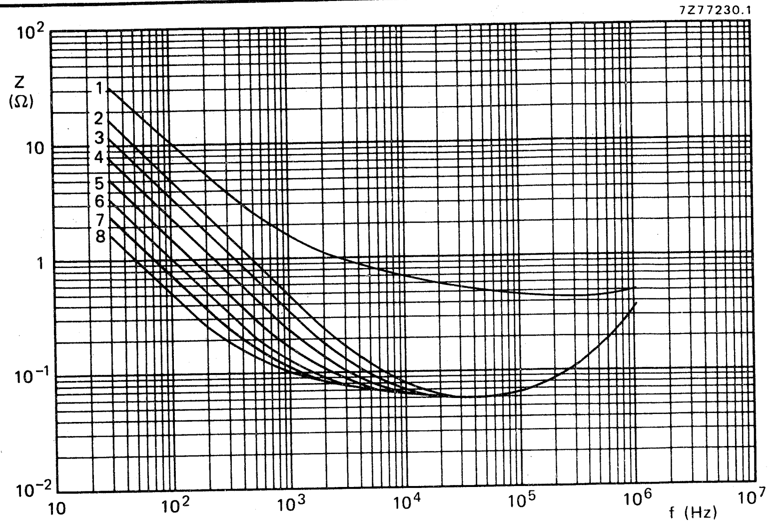


Fig. 48 Typical impedance as a function of frequency at 20 °C. **Case size 02:**
curve 1 = 150 μF, 100 V;
curve 2 = 330 μF, 63 V;
curve 3 = 470 μF, 63 V;
curve 4 = 680 μF, 40 V;
curve 5 = 1000 μF, 25 V;
curve 6 = 1500 μF, 16 V;
curve 7 = 2200 μF, 10 V;
curve 8 = 3300 μF, 6,3 V.

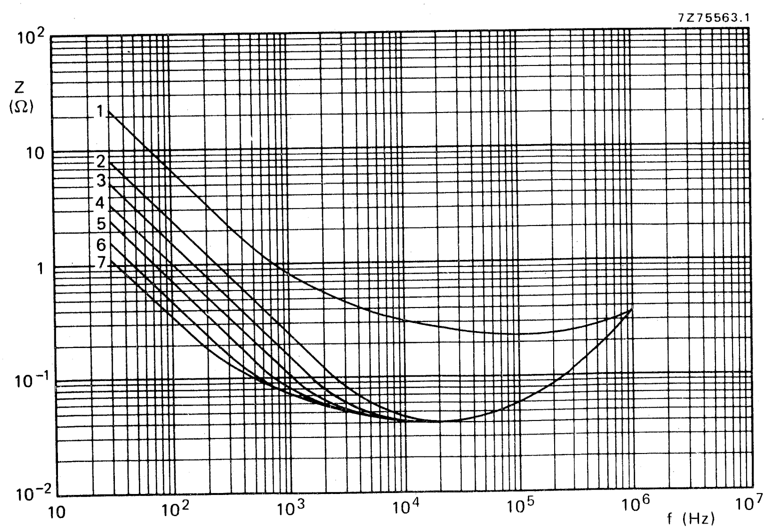


Fig. 49 Typical impedance as a function of frequency at 20 °C. **Case size 03:**
curve 1 = 220 μF, 100 V;
curve 2 = 680 μF, 63 V;
curve 3 = 1000 μF, 40 V;
curve 4 = 1500 μF, 25 V;
curve 5 = 2200 μF, 16 V;
curve 6 = 3300 μF, 10 V;
curve 7 = 4700 μF, 6,3 V.

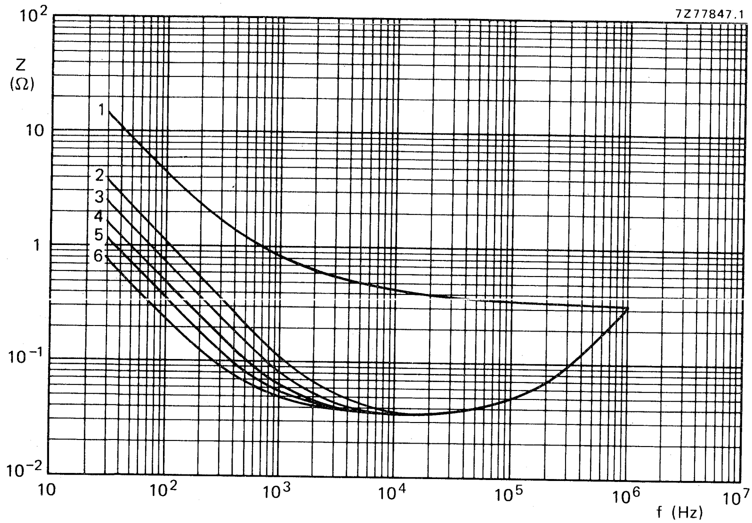


Fig. 50 Typical impedance as a function of frequency at 20 °C. **Case size 04:**
curve 1 = 330 μF, 100 V; curve 2 = 1500 μF, 40 V; curve 3 = 2200 μF, 25 V; curve 4 = 3300 μF, 16 V; curve 5 = 4700 μF, 10 V; curve 6 = 6800 μF, 6,3 V.

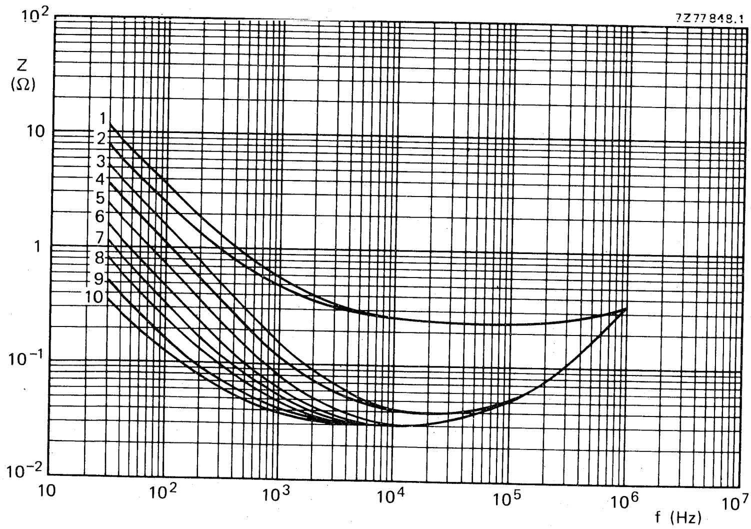


Fig. 51 Typical impedance as a function of frequency at 20 °C. **Case size 05:**
curve 1 = 470 μF, 100 V; curve 2 = 680 μF, 100 V; curve 3 = 1000 μF, 63 V; curve 4 = 1500 μF, 63 V; curve 5 = 2200 μF, 40 V; curve 6 = 3300 μF, 25 V; curve 7 = 4700 μF, 16 V; curve 8 = 6800 μF, 10 V; curve 9 = 10 000 μF, 6,3 V; curve 10 = 15 000 μF, 6,3 V.

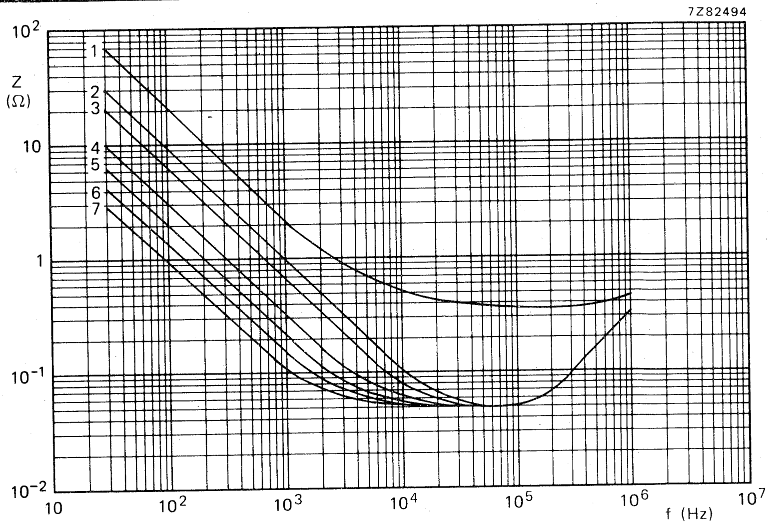


Fig. 52 Typical impedance as a function of frequency at 85 °C. **Case size 00:**
curve 1 = 68 μF, 100 V;
curve 2 = 150 μF, 63 V;
curve 3 = 220 μF, 40 V;
curve 4 = 470 μF, 25 V;
curve 5 = 680 μF, 16 V;
curve 6 = 1000 μF, 10 V;
curve 7 = 1500 μF, 6,3 V.

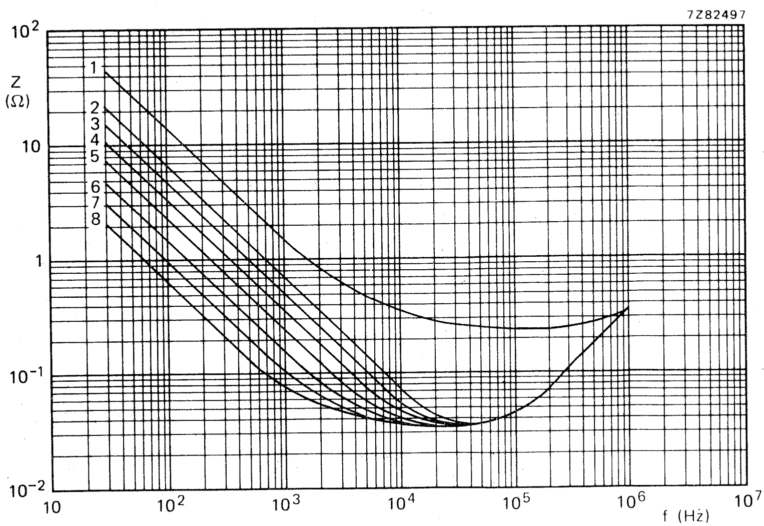


Fig. 53 Typical impedance as a function of frequency at 85 °C. **Case size 01:**
curve 1 = 100 μF, 100 V;
curve 2 = 220 μF, 63 V;
curve 3 = 330 μF, 40 V;
curve 4 = 470 μF, 40 V;
curve 5 = 680 μF, 25 V;
curve 6 = 1000 μF, 16 V;
curve 7 = 1500 μF, 10 V;
curve 8 = 2200 μF, 6,3 V.

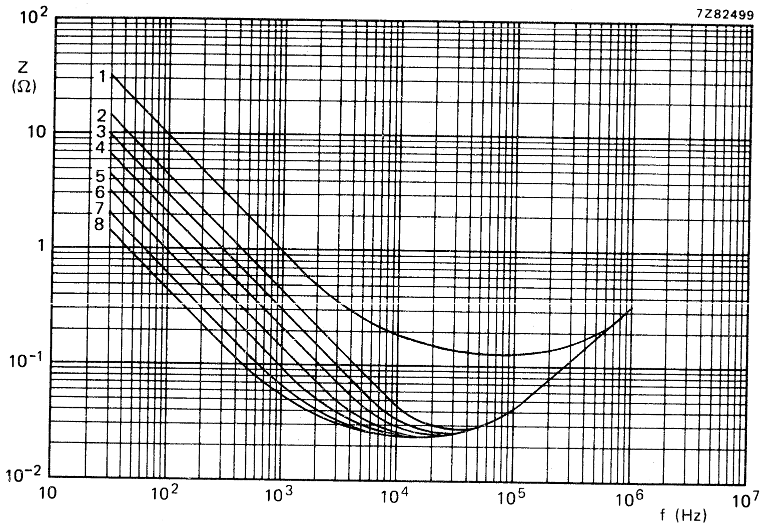


Fig. 54 Typical impedance as a function of frequency at 85 °C. **Case size 02:**
curve 1 = 150 μF, 100 V;
curve 2 = 330 μF, 63 V;
curve 3 = 470 μF, 63 V;
curve 4 = 680 μF, 40 V;
curve 5 = 1000 μF, 25 V;
curve 6 = 1500 μF, 16 V;
curve 7 = 2200 μF, 10 V;
curve 8 = 3300 μF, 6,3 V.

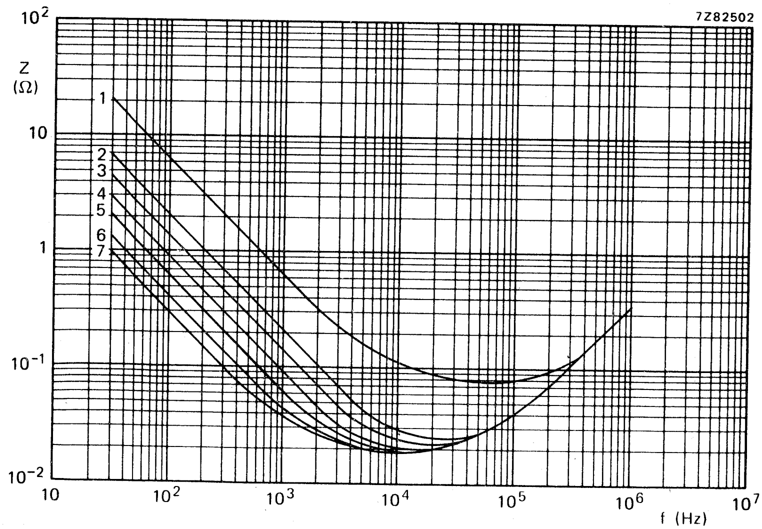


Fig. 55 Typical impedance as a function of frequency at 85 °C. **Case size 03:**
curve 1 = 220 μF, 100 V;
curve 2 = 680 μF, 63 V;
curve 3 = 1000 μF, 40 V;
curve 4 = 1500 μF, 25 V;
curve 5 = 2200 μF, 16 V;
curve 6 = 3300 μF, 10 V;
curve 7 = 4700 μF, 6,3 V.

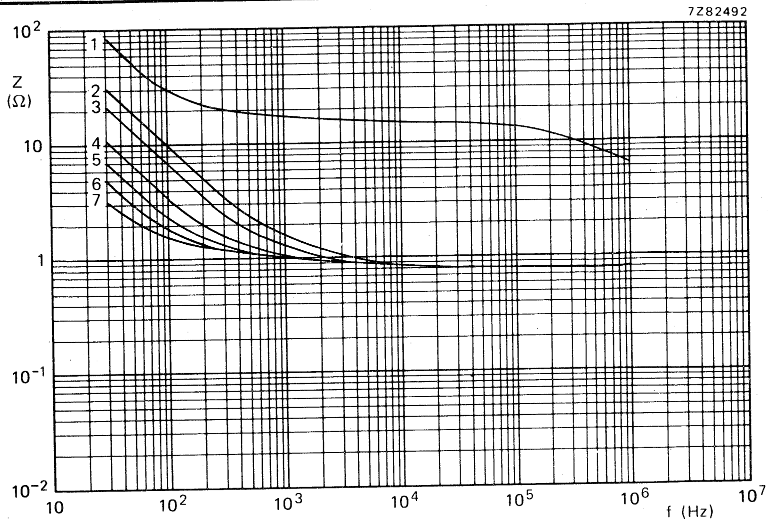


Fig. 56 Typical impedance as a function of frequency at –25 °C. **Case size 00:**
curve 1 = 68 μF, 100 V;
curve 2 = 150 μF, 63 V;
curve 3 = 220 μF, 40 V;
curve 4 = 470 μF, 25 V;
curve 5 = 680 μF, 16 V;
curve 6 = 1000 μF, 10 V;
curve 7 = 1500 μF, 6,3 V.

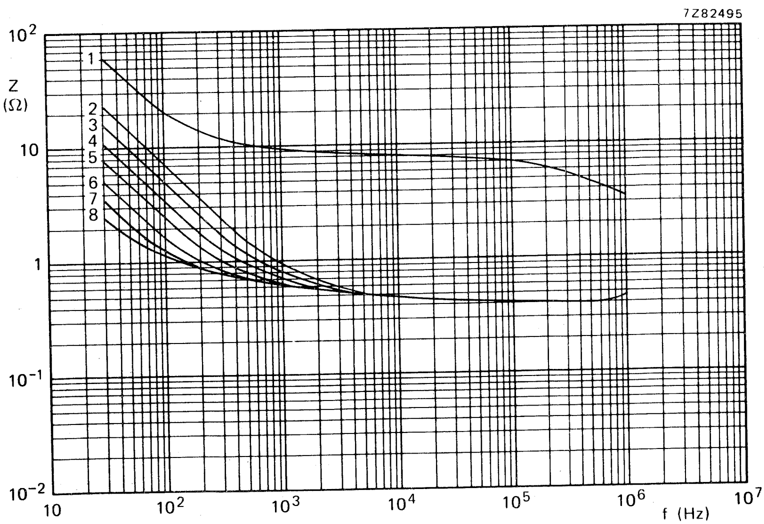


Fig. 57 Typical impedance as a function of frequency at –25 °C. **Case size 01:**
curve 1 = 100 μF, 100 V;
curve 2 = 220 μF, 63 V;
curve 3 = 330 μF, 40 V;
curve 4 = 470 μF, 40 V;
curve 5 = 680 μF, 25 V;
curve 6 = 1000 μF, 16 V;
curve 7 = 1500 μF, 10 V;
curve 8 = 2200 μF, 6,3 V.

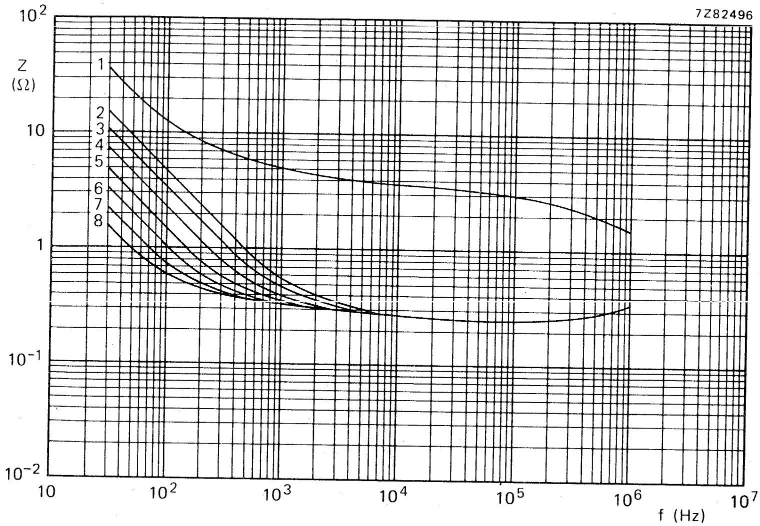


Fig. 58 Typical impedance as a function of frequency at −25 °C. **Case size 02:**
curve 1 = 150 μF, 100 V;
curve 2 = 330 μF, 63 V;
curve 3 = 470 μF, 63 V;
curve 4 = 680 μF, 40 V;
curve 5 = 1000 μF, 25 V;
curve 6 = 1500 μF, 16 V;
curve 7 = 2200 μF, 10 V;
curve 8 = 3300 μF, 6,3 V.

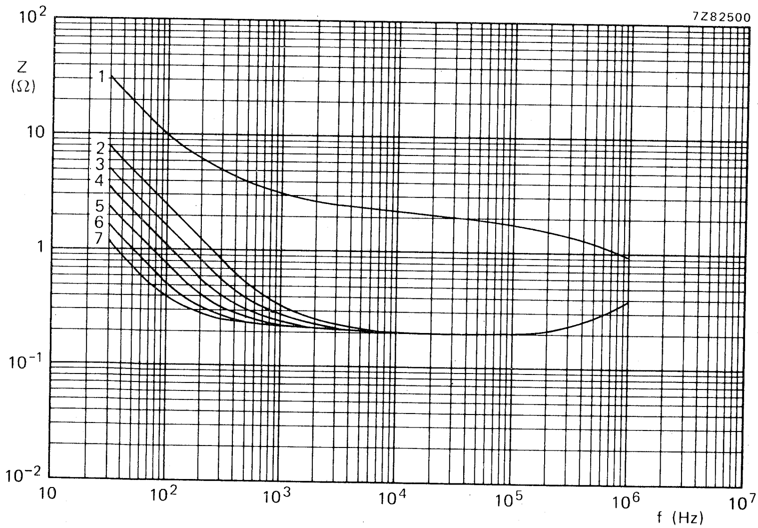


Fig. 59 Typical impedance as a function of frequency at −25 °C. **Case size 03:**
curve 1 = 220 μF, 100 V;
curve 2 = 680 μF, 63 V;
curve 3 = 1000 μF, 40 V;
curve 4 = 1500 μF, 25 V;
curve 5 = 2200 μF, 16 V;
curve 6 = 3300 μF, 10 V;
curve 7 = 4700 μF, 6,3 V.

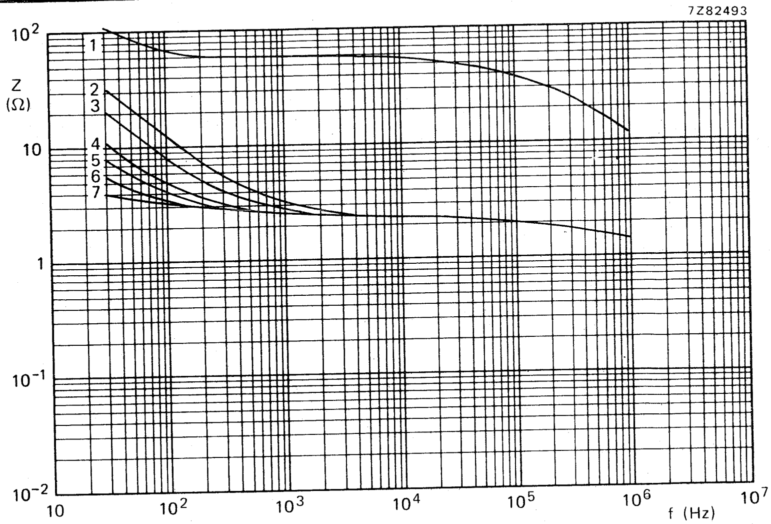


Fig. 60 Typical impedance as a function of frequency at −40 °C. **Case size 00:**
curve 1 = 68 μF, 100 V;
curve 2 = 150 μF, 63 V;
curve 3 = 220 μF, 40 V;
curve 4 = 470 μF, 25 V;
curve 5 = 680 μF, 16 V;
curve 6 = 1000 μF, 10 V;
curve 7 = 1500 μF, 6,3 V.

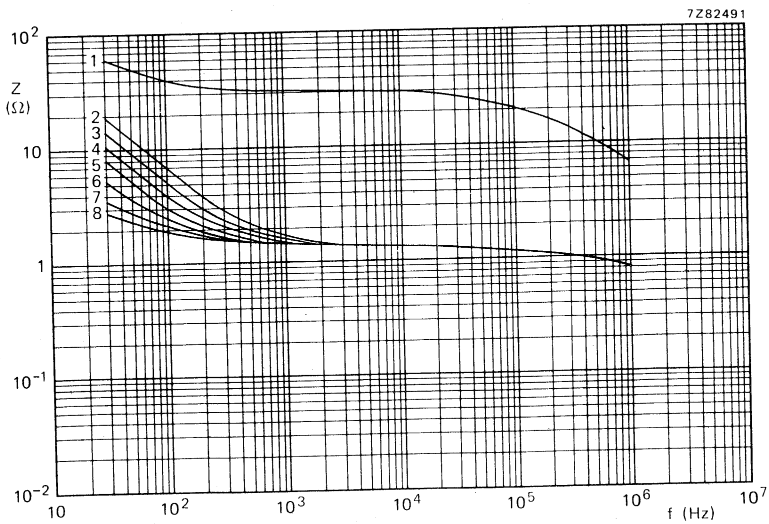


Fig. 61 Typical impedance as a function of frequency at −40 °C. **Case size 01:**
curve 1 = 100 μF, 100 V;
curve 2 = 220 μF, 63 V;
curve 3 = 330 μF, 40 V;
curve 4 = 470 μF, 40 V;
curve 5 = 680 μF, 25 V;
curve 6 = 1000 μF, 16 V;
curve 7 = 1500 μF, 10 V;
curve 8 = 2200 μF, 6,3 V.

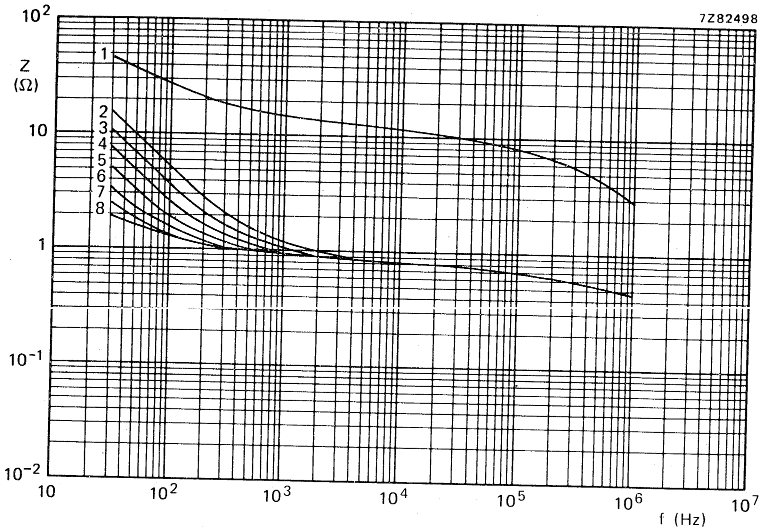


Fig. 62 Typical impedance as a function of frequency at −40 °C. **Case size 02:**
curve 1 = 150 μF, 100 V;
curve 2 = 330 μF, 63 V;
curve 3 = 470 μF, 63 V;
curve 4 = 680 μF, 40 V;
curve 5 = 1000 μF, 25 V;
curve 6 = 1500 μF, 16 V;
curve 7 = 2200 μF, 10 V;
curve 8 = 3300 μF, 6,3 V.

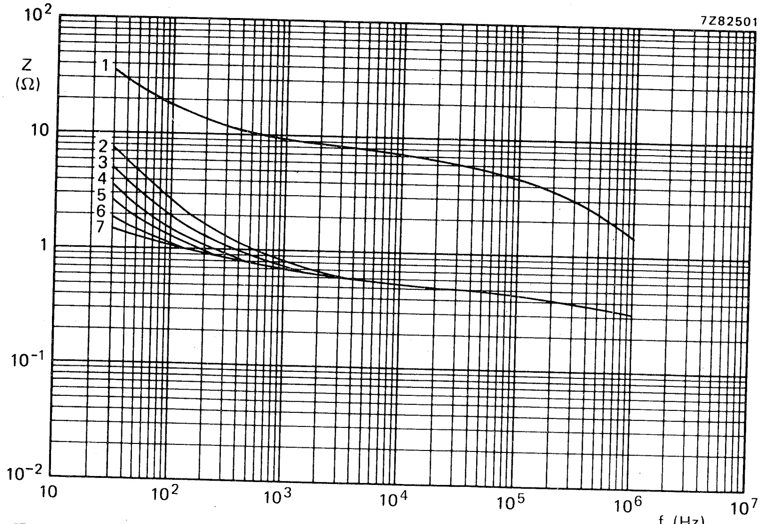


Fig. 63 Typical impedance as a function of frequency at −40 °C. **Case size 03:**
curve 1 = 220 μF, 100 V;
curve 2 = 680 μF, 63 V;
curve 3 = 1000 μF, 40 V;
curve 4 = 1500 μF, 25 V;
curve 5 = 2200 μF, 16 V;
curve 6 = 3300 μF, 10 V;
curve 7 = 4700 μF, 6,3 V.

Inductance (ESL)

Case sizes 00 and 01	50 nH	typical values
Case size 02	55 nH	
Case sizes 03, 04 and 05	60 nH	

OPERATIONAL DATA

Category temperature range	−40 to +85 °C
Typical life time at T_{amb} = 85 °C	
case size 1	1500 h
case sizes 2 to 7	3000 h
case sizes 00 to 05	10 000 h
Shelf life at 0 V and T_{amb} = 85 °C	500 h

PACKING

All capacitors are supplied in boxes, except case sizes 1 to 7 of style 1, which are on bandoliers in boxes or on reels. The number of capacitors per box or per reel is shown in Table 5.

Table 5

case size	number of capacitors		
	style 1 per reel	style 1 per box	styles 2 and 3 per box
1	4000	1000	1000
2	3000	1000	1000
3	1000	1000	1000
5a	500	500	1000
4	1000	1000	1000
5	500	500	1000
6	500	500	1000
7	500	500	500
00		200	200
01		200	200
02		200	200
03		200	200
04		100	100
05		100	100

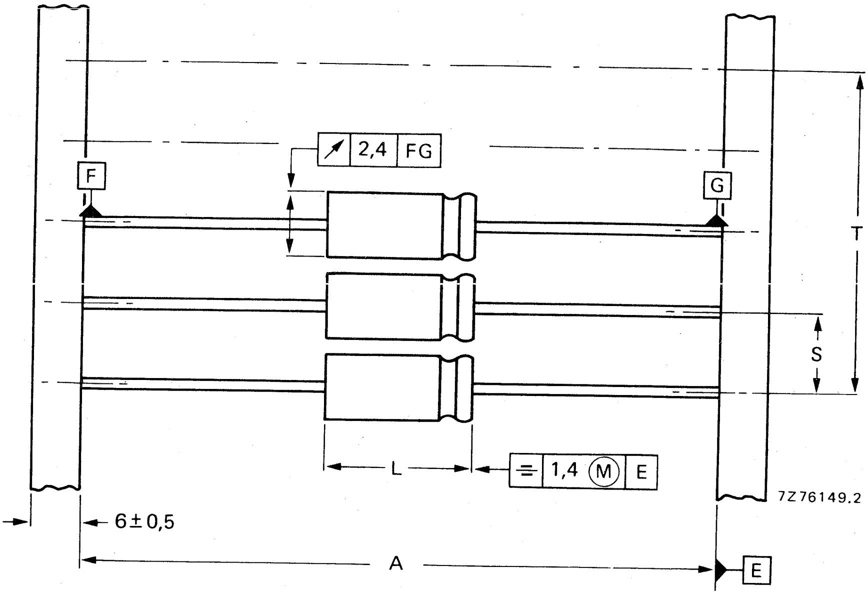


Fig. 64 Style 1 capacitors (case sizes 1 to 7) on bandoliers: the bandolier to which the negative capacitor terminals are connected is blue. See Table 6 for dimensions A, S, T and L.

Table 6

Dimensions in mm

case size	A	S	T for number (n) of capacitors		L_{max}
			$n < 50$	$50 < n < 100$	
1	63,5 ± 1,6	5 ± 0,4	5 (n-1) ± 2	5 (n-1) ± 4	11,0
2	63,5 ± 1,6	5 ± 0,4	5 (n-1) ± 2	5 (n-1) ± 4	10,5
3	63,5 ± 1,6	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	10,5
5a	63,5 ± 1,6	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	11,5
4	73 ± 1,6	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	18,5
5	73 ± 1,6	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	18,5
6	73 ± 1,6	15 ± 0,75	15 (n-1) ± 2	15 (n-1) ± 4	18,5
7	73 ± 1,6	15 ± 0,75	15 (n-1) ± 2	15 (n-1) ± 4	25,0

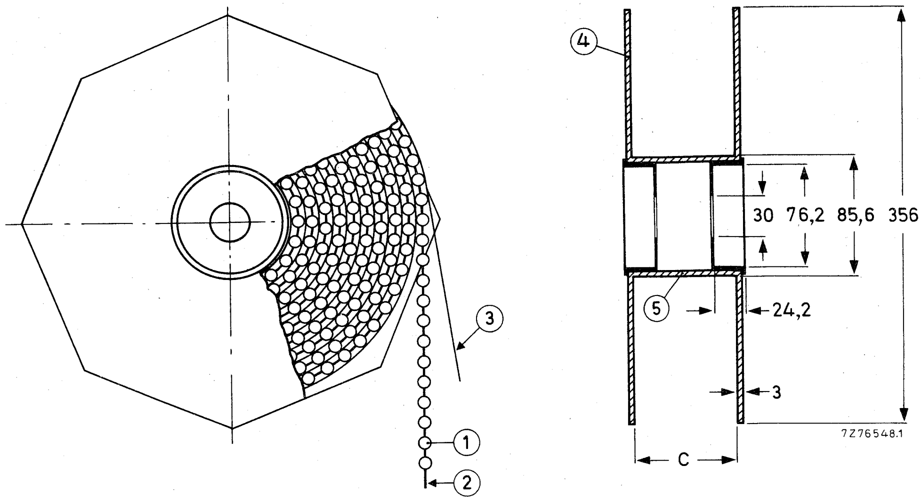


Fig. 65 Style 1 capacitors (case sizes 1 to 7) on bandoliers on reel; dimension C is 84,5 mm for case sizes 1, 2, 3 and 5a, and 88,0 mm for case sizes 4, 5, 6 and 7; the overall width of the reel is 94,5 mm and 99,5 mm respectively.

1 = capacitor
2 = bandolier
3 = paper
4 = flange
5 = cylinder

TESTS AND REQUIREMENTS

See Introduction, section 9, under aluminium electrolytic capacitors, with the following addition for **case sizes 1 to 7**.

After *endurance test, 2000 h, 85 °C,* the capacitors meet the following requirements:

$\Delta C/C \leqslant \pm$ 15%, for U_R = 10 to 100 V;

$\Delta C/C \leqslant +$ 15%, −25% for U_R = 6,3 V;

tan $\delta \leqslant$ 130% of specified value;

leakage current $\leqslant$ specified value;

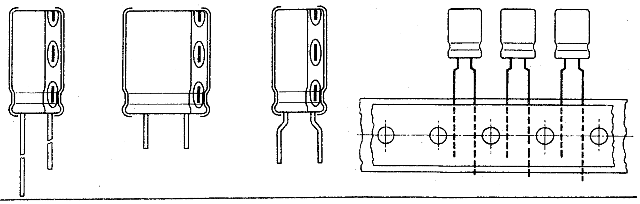
impedance at 10 kHz $\leqslant$ 200% of specified value.

After *shelf life test, 500 h, 85 °C,* the capacitors meet the same requirements, except for leakage current: $\leqslant$ 200% of specified value.

Note:

Capacitors 2222 030 and 2222 031 are miniature types, long-life grade.
Capacitors 2222 032 and 2222 033 are small types, long-life grade.

ALUMINIUM ELECTROLYTIC CAPACITORS



- **Miniature and small types**
- **Single ended**
- **General purpose**

QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	0,22 to 4700 μF
Tolerance on nominal capacitance	−20 to +20% *
Rated voltage range, U_R (R5 series)	6,3 to 100 V
Category temperature range	−40 to +85 °C
Endurance test	1000 h at 85 °C
Basic specification	IEC384-4, G.P. grade DIN 41332/DN 41259
Climatic category	
IEC 68	40/085/56
DIN 40040	GPF

Selection chart for C_{nom} −U_R and relevant case sizes.

C_{nom} μF	U_R (V) 6,3	10	16	25	35	40	50	63	100
0,22								11	11
0,33								11	
0,47								11	11
0,68								11	
1								11	11
1,5								11	11
2,2								11	11
3,3								11	11
4,7								11	12
6,8								11	12
10							11	12	13
15						11		12	13
22					11	12	12	13	14
33			11			12		13	15
47		11		12			13	14	16
68			12			13	14	15	17
100		12		13	14		15	16	18
150	12		13	14		15	16	17	18
220		13	14	15		16	17	18	19
330	13	14	15	16		17	18	19	20
470		15	16	17		18		19	
680	15	16	17	18		19	19	20	
1000	16	17	18	19	19		20		
1500	17	18	19	20					
2200	18		19						
3300	19		20						
4700	20								

case size	nominal dimensions (mm)
11	ϕ 5 x 11
12	ϕ 6 x 11
13	ϕ 8 x 12
14	ϕ 10 x 12
15	ϕ 10 x 16
16	ϕ 10 x 20
17	ϕ 12,5 x 20
18	ϕ 12,5 x 25
19	ϕ 16 x 25
20	ϕ 16 x 31

* ± 10% to special order.

APPLICATION

These capacitors with high CU-product per unit volume are mainly used for smoothing, coupling and decoupling purposes in consumer applications, such as audio and television circuits. Other applications are in timing and delay circuits.

DESCRIPTION

The capacitor has etched and oxidized aluminium foil electrodes rolled up with a paper strip impregnated with an electrolyte. The capacitor is in an insulated aluminium case.

MECHANICAL DATA

Dimensions in mm

The capacitor is available in 5 styles:
style 1: long leads; in boxes;
style 2: straight short leads; non preferred, in boxes;
style 3: bent short leads only case sizes 11, 12 and 13; non preferred, in boxes;
style 4: long leads; on tape on reel, positive leading; only case sizes 11 to 13;
style 5: long leads; on tape in ammunition pack; only case sizes 11 to 13.

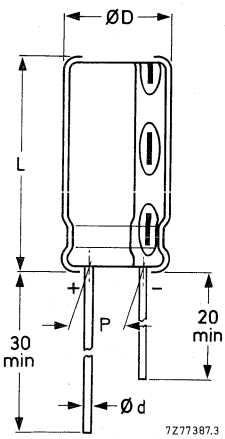


Fig. 1 Style 1; see Table 1 for dimensions d, D, L and P.

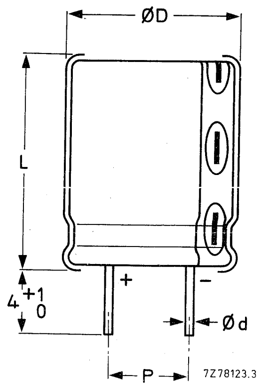


Fig. 2 Style 2; non preferred, see Table 1 for dimensions d, D, L and P.

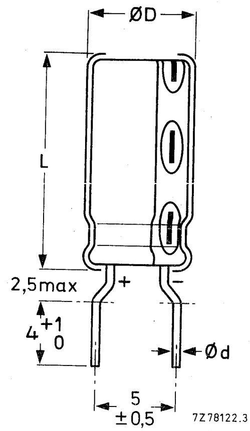


Fig. 3 Style 3, case sizes 11, 12 and 13; non preferred, see Table 1 for dimensions d, D and L.

Table 1

case size	dimensions					mass
	d	D_{max}	L_{max}	P		g
11	0,5*	5,5	12,0	2,0	± 0,5	0,4
12	0,6	6,5	12,0	2,5	± 0,5	0,6
13	0,6	8,5	12,5	3,5	± 0,5	1,1
14	0,6	10,5	12,5	5,0	± 0,5	1,6
15	0,6	10,5	17,0	5,0	± 0,5	1,9

case size	dimensions					mass
	d	D_{max}	L_{max}	P		g
16	0,6	10,5	21,0	5,0	± 0,5	2,2
17	0,6	13,0	21,0	5,0	± 0,5	4,0
18	0,6	13,0	26,0	5,0	± 0,5	5,0
19	0,8	16,5	26,0	7,5	± 0,5	8,0
20	0,8	16,5	32,0	7,5	± 0,5	9,0

* 0,6 mm under consideration.

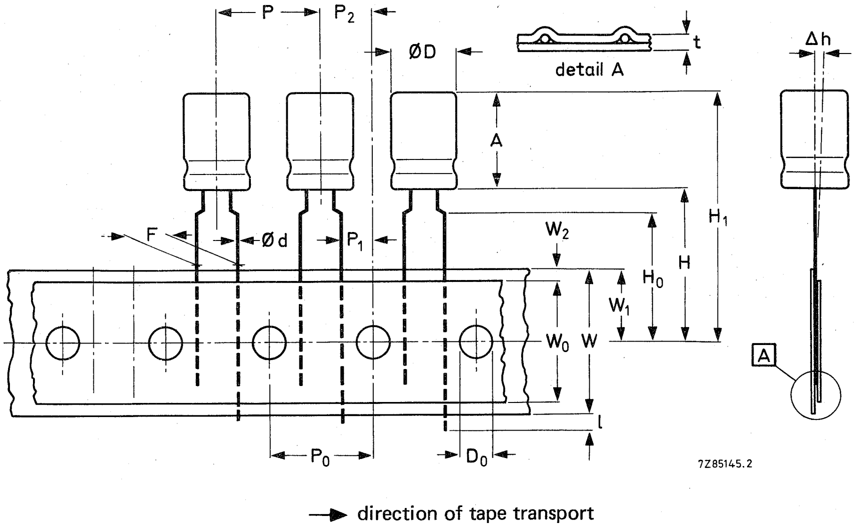


Fig. 4 Styles 4 and 5, case sizes 11 to 13; see Table 2 for dimensions.

Table 2

	sym-bol	case size			tol.
		11	12	13	
Body diameter	D	5,5	6,5	8,5	max.
Body height	A	12,0	12,0	12,5	max.
Lead-wire diameter	d	0,5*	0,6	0,6	± 0,05
Pitch of component	P	12,7	12,7	12,7	± 1,0
Feed-hole pitch	P_0	12,7	12,7	12,7	± 0,2**
Hole centre to lead	P_1	3,85	3,85	3,85	± 0,5
Feed hole centre to component centre	P_2	6,35	6,35	6,35	± 1,0
Lead-to-lead distance	F	5,0	5,0	5,0	+ 0,6/−0
Component alignment	Δh	0	0	0	± 1,0
Tape width	W	18,0	18,0	18,0	± 0,5
Hold-down tape width	W_0	12,5	12,5	12,5	min. ***
Hole position	W_1	9,0	9,0	9,0	± 0,5
Hold-down tape position	W_2	2,5	2,5	2,5	max.
Height of component from tape centre	H	18,0	18,0	18,0	+ 1,5/−0
Lead-wire clinch height	H_0	16,0	16,0	16,0	± 0,5
Component height	H_1	32,20	32,20	32,20	max.
Lead-wire protrusion	l	2,0	2,0	2,0	max.
Feed-hole diameter	D_0	4,0	4,0	4,0	± 0,2
Total tape thickness	t	0,9	0,9	0,9	max.

* 0,6 mm under consideration.
** Cumulative pitch error: ± 1 mm/20 pitches.
*** Other widths under consideration.

Marking

The capacitors are marked with: nominal capacitance, rated voltage, a symbol to identify the negative terminal, group number (035), code for factory of origin, name of manufacturer and date code (year and month) according to IEC 62.

Minimum atmospheric pressure 8,5 kPa

ELECTRICAL DATA

Unless otherwise specified all electrical values in Table 3 apply at an ambient temperature of 20 to 25 °C, a frequency of 100 Hz, an atmospheric pressure of 86 to 106 kPa and a relative humidity of 45 to 75%.

Table 3

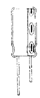
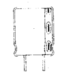
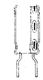
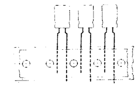
U_R	nom. cap.	max. r.m.s. ripple current at T_{amb} = 85 °C	max. leakage current at U_R after 1 min	max. tan δ	max. impedance (Ω) at T_{amb} = 20 °C		case size	catalogue number 2222 035 followed by				
					at 1 kHz	at 10 kHz		 style 1	 style 2	 style 3	 on reel style 4	in ammopack style 5
V	μF	mA	μA									
6,3	150	260	22	0,24		1,33	12	53151	83151	63151	23151	33151
	330	320	45	0,24		0,61	13	53331	83331	63331	23331	33331
	680	460	89	0,24		0,29	15	53681	63681			
	1000	530	129	0,24		0,20	16	53102	63102			
	1500	640	192	0,24	0,23		17	53152	63152			
	2200	800	280	0,24	0,16		18	53222	63222			
	3300	850	419	0,24	0,11		19	53332	63332			
	4700	960	595	0,24	0,07		20	53472	63472			
10	47	100	12	0,20		3,40	11	54479	84479	64479	24479	34479
	100	160	23	0,20		1,60	12	54101	84101	64101	24101	34101
	220	250	47	0,20		0,73	13	54221	84221	64221	24221	34221
	330	340	69	0,20		0,48	14	54331	64331			
	470	400	97	0,20		0,34	15	54471	64471			
	680	480	139	0,20		0,24	16	54681	64681			
	1000	580	203	0,20		0,16	17	54102	64102			
	1500	720	303	0,20	0,2		18	54152	64152			
16	33	90	14	0,16		3,64	11	55339	85339	65339	25339	35339
	68	180	25	0,16		1,76	12	55689	85689	65689	25689	35689
	150	270	51	0,16		0,80	13	55151	85151	65151	25151	35151
	220	320	73	0,16		0,55	14	55221	65221			
	330	405	109	0,16		0,36	15	55331	65331			
	470	480	153	0,16		0,26	16	55471	65471			
	680	590	221	0,16		0,18	17	55681	65681			
	1000	700	323	0,16		0,12	18	55102	65102			
	1500	820	483	0,16	0,17		19	55152	65152			
	2200	1000	707	0,16	0,11		19	55222	65222			
	3300	1200	1059	0,16	0,08		20	55332	65332			

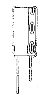
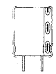
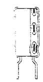
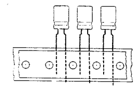
Table 3 (continued)

U_R	nom. cap.	max. r.m.s. ripple current at T_{amb} = 85 °C	max. leakage current at U_R after 1 min	max. tan δ	max. impedance (Ω) at T_{amb} = 20 °C		case size	catalogue number 2222 035 followed by				
V	μF	mA	μA		at 1 kHz	at 10 kHz		style 1	style 2	style 3	on reel style 4	in ammopack style 5
25	47	140	27	0,14		1,91	12	56479	86479	66479	26479	36479
	100	230	53	0,14		0,90	13	56101	86101	66101	26101	36101
	150	330	78	0,14		0,60	14	56151	66151			
	220	400	113	0,14		0,41	15	56221	66221			
	330	500	168	0,14		0,27	16	56331	66331			
	470	600	238	0,14		0,19	17	56471	66471			
	680	710	343	0,14		0,13	18	56681	66681			
	1000	850	503	0,14		0,09	19	56102	66102			
	1500	1000	753	0,14	0,15		20	56152	66152			
35	22	90	18	0,12		3,41	11	90003	90004	90005	90034	90085
	100	280	73	0,12		0,75	14	90059	90081			
	1000	1050	703	0,12		0,08	19	90006	90007			
40	15	70	15	0,12		4,67	11	57159	87159	67159	27159	37159
	22	90	21	0,12		3,18	12	57229	87229	67229	27229	37229
	33	140	29	0,12		2,12	12	57339	87339	67339	27339	37339
	68	200	57	0,12		1,03	13	57689	87689	67689	27689	37689
	150	320	123	0,12		0,47	15	57151	67151			
	220	470	179	0,12		0,32	16	57221	67221			
	330	590	267	0,12		0,21	17	57331	67331			
	470	800	379	0,12		0,15	18	57471	67471			
	680	960	547	0,12		0,10	19	57681	67681			
50	10	60	13	0,10		6,00	11	90008	90009	90011	90035	90087
	22	100	25	0,10		2,73	12	90012	90013	90014	90036	90088
	47	180	50	0,10		1,28	13	90015	90016	90033	90037	90038
	68	260	71	0,10		0,88	14	90017	90018			
	100	320	103	0,10		0,60	15	90019	90021			
	150	410	153	0,10		0,40	16	90022	90023			
	220	500	223	0,10		0,27	17	90024	90025			
	330	650	333	0,10		0,18	18	90026	90027			
	680	980	683	0,10		0,09	19	90028	90029			
	1000	1100	1003	0,10		0,06	20	90031	90032			

Table 3 (continued)

U_R	nom. cap.	max. r.m.s. ripple current at T_{amb} = 85 °C	max. leakage current at U_R after 1 min	max. tan δ	max. impedance (Ω) at T_{amb} = 20 °C		case size	catalogue number 2222 035 followed by				
					at 1 kHz	at 10 kHz		style 1	style 2	style 3	on reel style 4	in ammopack style 5
V	µF	mA	µA									
63	0,22	6	3	0,08		250	11	58227	88227	68227	28227	38227
	0,33	7	3	0,08		167	11	58337	88337	68337	28337	38337
	0,47	8	4	0,08		117	11	58477	88477	68477	28477	38477
	0,68	10	4	0,08		81	11	58687	88687	68687	28687	38687
	1,0	12	4	0,08		55,0	11	58108	88108	68108	28108	38108
	1,5	16	5	0,08		36,7	11	58158	88158	68158	28158	38158
	2,2	22	6	0,08		25,0	11	58228	88228	68228	28228	38228
	3,3	32	7	0,08		16,7	11	58338	88338	68338	28338	38338
	4,7	40	9	0,08		11,7	11	58478	88478	68478	28478	38478
	6,8	55	12	0,08		8,09	11	58688	88688	68688	28688	38688
	10	70	16	0,08		5,50	12	58109	88109	68109	28109	38109
	15	98	22	0,08		3,67	12	58159	88159	68159	28159	38159
	22	120	31	0,08		2,50	13	58229	88229	68229	28229	38229
	33	160	45	0,08		1,67	13	58339	88339	68339	28339	38339
	47	200	62	0,08		1,17	14	58479	68479			
	68	280	89	0,08		0,81	15	58689	68689			
	100	360	129	0,08		0,55	16	58101	68101			
	150	480	192	0,08		0,37	17	58151	68151			
	220	600	280	0,08		0,25	18	58221	68221			
	330	750	419	0,08		0,17	19	58331	68331			
	470	900	595	0,08		0,12	19	58471	68471			
	680	1040	860	0,08		0,08	20	58681	68681			

Table 3 (continued)

U_R	nom. cap.	max. r.m.s. ripple current at T_{amb} = 85 °C	max. leakage current at U_R after 1 min	max. tan δ	max. impedance (Ω) at T_{amb} = 20 °C		case size	catalogue number 2222 035 followed by				
					at 1 kHz	at 10 kHz		 style 1	 style 2	 style 3	 on reel style 4	in ammopack style 5
V	μF	mA	μA									
100	0,22	10	3	0,07		205	11	59227	89227	69227	29227	39227
	0,47	12	4	0,07		95,7	11	59477	89477	69477	29477	39477
	1,0	15	5	0,07		45,0	11	59108	89108	69108	29108	39108
	1,5	20	6	0,07		30,0	11	59158	89158	69158	29158	39158
	2,2	27	7	0,07		20,5	11	59228	89228	69228	29228	39228
	3,3	35	10	0,07		13,6	11	59338	89338	69338	29338	39338
	4,7	45	12	0,07		9,57	12	59478	89478	69478	29478	39478
	6,8	59	17	0,07		6,62	12	59688	89688	69688	29688	39688
	10	80	23	0,07		4,50	13	59109	89109	69109	29109	39109
	15	105	33	0,07		3,00	13	59159	89159	69159	29159	39159
	22	140	47	0,07		2,05	14	59229	69229			
	33	180	69	0,07		1,36	15	59339	69339			
	47	240	97	0,07		0,96	16	59479	69479			
	68	340	139	0,07		0,66	17	59689	69689			
	100	440	203	0,07		0,45	18	59101	69101			
	150	630	303	0,07		0,30	18	59151	69151			
	220	800	443	0,07		0,20	19	59221	69221			
	330	900	663	0,07		0,14	20	59331	69331			

Capacitance

Nominal capacitance at 100 Hz and T_{amb} = 25 °C	see Table 3
Tolerance on nominal capacitance at 100 Hz	−20 to +20%

Voltage

	< 40 °C	40 to 85 °C
Rated voltage = max. permissible voltage	1,15 x U_R	U_R
Ripple voltage* = max. permissible a.c. voltage providing the following three conditions are met:		
a) max. (d.c.) + peak a.c.) voltage	⩽ 1,15 x U_R	⩽ U_R
b) max. peak a.c. voltage with d.c. voltage applied	⩽ applied d.c. voltage + 2 V	
c) max. peak a.c. voltage without d.c. voltage applied	2 V	
Surge voltage = max. permissible voltage for short periods	1,2 x U_R	
Reverse voltage = max. d.c. voltage applied in the reverse polarity for short periods	2 V	

Ripple current**

Maximum permissible r.m.s. ripple current at 100 Hz and T_{amb} = 85 °C	see Table 3

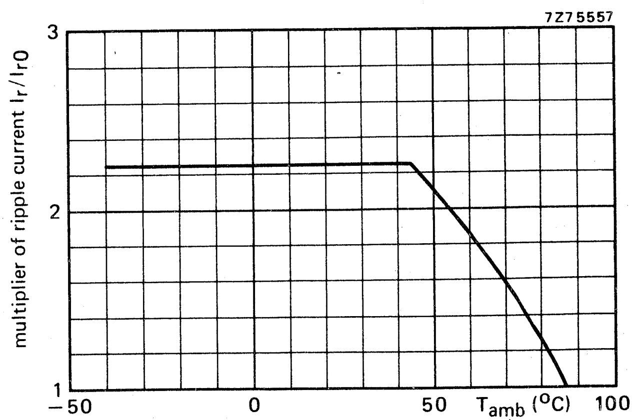


Fig. 5 Typical multiplier of ripple current as a function of ambient temperature; I_{r0} = ripple current at 85 °C, 100 Hz.

* Ripple voltages are not applicable if the maximum permissible ripple current is exceeded. In that case the ripple current is decisive.

** Ripple currents are not applicable if the maximum permissible ripple voltage is exceeded. In that case the ripple voltage is decisive.

Non-sinusoidal ripple currents have to be analyzed into a number of sinusoidal currents and the following requirements shall then be satisfied:

$$\sum_n \frac{I_n^2}{r_n} \leqslant I_{r\,max}^2$$

$I_{r\,max}$ = maximum ripple current at 100 Hz and applicable ambient temperature;
I_n = ripple current at a certain frequency;
$r_n = I_r/I_{r0}$ = multiplying factor at a same frequency.

Charge and discharge current

The capacitors may be charged from a source without internal resistance and they may be discharged by short-circuiting. If the capacitors are charged and discharged continuously several times per minute, the charge and discharge currents have to be considered as ripple currents flowing through the capacitor. The r.m.s. value of these currents should be determined and the value thus found must not exceed the applicable limit. (See also Tests and requirements.)

Leakage current

Maximum leakage current 1 min after application of U_R at T_{amb} = 25 °C	see Table 3 (0,02 CU + 3 μA)
Leakage current during continuous operation at U_R,	
at T_{amb} = 25 °C	approx. 0,1 x value stated in Table 3
at T_{amb} = 85 °C	$\leqslant$ value stated in Table 3

If owing to prolonged storage and/or storage at an excessive temperature (> 40 °C) the leakage current is too high, application of the rated voltage for some hours will cause the leakage current to fall to a value lower than specified in Table 3.

Tan δ (dissipation factor)

Maximum tan δ at 100 Hz and T_{amb} = 25 °C, measured by means of a four-terminal circuit (Thomson circuit)	see Table 3

Equivalent series resistance (ESR)

ESR = tan δ/ωC	
Maximum tan δ and C at 100 Hz and T_{amb} = 25 °C	see Table 3

Impedance (Z)

Maximum impedance at T_{amb} = 20 °C and 10 kHz ($C_{nom} \leqslant$ 1000 μF) or 1 kHz (C_{nom} > 1000 μF), measured by means of a four-terminal circuit (Thomson circuit)	see Table 3
z = Z x C_{nom}	see Table 4
Maximum ratio between impedances at T_{amb} = −25 °C and + 20 °C, and at T_{amb} = −40 °C and + 20 °C, at 100 Hz measured by means of a four-terminal circuit (Thomson circuit)	see Table 5

Table 4

	T_{amb}	$z = Z \times C_{nom}$ ($\Omega\ \mu F$) at U_R								
		6,3 V	10 V	16 V	25 V	35 V	40 V	50 V	63 V	100 V
$C_{nom} > 1000\ \mu F$, measured at 1 kHz	+20 °C –25 °C –40 °C	350 1700 4500	300 1100 2800	250 800 2000	220 570 1400	– – –	200 430 1100	– – –	180 330 800	175 300 700
$C_{nom} \leqslant 1000\ \mu F$, measured at 10 kHz	+20 °C –25 °C –40 °C	200 1200 3200	160 750 2000	120 560 1500	90 400 1100	75 330 950	70 300 900	60 220 700	55 180 500	45 130 350

Table 5

	maximum impedance ratio at U_R and 100 Hz								
	6,3 V	10 V	16 V	25 V	35 V	40 V	50 V	63 V	100 V
$\frac{Z \text{ at } -25\ ^\circ C}{Z \text{ at } +20\ ^\circ C}$	4	3	2	2	2	2	2	2	2
$\frac{Z \text{ at } -40\ ^\circ C}{Z \text{ at } +20\ ^\circ C}$	7	5	5	4	4	4	4	4	4

OPERATIONAL DATA

Category temperature range — –40 to + 85 °C

Life expectancy
- at T_{amb} = 85 °C — 2000 h
- at T_{amb} = 105 °C — 500 h

PACKING

Capacitors of styles 1, 2 and 3 are supplied in boxes, those of styles 4 and 5 on tape on reel and in ammunition pack respectively. The numbers per box, per reel and per ammunition pack are given in Table 6

Table 6

case size	number of capacitors				
	style 1 per box	style 2 per box	style 3 per box	style 4 per reel	style 5 per ammunition pack
11	1000	1000	1000	1000	2000
12	1000	1000	1000	1000	2000
13	1000	1000	1000	500	1000
14	1000	1000			
15	500	500			
16	500	500			
17	200	200			
18	200	200			
19	200	200			
20	200	200			

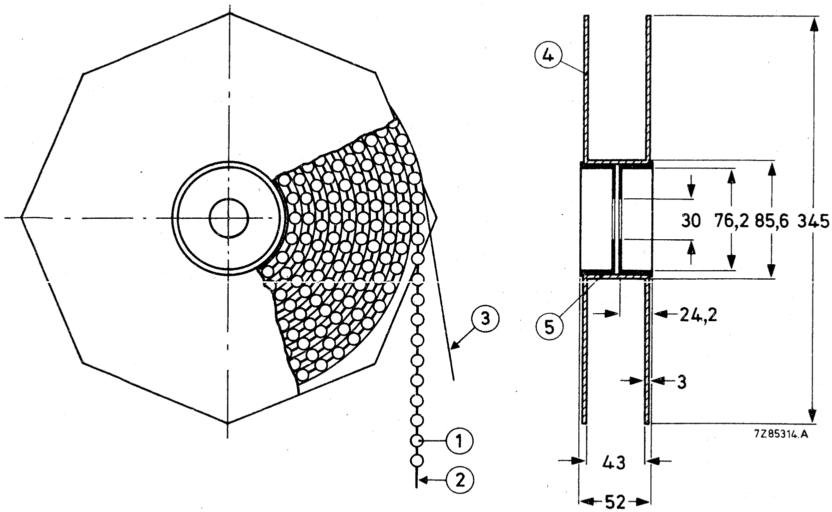


Fig. 6 Capacitors (style 4) on tape on reel.

1 = capacitor
2 = tape
3 = paper
4 = flange
5 = cylinder

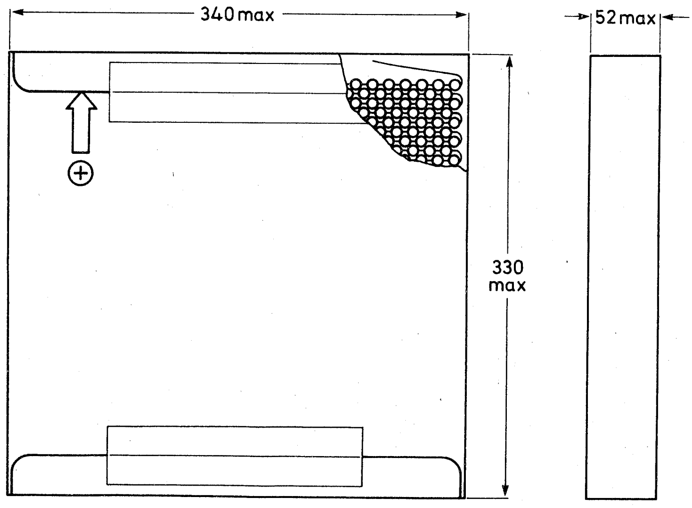


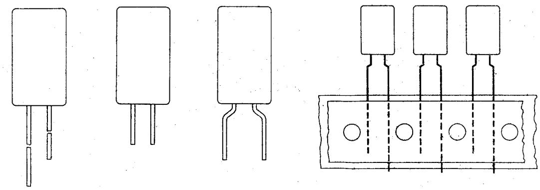
Fig. 7 Capacitors (style 5) on tape in ammunition pack.

TESTS AND REQUIREMENTS

See Introduction, section 9, under aluminium electrolytic capacitors.

Note: Capacitors 2222 035 are miniature and small, general-purpose types.

ALUMINIUM ELECTROLYTIC CAPACITORS



- **Miniature**
- **Single ended**
- **General and industrial applications**

QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	0,22 to 330 μF
Tolerance on nominal capacitance	−20 to +20% *
Rated voltage range, U_R (R5 series)	6,3 to 63 V
Category temperature range	−55 to +85 °C
Endurance test	2000 h at 85 °C
Shelf life at 0 V	500 h at 85 °C
Basic specification	IEC 384-4, G.P. grade DIN 41332/DIN 41259
Climatic category	
IEC68	55/085/56
DIN40040	FPF

Selection chart for C_{nom} – U_R and relevant case sizes.

C_{nom} μF	U_R (V)							
	6,3	10	16	25	35	40	50	63
0,22								11
0,33								11
0,47								11
0,68								11
1								11
1,5								11
2,2								11
3,3								11
4,7								11
6,8								11
10							11	11
15						11		
22					11			13
33			11					13
47		11					13	
68		11				13		
100	11			13				
150			13					
220		13						
330	13							

case size	nominal dimensions (mm)
11	ϕ 5 x 11
13	ϕ 8,2 x 11

* ± 10% to special order.

APPLICATION

These capacitors with high CV product to volume ratio mainly used for smoothing, coupling and decoupling purposes in consumer applications, such as audio and television circuits. Other applications are in timing and delay circuits.

DESCRIPTION

The capacitor has etched and oxidised aluminium foil electrodes rolled up with a paper strip impregnated with an electrolyte. The capacitor is in an insulated aluminium case.

MECHANICAL DATA

Dimensions in mm

The capacitor is available in 5 styles:
style 1: long leads; in boxes;
style 2: straight short leads; non preferred, in boxes;
style 3: bent short leads (only case size 11); non preferred, in boxes;
style 4: long leads; on tape on reel, positive leading;
style 5: long leads; on tape in ammunition pack.

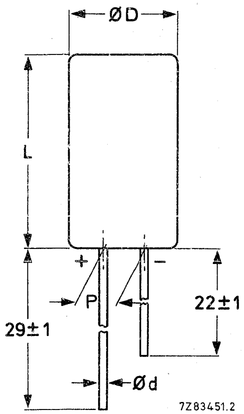


Fig. 1 Style 1; see Table 1 for dimensions d, D, L and P.

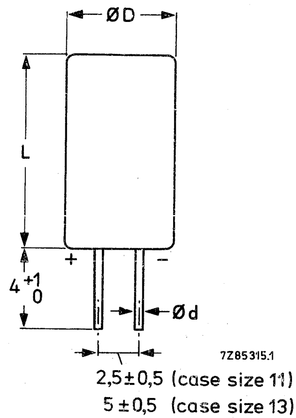


Fig. 2 Style 2; non preferred, see Table 1 for dimensions d, D and L.

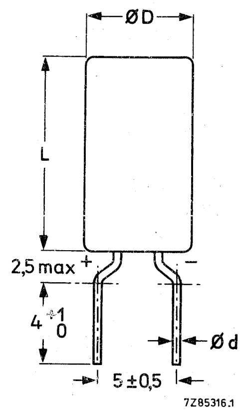
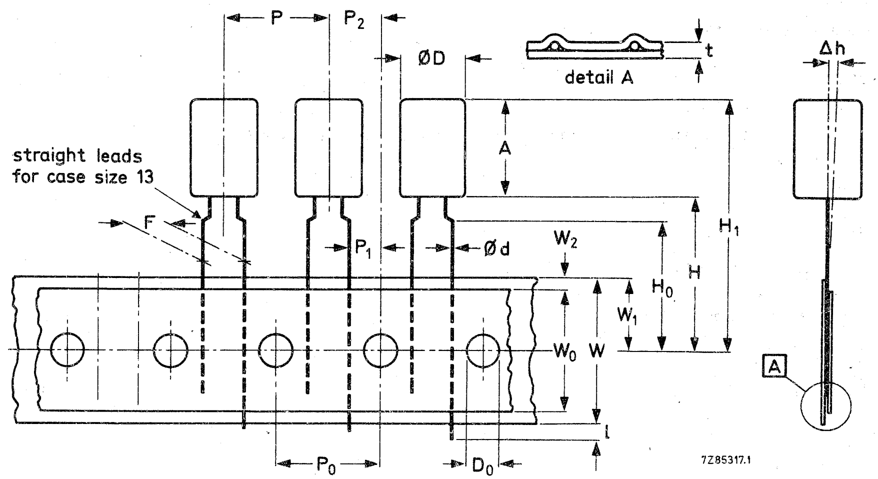


Fig. 3 Style 3; case size 11 only; non preferred, see Table 1 for dimensions d, D and L.

Table 1

case size	dimensions				mass approx. g
	d	D_{max}	L_{max}	P	
11	0,5*	5,5	12,0	2,5	0,4
13	0,6	8,7	12,0	5,0	1,1

* 0,6 mm under consideration.



→ direction of tape transport

Fig. 4 Styles 4 and 5; see Table 2 for dimensions.

Table 2

	symbol	case size		tol.
		11	13	
Body diameter	D	5,5	8,7	max.
Body height	A	12,0	12,0	max.
Lead-wire diameter	d	0,5*	0,6	± 0,05
Pitch of component	P	12,7	12,7	± 1,0
Feed-hole pitch	P_0	12,7	12,7	± 0,2**
Hole centre to lead	P_1	3,85	3,85	± 0,5
Feed hole centre to component centre	P_2	6,35	6,35	± 0,7
Lead-to-lead distance	F	5,0	5,0	+ 0,6/–0
Component alignment	Δh	0	0	± 1,0
Tape width	W	18,0	18,0	± 0,5
Hold-down tape width	W_0	12,5	12,5	min. ***
Hole position	W_1	9,0	9,0	± 0,5
Hold-down tape position	W_2	2,5	2,5	max.
Height of component from tape centre	H	18,0	18,0	+ 1,5/–0
Lead-wire clinch height	H_0	16,0	—	± 0,5
Component height	H_1	32,20	32,20	max.
Lead-wire protrusion	l	2,0	2,0	max.
Feed-hole diameter	D_0	4,0	4,0	± 0,2
Total tape thickness	t	0,9	0,9	max.

* 0,6 mm under consideration.
** Cumulative pitch error: ± 1 mm/20 pitches.
*** Other widths under consideration.

Marking

The capacitors are marked as follows:

on the top

- nominal capacitance;
- code letter for tolerance on nominal capacitance, according to IEC62;
- rated voltage;
- polarity identification.

on the circumference

- name of manufacturer;
- group number (036);
- code letter of manufacturer;
- date code (year and month) according to IEC 62.

Minimum atmospheric pressure 8,5 kPa

ELECTRICAL DATA

Unless otherwise specified all electrical values in Table 3 apply at an ambient temperature of 20 to 25 °C, a frequency of 100 Hz, an atmospheric pressure of 86 to 106 kPa and a relative humidity of 45 to 75%.

Table 3

UR V	nom. cap. μF	max. r.m.s. ripple current at T_{amb} = 85 °C mA	max. leakage current at U_R after 1 min. μA	max. tan δ	max. impedance at 10 kHz, T_{amb} = 20 °C Ω	case size*	catalogue number 2222 036 followed by style 1	style 2	style 3	on reel style 4	in ammopack style 5
6,3	100	160	7	0,20	1,7	11	53101	83101	63101	23101	33101
	330	320	16	0,20	0,52	13	53331	63331		23331	33331
10	47	100	6	0,16	2,77	11	54479	84479	64479	24479	34479
	68	120	7	0,16	1,91	11	54689	84689	64689	24689	34689
	220	250	17	0,16	0,59	13	54221	64221		24221	34221
16	33	90	7	0,14	2,73	11	55339	85339	65339	25339	35339
	150	270	18	0,14	0,60	13	55151	65151		25151	35151
25	100	230	18	0,12	0,70	13	56101	66101		26101	36101
35	22	90	8	0,10	2,73	11	90001	90002	90003	90016	90027
40	15	70	7	0,10	3,67	11	57159	87159	67159	27159	37159
	68	200	20	0,10	0,81	13	57689	67689		27689	37689
50	10	60	6	0,08	4,5	11	90004	90005	90006	90017	90028
	47	180	18	0,08	0,96	13	90011	90012		90019	90031
63	0,22	5,5	4	0,06	182	11	58227	88227	68227	28227	38227
	0,33	7	4	0,06	121	11	58337	88337	68337	28337	38337
	0,47	8	4	0,06	85,1	11	58477	88477	68477	28477	38477
	0,68	10	4	0,06	58,5	11	58687	88687	68687	28687	38687
	1,0	12	4	0,06	40	11	58108	88108	68108	28108	38108
	1,5	16	4	0,06	26,7	11	58158	88158	68158	28158	38158
	2,2	22	4	0,06	18,2	11	58228	88228	68228	28228	38228
	3,3	32	5	0,06	12,1	11	58338	88338	68338	28338	38338
	4,7	40	5	0,06	8,5	11	58478	88478	68478	28478	38478
	6,8	55	6	0,06	5,88	11	58688	88688	68688	28688	38688
	10	70	7	0,06	4,0	11	58109	88109	68109	28109	38109
	22	120	12	0,06	1,82	13	58229	68229		28229	38229
	33	160	16	0,06	1,21	13	58339	68339		28339	38339

* Case size 11: ϕ5 mm x 11 mm; case size 13: ϕ8,2 mm x 11 mm (nominal dimensions).

Capacitance

Nominal capacitance at 100 Hz and T_{amb} = 20 °C	see Table 3
Tolerance on nominal capacitance at 100 Hz	−20 to +20%

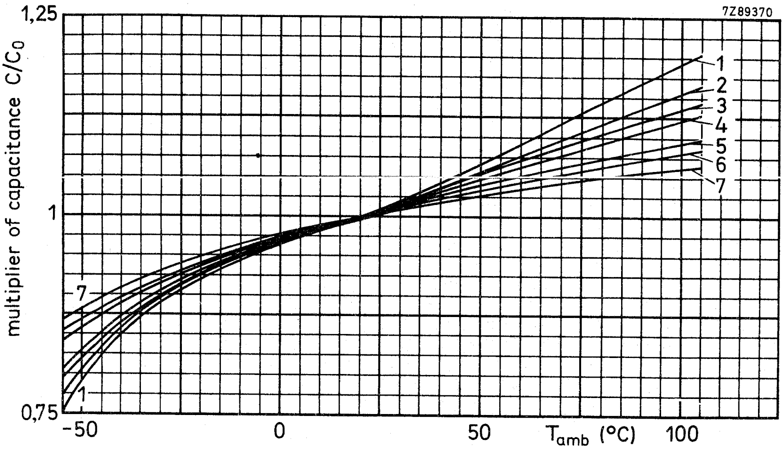


Fig. 5 Typical multiplier of capacitance as a function of ambient temperature case size 11; C_0 = capacitance at 25 °C, 100 Hz.

curve 1 = 100 μF, 6,3 V;
curve 2 = 47 μF, 10 V and 68 μF, 10 V;
curve 3 = 22 μF, 35 V;
curve 4 = 33 μF, 16 V;
curve 5 = 1 μF; 63 V;
curve 6 = 15 μF, 40 V
curve 7 = 10 μF, 50 V.

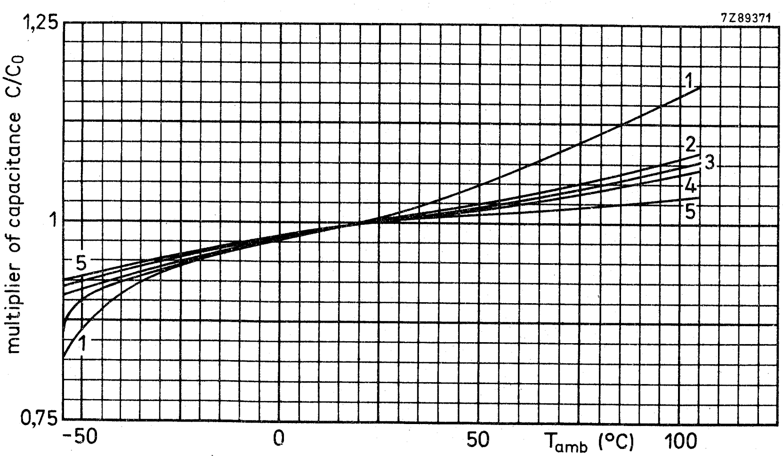


Fig. 6 Typical multiplier of capacitance as a function of ambient temperature case size 13; C_0 = capacitance at 25 °C, 100 Hz.

curve 1 = 220 μF, 10 V;
curve 2 = 100 μF, 25 V;
curve 3 = 47 μF, 50 V;
curve 4 = 10 μF, 63 V;
curve 5 = 22 μF, 63 V.

Voltage

	< 40 °C	40 to 85 °C
Rated voltage = max. permissible voltage	1,15 x U_R	U_R
Ripple voltage* = max. permissible a.c. voltage providing the following three conditions are met:		
(a) max. (d.c. + peak a.c.) voltage	1,15 x U_R	U_R
(b) max. peak a.c. voltage with d.c. voltage applied	applied d.c. voltage + 2 V	
(c) max. peak a.c. voltage without d.c. voltage applied	2 V	
Surge voltage = max. permissible voltage for short periods	1,2 x U_R	
Reverse voltage = max. d.c. voltage applied in the reverse polarity for short periods	2 V	

Ripple current**

Maximum permissible r.m.s. ripple current at 100 Hz and T_{amb} = 85 °C — see Table 3

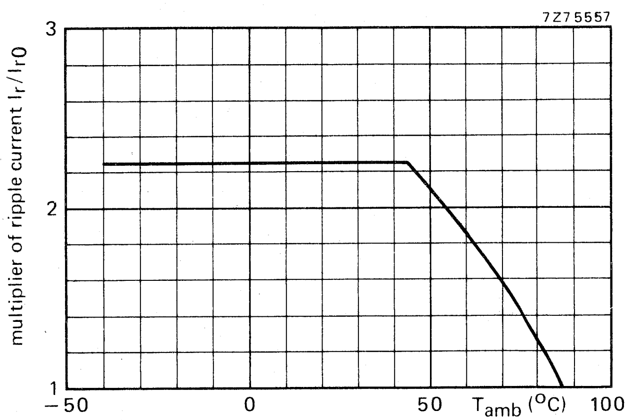


Fig. 7 Typical multiplier of ripple current as a function of ambient temperature; I_{r0} = ripple current at 85 °C, 100 Hz.

Non-sinusoidal ripple currents have to be analyzed into a number of sinusoidal currents. The following requirements must then be satisfied:

$$\sum_n \frac{I_n^2}{r_n} \leqslant I_{r\,max}^2$$

$I_{r\,max}$ = maximum ripple current at 100 Hz and applicable ambient temperature;
I_n = ripple current at the required frequency;
$r_n = I_r/I_{r0}$ = multiplying factor at the required frequency.

* Specified ripple voltages are not applicable if the maximum permissible ripple current is exceeded. In that case the ripple current is decisive.

** Specified ripple currents are not applicable if the maximum permissible ripple voltage is exceeded. In that case the ripple voltage is decisive.

Charge and discharge current

There is no limit on the charge or discharge rate. If the capacitors are charged and discharged continuously several times per minute, the charge and discharge currents have to be considered as ripple currents flowing through the capacitor. The r.m.s. value of these currents should be determined and the value thus found must not exceed the applicable limit. (See also Tests and requirements.)

Leakage current

Maximum leakage current 1 min after application of U_R at T_{amb} = 25 °C	see Table 3 (0,006 CU + 3 μA)
Leakage current during continuous operation at U_R,	
at T_{amb} = 25 °C	approx. 0,1 x value stated in Table 3
at T_{amb} = 85 °C	≤ value stated in Table 3

Tan δ (dissipation factor)

Maximum tan δ at 100 Hz and T_{amb} = 25 °C, measured by a four-terminal circuit (Thomson circuit)	see Table 3

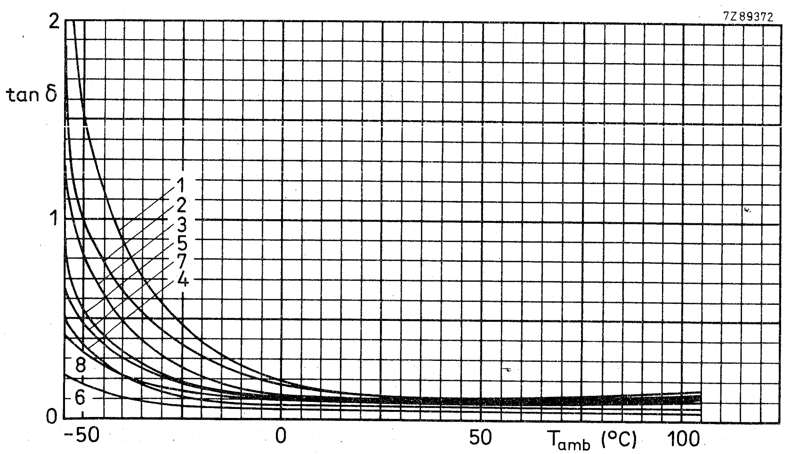


Fig. 8 Typical tan δ at 100 Hz as a function of ambient temperature, case size 11;

curve 1 = 100 μF, 6,3 V;
curve 2 = 68 μF, 10 V;
curve 3 = 47 μF, 10 V;
curve 4 = 22 μF, 35 V;
curve 5 = 33 μF, 16 V;
curve 6 = 1 μF, 63 V;
curve 7 = 15 μF, 40 V;
curve 8 = 10 μF, 50 V.

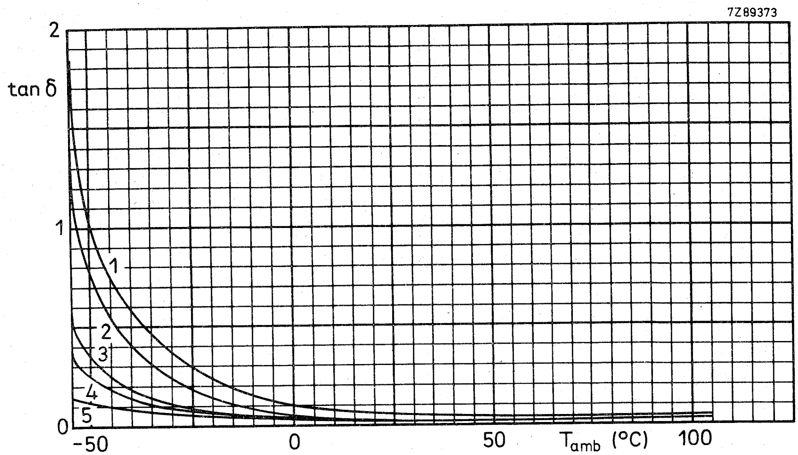


Fig. 9 Typical tan δ at 100 Hz as a function of ambient temperature, case size 13;

curve 1 = 220 μF, 10 V;
curve 2 = 100 μF, 25 V;
curve 3 = 47 μF, 50 V;
curve 4 = 10 μF, 63 V;
curve 5 = 22 μF, 63 V.

Equivalent series resistance (ESR)

ESR = tan $\delta/\omega C$

Maximum tan δ and C at 100 Hz and T_{amb} = 25 °C — see Table 3

Impedance (Z)

Maximum impedance at T_{amb} = 20 °C and 10 kHz, measured by a four-terminal circuit (Thomson circuit) — see Table 3

$z = Z \times C_{nom}$ — see Table 4

Maximum ratio between impedances at T_{amb} = −25 °C and + 20 °C, and at T_{amb} = −55 °C and + 20 °C, at 100 Hz measured by a four-terminal circuit (Thomson circuit) — see Table 5

Table 4

T_{amb}	$z = Z \times C_{nom}$ (Ω µF) at U_R and 10 kHz							
	6,3 V	10 V	16 V	25 V	35 V	40 V	50 V	63 V
+20 °C	⩽ 170	⩽ 130	⩽ 90	⩽ 70	⩽ 60	⩽ 55	⩽ 45	⩽ 40
−25 °C	⩽ 900	⩽ 560	⩽ 400	⩽ 300	⩽ 250	⩽ 220	⩽ 160	⩽ 130
−40 °C	⩽ 2500	⩽ 1500	⩽ 1100	⩽ 900	⩽ 750	⩽ 700	⩽ 580	⩽ 400
−55 °C	typ.5500	typ.3500	typ.2500	typ.1800	typ.1200	typ.1000	typ. 750	typ. 500

Table 5

	maximum impedance ratio at U_R and 100 Hz							
	6,3 V	10 V	16 V	25 V	35 V	40 V	50 V	63 V
$\frac{Z \text{ at } -25\ ^\circ C}{Z \text{ at } +20\ ^\circ C}$	4	3	3	2	2	2	2	2
$\frac{Z \text{ at } -40\ ^\circ C}{Z \text{ at } +20\ ^\circ C}$	7	5	5	4	4	4	4	4

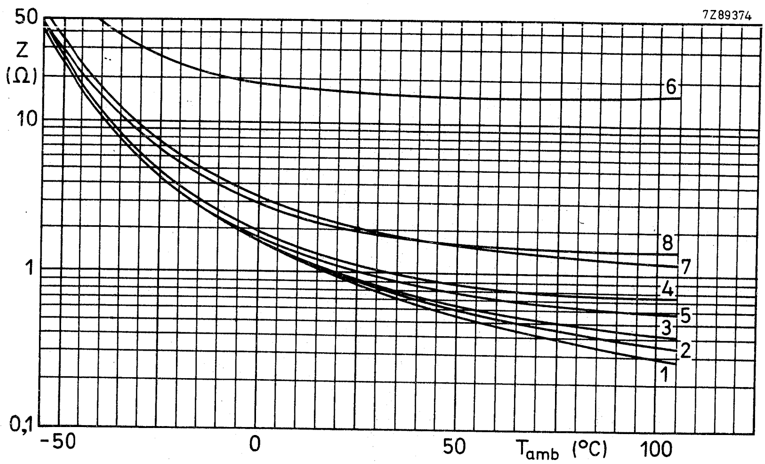


Fig. 10 Typical impedance at 10 kHz as a function of ambient temperature, case size 11;

curve 1 = 100 µF, 6,3 V;
curve 2 = 68 µF, 10 V;
curve 3 = 47 µF, 10 V;
curve 4 = 22 µF, 35 V;
curve 5 = 33 µF, 16 V;
curve 6 = 1 µF, 63 V;
curve 7 = 15 µF; 40 V;
curve 8 = 10 µF, 50 V.

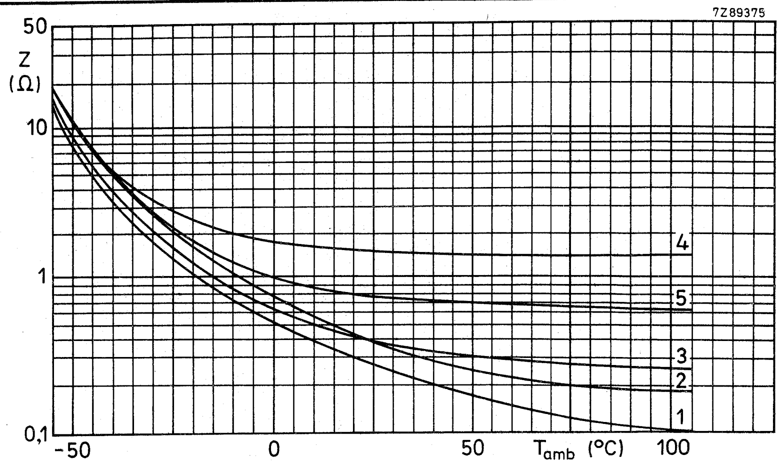


Fig. 11 Typical impedance at 10 kHz as a function of ambient temperature, case size 13;

curve 1 = 220 μF, 10 V;
curve 2 = 100 μF, 25 V;
curve 3 = 47 μF, 50 V;
curve 4 = 10 μF, 63 V;
curve 5 = 22 μF, 63 V.

OPERATIONAL DATA

Category temperature range	−55 to + 85 °C
Life guarantee	
at T_{amb} = 85 °C	> 2000 h
at T_{amb} = 95 °C	> 1000 h
at T_{amb} = 105 °C	> 500 h

PACKING

Capacitors of styles 1, 2 and 3 are supplied in boxes, those of styles 4 and 5 on tape on reel and in ammunition pack respectively. The numbers per box, per reel and per ammunition pack are given in Table 6.

Table 6

case size	number of capacitors				
	style 1 per box	style 2 per box	style 3 per box	style 4 per reel (min.)	style 5 per ammunition pack
11	1000	1000	1000	1000	2000
13	1000	1000	1000	500	1000

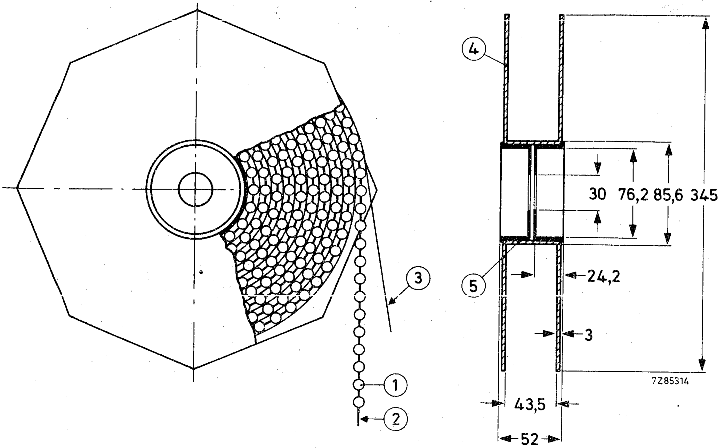


Fig. 12 Capacitors (style 4) on tape on reel.

1 = capacitor
2 = tape
3 = paper
4 = flange
5 = cylinder

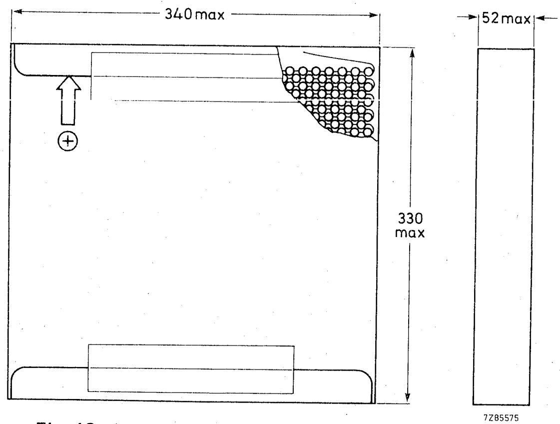


Fig. 13 Capacitors (style 5) on tape in ammunition pack.

TESTS AND REQUIREMENTS

See Introduction, section 9, under aluminium electrolytic capacitors, with the following addition. After *endurance test, 2000 h, 85 °C,* the capacitors meet the following requirements:

$\Delta C/C \leqslant \pm 15\%$, for U_R = 10 to 63 V,

$\Delta C/C \leqslant +15\%, -25\%$ for U_R = 6,3 V;

tan $\delta \leqslant$ 130% of specified value;

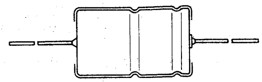
leakage current $\leqslant$ specified value.

After *shelf life test, 500 h, 85 °C,* the capacitors meet the same requirements.

Note: Capacitors 2222 036 are miniature, general-purpose types.

ALUMINIUM ELECTROLYTIC CAPACITORS

- **Small type**
- **Bipolar**
- **Long life**
- **General and industrial applications**



QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	1 to 47 μF
Tolerance on nominal capacitance	–20 to +20%
Rated voltage U_R (a.c.), frequency > 15 Hz	63 V peak (40 V r.m.s.), provided ripple current remains within specified limits
Rated voltage U_R (d.c.)	63 V (in both directions)
Category temperature range	–40 to +85 °C
Endurance test at 85 °C	5000 h
Basic specification	IEC384-4, long-life grade
Climatic category, IEC68	40/085/56

Selection chart for C-U_R and relevant case sizes

U_R V	C_{nom} μF	case size	nom. dimensions mm
	1	00	ϕ 10 x 30
	1,5	00	ϕ 10 x 30
	2,2	00	ϕ 10 x 30
	3,3	00	ϕ 10 x 30
	4,7	00	ϕ 10 x 30
63	6,8	00	ϕ 10 x 30
	10	01	ϕ 12,5 x 30
	15	01	ϕ 12,5 x 30
	22	02	ϕ 15 x 30
	33	02	ϕ 15 x 30
	47	03	ϕ 18 x 30

APPLICATION

These capacitors are especially designed for those applications where a low impedance, small dissipation and an excellent temperature constancy over the audio frequency range is required such as crossover filters in loudspeaker boxes and intercom systems.

DESCRIPTION

The capacitor has etched aluminium-foil electrodes rolled up with a porous paper spacer which separates the two anodes. The spacer is impregnated with an electrolyte which is the electrical connection between the two anode foils and retains its good characteristics both at low and at high temperatures. The capacitor is housed in an aluminium case. It has soldered-copper leads.

MECHANICAL DATA

Dimensions in mm

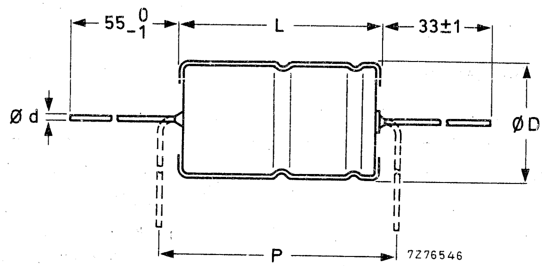


Fig. 1 For dimensions d, D, L and P, see Table 1.

Table 1

case size	d	D_{nom}	L_{nom}	D_{max}	L_{max}	P_{min}	mass approx. g
00	0,8	10	30	10,5	30,5	35	4,0
01	0,8	12,5	30	13,0	30,5	35	6,3
02	0,8	15	30	15,5	30,5	35	8,2
03	0,8	18	30	18,5	30,5	35	10,9

Marking

The capacitors are marked with:
- nominal capacitance;
- tolerance on nominal capacitance;
- rated voltage;
- group number 039;
- name of manufacturer;
- date code (year and month) according to IEC62;
- bipolar.

Mounting

The diameter of the mounting holes in the printed-wiring board is 1 + 0,1 mm.

Minimum atmospheric pressure 8,5 kPa

ELECTRICAL DATA

Table 2

Unless otherwise specified all electrical values in Table 2 apply at an ambient temperature of 20 to 25 °C, a frequency of 100 Hz, an atmospheric pressure of 93 to 106 kPa and a relative humidity of 45 to 75%.

U_R V	nom. cap. µF	max r.m.s. ripple current at T_{amb} = 85 °C mA*	max leakage current at U_R after 5 min µA*	typ ESR Ω*	max ESR Ω*	case size	catalogue number
63	1	14	7	260	570	00	2222 039 18108 ←
	1,5	19	7	140	290	00	18158 ←
	2,2	25	7	80	135	00	18228 ←
	3,3	35	10	38	85	00	18338
	4,7	42	15	26	59	00	18478
	6,8	51	21	18	41	00	18688
	10	70	31	12	28	01	18109
	15	84	47	8,5	19	01	18159
	22	121	61	5	11	02	18229
	33	147	82	3,1	7	02	18339
	47	213	109	1,9	4,3	03	18479

Capacitance

The nominal capacitance values at 100 Hz are given in Table 2. The tolerance on nominal capacitance at 100 Hz is −20 to +20%.

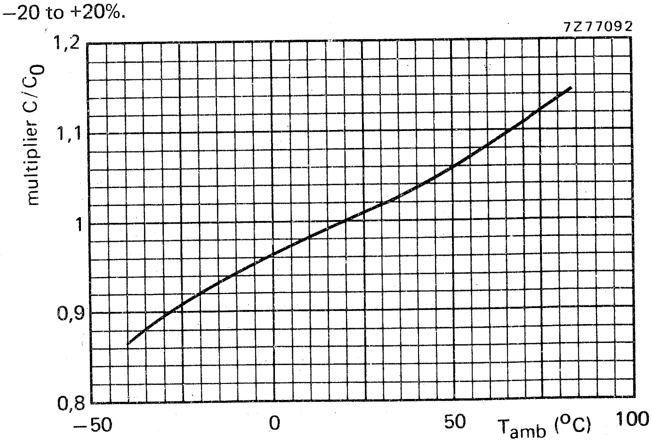


Fig. 2 Typical capacitance as a function of ambient temperature; C_0 = capacitance at 20 °C and 100 Hz.

* See also corresponding paragraph.

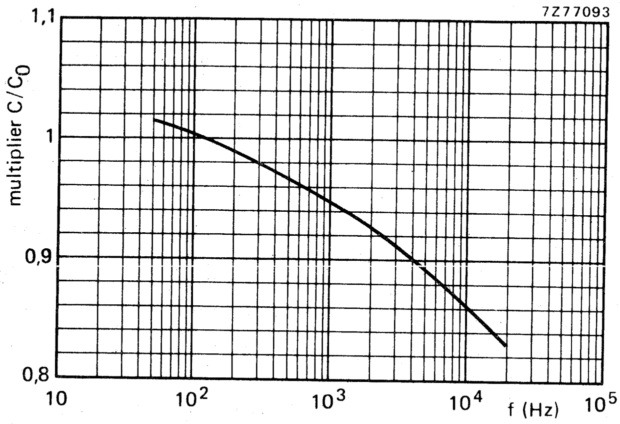


Fig. 3 Typical capacitance as a function of frequency; C_0 = capacitance at 20 °C and 100 Hz.

Voltage

The rated voltage U_R (a.c.) in the temperature range −40 to +85 °C is 63 V peak (40 V r.m.s.), provided the ripple current remains below the specified values in Table 2.

The rated voltage U_R (d.c.) in the temperature range −40 to +85 °C is 63 V, independent of polarity.

Ripple current

The maximum permissible r.m.s. ripple current at 100 Hz and T_{amb} = 85 °C is given in Table 2.

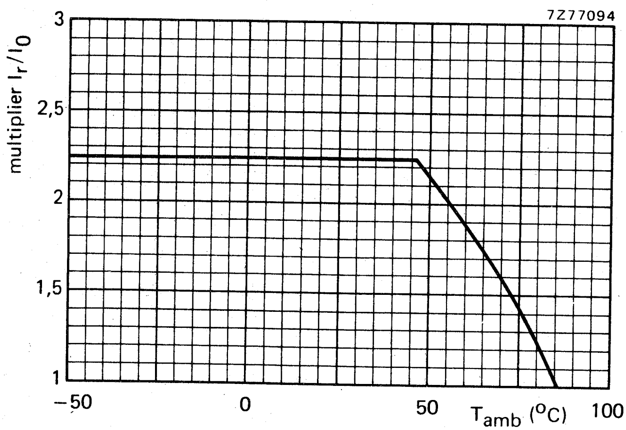


Fig. 4 Typical ripple current as a function of ambient temperature; I_0 = ripple current at 85 °C and 100 Hz.

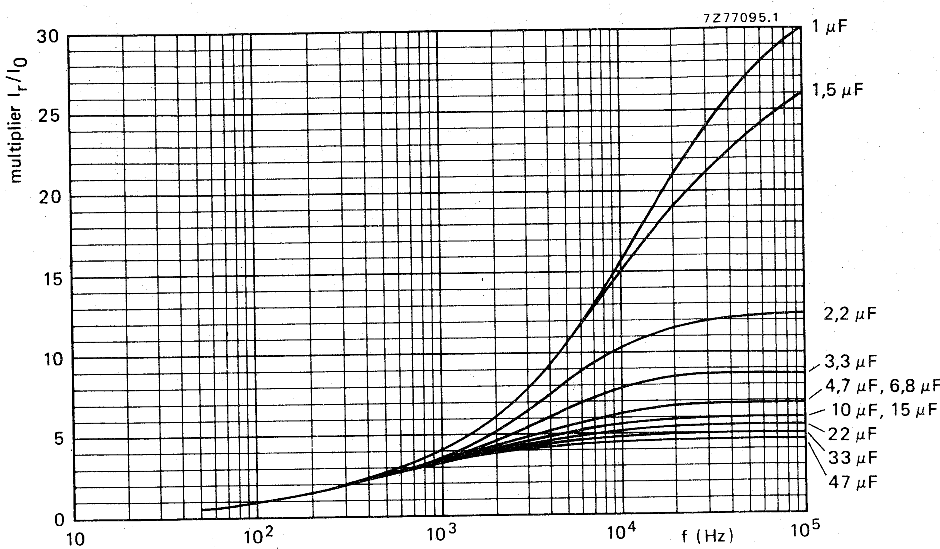


Fig. 5 Typical ripple current as a function of frequency; I_0 = ripple current at 85 °C and 100 Hz.

Leakage current

The maximum leakage current, when the case is at negative potential with respect to the other connection, 5 min after application of the rated voltage at T_{amb} = 20 to 25 °C is given in Table 2.

The maximum leakage current, when the case is at positive potential with respect to the other connection, may be up to 100 μA higher than the values given in Table 2.

If the leakage current is too high, owing to prolonged storage and/or storage at an excessive temperature, application of the rated voltage for some hours will cause the leakage current to fall to a value lower than specified in Table 2.

Equivalent series resistance (ESR)

The ESR at 100 Hz and T_{amb} = 25 °C, measured by means of a four-terminal circuit (Thomson circuit) is given in Table 2.

For ESR at different frequencies, see graphs on the next page.

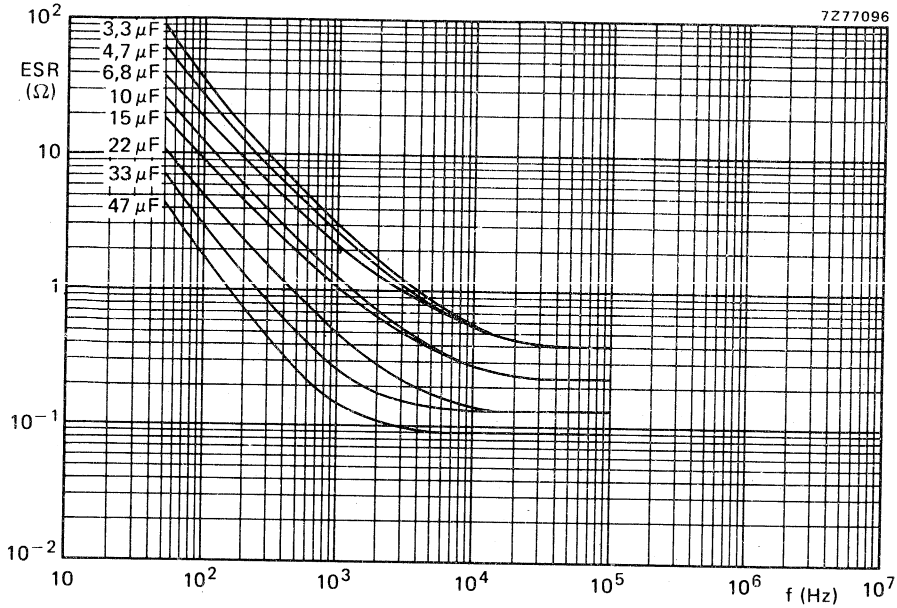


Fig. 6 Typical ESR as a function of frequency at 25 °C.

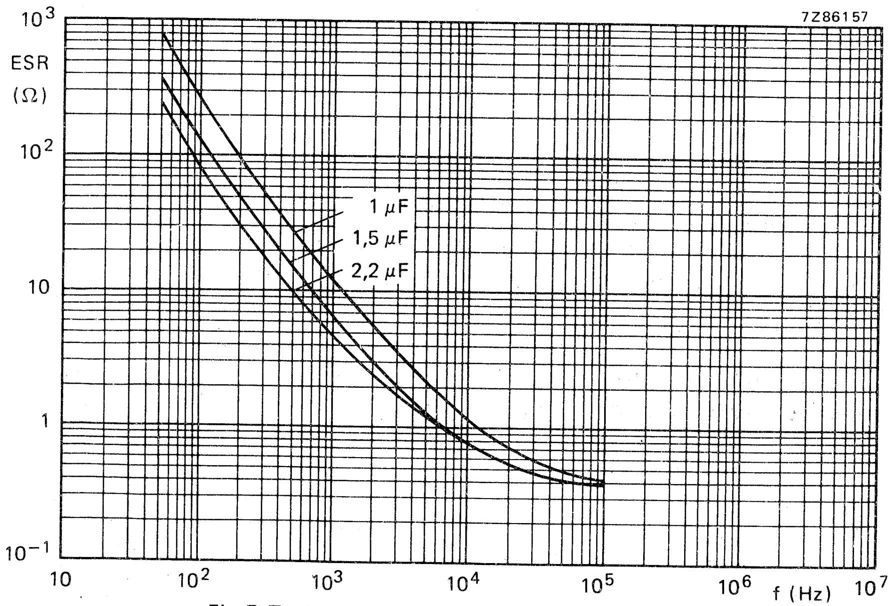


Fig. 7 Typical ESR as a function of frequency at 25 °C.

Impedance

Impedance at T_{amb} = 25 °C measured by means of a four-terminal circuit (Thomson circuit).

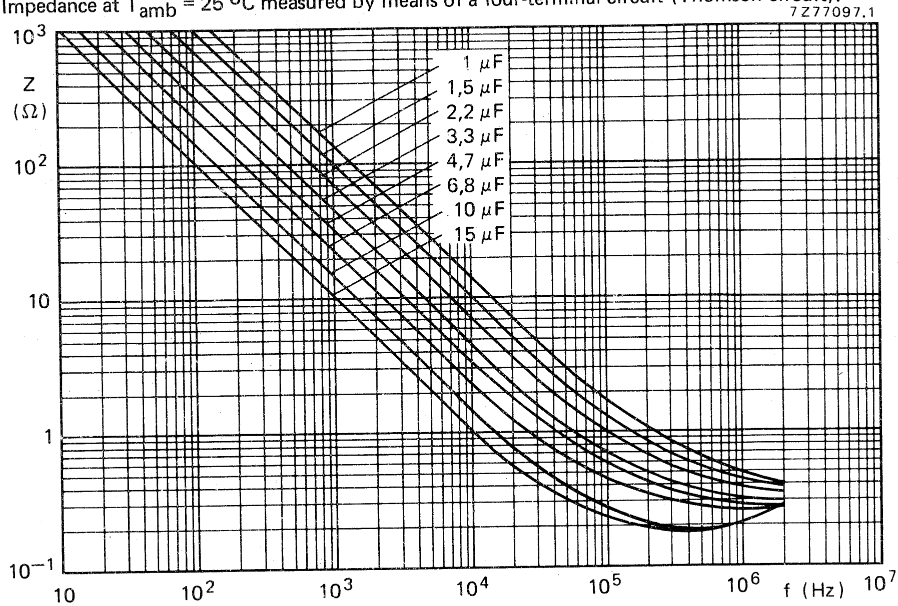


Fig. 8 Typical impedance as a function of frequency at 25 °C.

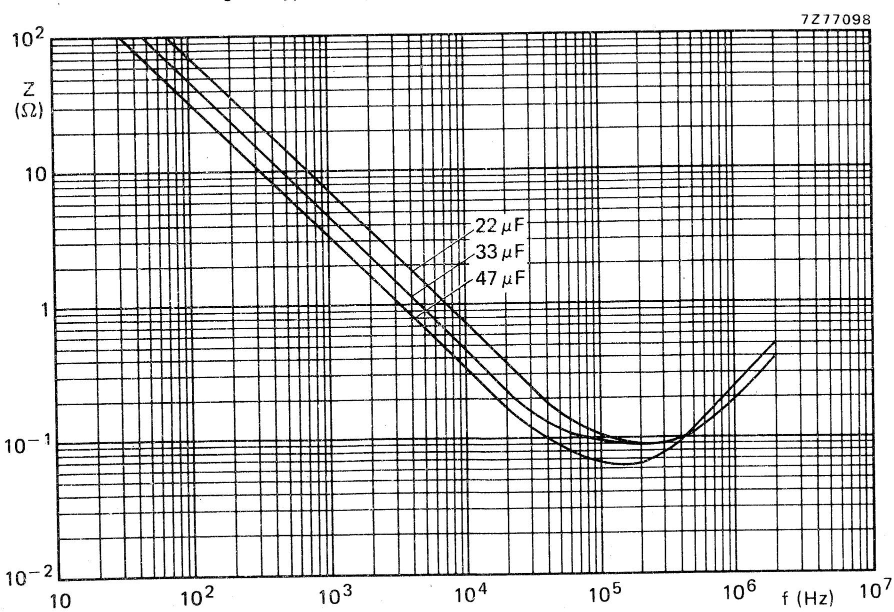


Fig. 9 Typical impedance as a function of frequency at 25 °C.

OPERATIONAL DATA

Category temperature range —40 to +85 °C

PACKING

The capacitors are packed in boxes of 200.

TEST AND REQUIREMENTS

See Introduction, section 9, under aluminium electrolytic capacitors, with the exception of IEC384-4 sub clause 9.14, and the figures of tan δ, for which the following is valid.

IEC384-4 sub clause 9.14.
IEC68-2 test method: no reference.
Name of test: Endurance

Procedure a: 5000 h at 85 °C, rated d.c. voltage applied in any direction.
Requirements: no visible damage, no leakage of electrolyte, leakage current at applied d.c. voltage in applied direction $\leqslant$ stated limit, ESR $\leqslant$ 1,3 x stated limit, $\Delta C/C \leqslant 15\%$, ratio of impedances at 10 kHz before and after test $\leqslant$ 2, insulation resistance $>$ 100 MΩ, no breakdown or flashover.

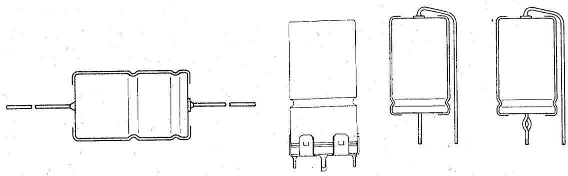
Procedure b: 5000 h at 85 °C, rated ripple current applied, no d.c. voltage applied.
Requirements: no visible damage, no leakage of electrolyte, ESR $\leqslant$ 2 x stated limit, $\Delta C/C \leqslant 15\%$, ratio of impedances at 10 kHz before and after test $\leqslant$ 2, insulation resistance $>$ 100 MΩ, no breakdown or flashover.

In this data sheet no value is given for tan δ; where in the tests and requirements tan δ is mentioned, ESR must be read instead.

Note: Capacitors 2222 039 are small types, long-life grade.

ALUMINIUM ELECTROLYTIC CAPACITORS

- Miniature and small types
- Axial leads or single ended
- Long life
- General and industrial applications



QUICK REFERENCE DATA

Nominal capacitance range	1 to 220 μF
Tolerance on nominal capacitance	−10 to + 50%
Rated voltage range, U_R (R5 series)	160 to 385 V
Category temperature range	−40 to + 85 °C
Endurance test at 85 °C	
case sizes 4 to 7	2000 h
case sizes 00 to 05	5000 h
Basic specifications	IEC 384-4, type 1, long-life grade DIN 41240
Climatic category	
IEC 68	40/085/56
DIN 40040	GPF

Selection chart for C_{nom}-U_R and relevant case sizes.

C_{nom} μF	U_R (V) 160	250	350	385
1				4
2,2		4		5
4,7	4	5	6	7
6,8			00	00
10	5	00/7	01	01
15		01	01	02
22	00/7	01	02	03
33	01	02	03	04
47	02	03	04	04
68	02	04	05	05
100	03	05		
150	04			
220	05			

case size	nominal dimensions (mm)	series number	
4	Ø 6,5 x 18	041	miniature
5	Ø 8 x 18		
6	Ø 10 x 18		
7	Ø 10 x 25		
00	Ø 10 x 30	042	small
01	Ø 12,5 x 30		
02	Ø 15 x 30		
03	Ø 18 x 30		
04	Ø 18 x 40	043	
05	Ø 21 x 40		

APPLICATION

For smoothing, coupling and decoupling purposes in circuits where a high voltage is required. The bandoliered version is extremely suitable for automatic insertion and for cutting and forming equipment.

DESCRIPTION

The capacitor has etched aluminium foil electrodes rolled up with a paper strip impregnated with an electrolyte. The capacitor is in an aluminium case, which is insulated with a blue plastic sleeve.

The capacitor is available in 4 styles, all with soldered-copper leads.

Style 1: axial leads; all case sizes; case sizes 4 to 7 are supplied on bandoliers.
Style 2: single ended; with mounting ring with printed-wiring pins; especially for use in applications with severe shocks and vibrations; case sizes 03, 04 and 05.
Style 3: single ended; case sizes 4 to 7 and 00 to 02.
Style 4: single ended with self-locking lead; case sizes 4 to 7; non-preferred.

MECHANICAL DATA

Dimensions in mm

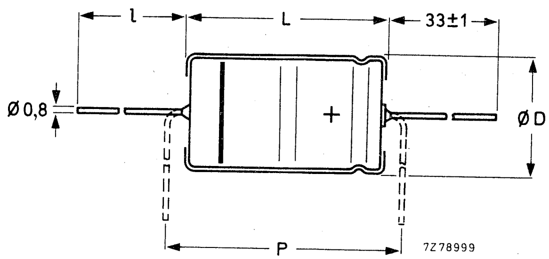


Fig. 1 Style 1; see Table 1a for dimensions D, L, l and P.

Table 1a

case size	style 1						mass approx. g
	l	D_{nom}	L_{nom}	D_{max}	L_{max}	P_{min}	
4	*	6,5	18,0	6,9	18,5	25	1,3
5	*	8,0	18,0	8,5	18,5	25	1,7
6	*	10,0	18,0	10,5	18,5	25	2,5
7	*	10,0	25,0	10,5	25,0	30	3,3
00	55 ± 1	10,0	30,0	10,5	30,5	35,0	4,0
01	55 ± 1	12,5	30,0	13,0	30,5	35,0	6,3
02	55 ± 1	15,0	30,0	15,5	30,5	35,0	8,2
03	55 ± 1	18,0	30,0	18,5	30,5	35,0	10,9
04	34 ± 1	18,0	40,0	18,5	41,5	45,0	14
05	34 ± 1	21,0	40,0	21,5	41,5	45,0	19

* Case sizes 4 to 7 are supplied on bandoliers in boxes or on reels (see PACKING).

Table 1b

case size	style 2						mass approx. g
	d_1	d_2	D1	$D2_{max}$	D3	L	
03	0,8	1 + 0,1	18,0	20,5	18,5 ± 0,2	31 ± 1	11,5
04	1,0	1,3 + 0,1	18,0	20,5	18,5 ± 0,2	42 ± 1	15
05	1,0	1,3 + 0,1	21,0	23,5	21,5 ± 0,2	42 ± 1	20

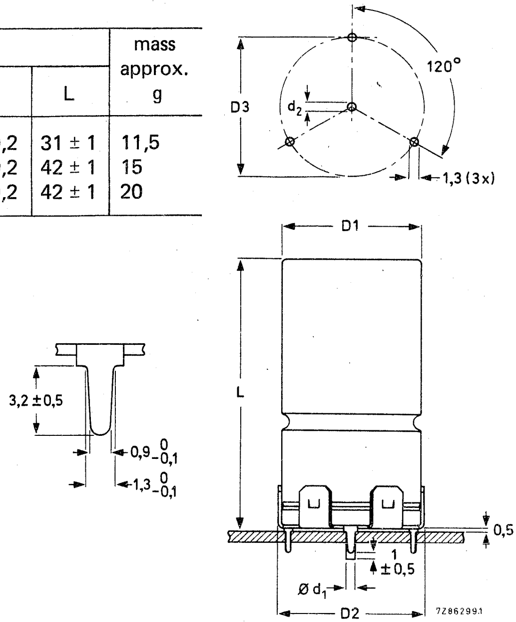


Fig. 2 Style 2; see Table 1b for dimensions d_1, d_2, D1, D2, D3 and L.

Table 1c

case size	d	style 3			mass approx. g
		D_{max}	L_{max}	P	
4	0,8	6,9	21,5	5 -10	1,2
5	0,8	8,5	21,5	5 -10	1,6
6	0,8	10,5	21,5	7,5-12,5	2,3
7	0,8	10,5	28,0	7,5-12,5	3,1
00	0,8	10,5	34,0	7,5-12,5	3,8
01	0,8	13,0	34,0	7,5-12,5	6,1
02	0,8	15,5	34,0	10,0-15,0	8,0

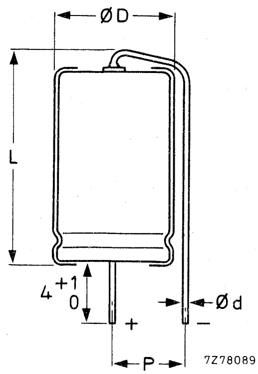


Fig. 3 Style 3 see Table 1c for dimensions d, D, L and P.

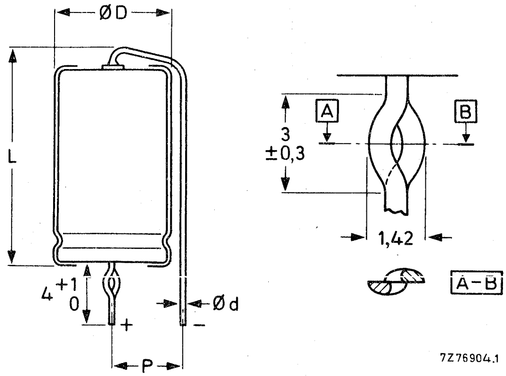


Fig. 4 Style 4; **non-preferred**; see Table 1d for dimensions d, D, L and P.

Table 1d

case size	d	style 4			mass approx. g
		D_{max}	L_{max}	P	
4	0,8	6,9	21,5	5 -10	1,2
5	0,8	8,5	21,5	5 -10	1,6
6	0,8	10,5	21,5	7,5-12,5	2,3
7	0,8	10,5	28,0	7,5-12,5	3,1

Marking

The capacitors are marked with:
- nominal capacitance;
- tolerance on nominal capacitance;
- rated voltage;
- group number; code of origin;
- name of manufacturer;
- date code (year and month) according to IEC62;
- band to identify the negative terminal;
- + signs to identify the positive terminal.

Mounting

The diameter of the holes in the printed-wiring board for styles 1, 3 and 4 is 1 + 0,1 mm, except that of the hole for the anode lead of style 4 capacitors: 1,3 + 0,1 mm.

The hole diameter for style 2 is 1,3 + 0,1 mm, except that for the anode pin of case size 03: 1 + 0,1 mm.

Minimum atmospheric pressure 8,5 kPa

ELECTRICAL DATA

Table 2

Unless otherwise specified all electrical values in Table 2 apply at an ambient temperature of 20 to 25 °C, a frequency of 100 Hz, an atmospheric pressure of 86 to 106 kPa and a relative humidity of 45 to 75%. (See also the relevant paragraphs.)

U_R V	nom. cap. µF	max. r.m.s. ripple current at T_{amb} = 85 °C mA	max. leakage current at U_R after 1 min µA	max. ESR Ω	max. tan δ	typ. impedance at 10 kHz Ω	case size	catalogue number* 2222 followed by
160	4,7	26	38	53,2	0,15	26	4	041 .1478
	10	41	68	25,0	0,15	12	5	041 .1109
	22	77	126	11,4	0,15	5,5	7	041 .1229
	22	106	42	6,8	0,10	1,3	00	042 .1229
	33	146	58	4,5	0,10	1,0	01	042 .1339
	47	194	78	3,2	0,10	0,66	02	042 .1479
	68	233	108	2,2	0,10	0,48	02	042 .1689
	100	313	154	1,5	0,10	0,37	03	042 .1101
	150	433	226	1,0	0,10	0,21	04	043 .1151
	220	571	327	0,7	0,10	0,18	05	043 .1221
250	2,2	18	28	132	0,18	50	4	041 .3228
	4,7	29	55	61,7	0,18	23	5	041 .3478
	10	55	95	29	0,18	11	7	041 .3109
	10	72	33	15	0,10	4,2	00	042 .3109
	15	100	44	10	0,10	2,8	01	042 .3159
	22	120	60	6,8	0,10	2,2	01	042 .3229
	33	162	84	4,5	0,10	1,4	02	042 .3339
	47	215	116	3,2	0,10	0,75	03	042 .3479
	68	291	163	2,2	0,10	0,4	04	043 .3689
	100	385	235	1,5	0,10	0,28	05	043 .3101
350	4,7	32	69	68,1	0,20	21	6	041 .5478
	6,8	60	32	22	0,10	5,0	00	042 .5688
	10	81	42	15	0,10	4,2	01	042 .5109
	15	100	57	10	0,10	2,8	01	042 .5159
	22	133	79	6,8	0,10	2,1	02	042 .5229
	33	162	114	4,5	0,10	0,9	03	042 .5339
	47	242	158	3,2	0,10	0,7	04	043 .5479
	68	317	224	2,2	0,10	0,4	05	043 .5689
385	1	12	19	335	0,20	100	4	041 .8108
	2,2	23	42	152	0,20	45	5	041 .8228
	4,7	43	71	71,3	0,20	21	7	041 .8478
	6,8	60	34	22	0,10	5,0	00	042 .8688
	10	81	45	15	0,10	4,2	01	042 .8109
	15	110	62	10	0,10	2,3	02	042 .8159
	22	147	86	6,8	0,10	2,0	03	042 .8229
	33	203	124	4,5	0,10	0,8	04	043 .8339
	47	242	173	3,2	0,10	0,7	04	043 .8479
	68	317	246	2,2	0,10	0,4	05	043 .8689

* Note is on the next page.

* Replace dot in catalogue number by:
1 for style 1, case sizes 00 to 05, supplied in box;
2 for style 1 on bandoliers on reel; } case sizes 4 to 7
3 for style 1 on bandoliers in box; }
4 for style 2, case sizes 03, 04, 05;
8 for style 3;
7 for style 4.

Capacitance

Nominal capacitance values at 100 Hz and T_{amb} = 20 °C	see Table 2
Tolerance on nominal capacitance at 100 Hz	−10 to + 50%

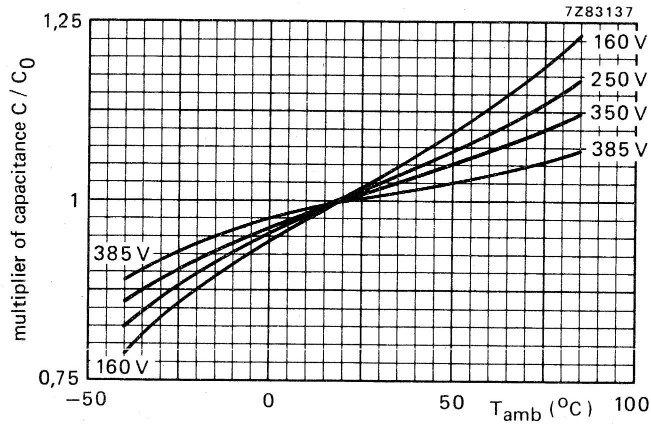


Fig. 5 Multiplier of capacitance as a function of ambient temperature; **case sizes 4 to 7**;
C_0 = capacitance at 20 °C, 100 Hz.

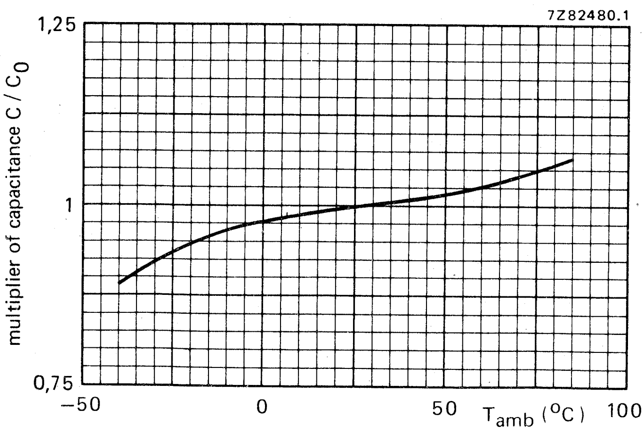


Fig. 6 Multiplier of capacitance as a function of ambient temperature; **case sizes 00 to 05**;
C_0 = capacitance at 25 °C, 100 Hz.

Voltage

Rated voltage = max. permissible voltage	
at < 40 °C	1,1 x U_R
at 40 to 85 °C	U_R
Ripple voltage* = max. permissible a.c. voltage providing the following three conditions are met:	
a) max. (d.c. + peak a.c.) voltage	U_R
b) max. peak a.c. voltage without d.c. voltage applied	1 V
c) momentary value of applied voltage	between U_R and −1 V
Surge voltage = max. permissible voltage for short periods	
for U_R = 160 V or 250 V	1,15 x U_R
for U_R = 350 V or 385 V	1,1 x U_R
Reverse voltage = max. d.c. voltage applied in the reverse polarity at 85 °C for short periods	1 V

Ripple current **

Maximum permissible r.m.s. ripple current at 100 Hz and T_{amb} = 85 °C	see Table 2

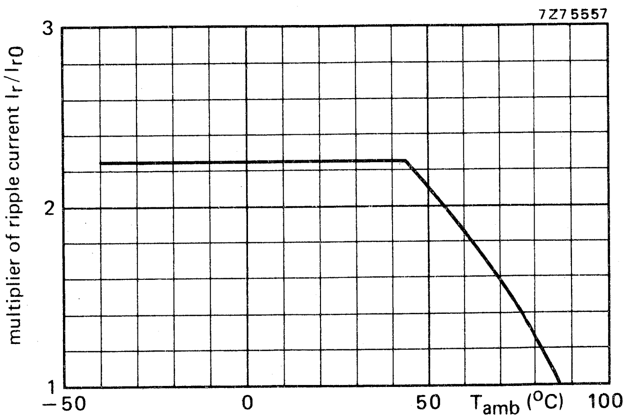


Fig. 7 Multiplier of ripple current as a function of ambient temperature; I_{r0} = ripple current at 85 °C, 100 Hz.

* Ripple voltages are not applicable if the maximum permissible ripple current is exceeded. In that case the ripple current is decisive.

** Ripple currents are not applicable if the maximum permissible ripple voltage is exceeded. In that case the ripple voltage is decisive.

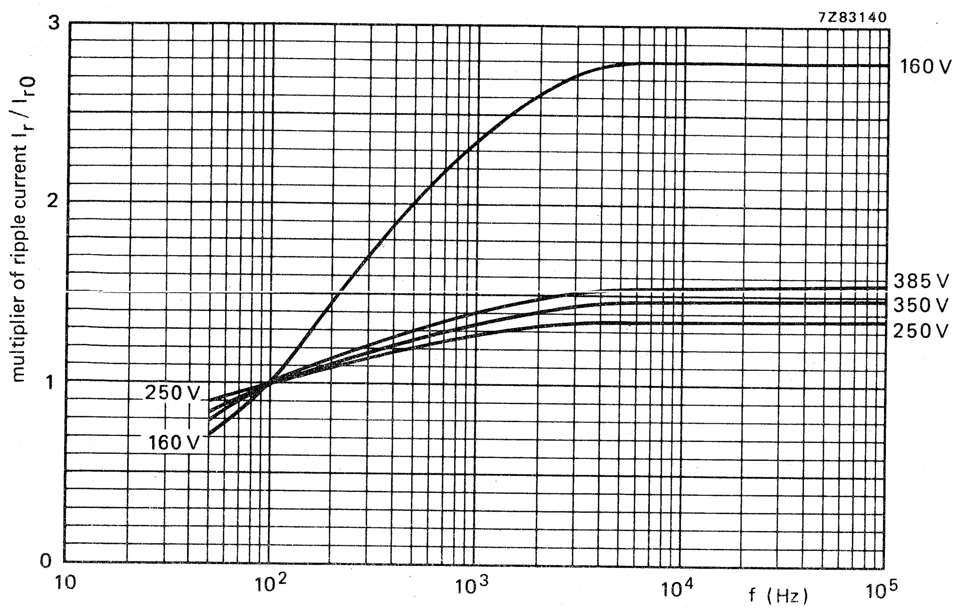


Fig. 8 Multiplier of ripple current as a function of frequency; **case sizes 4 to 7**; I_{r0} = ripple current at 85 °C, 100 Hz.

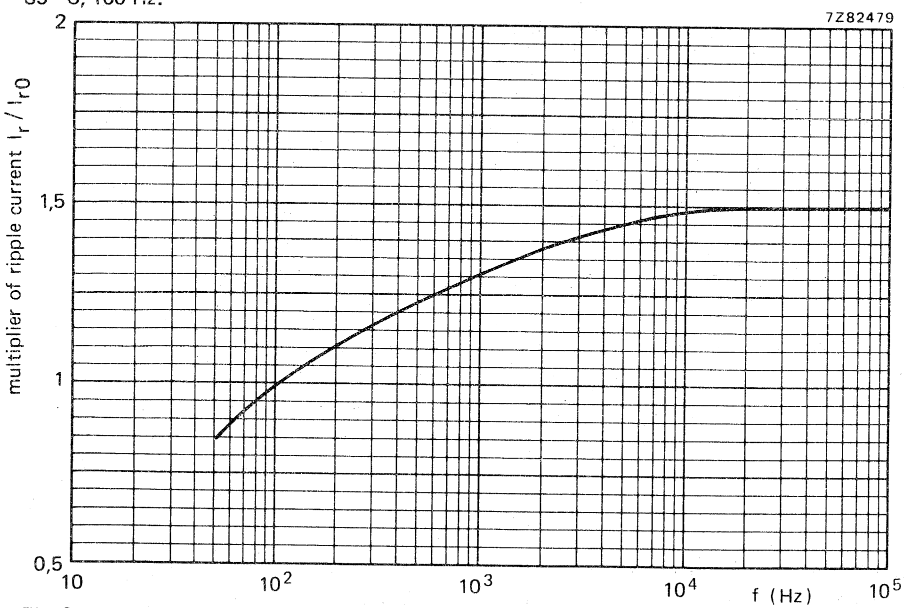


Fig. 9 Multiplier of ripple current as a function of frequency; **case sizes 00 to 05**; I_{r0} = ripple current at 85 °C, 100 Hz.

Non-sinusoidal ripple currents have to be analyzed into a number of sinusoidal currents and the following requirements shall then be satisfied:

$$\sum_n \frac{I_n^2}{r_n} \leqslant I_{r\,max}^2$$

$I_{r\,max}$ = maximum ripple current at 100 Hz and applicable ambient temperature;
I_n = ripple current at a certain frequency;
$r_n = I_r/I_{r0}$ = multiplying factor at a same frequency.

Charge and discharge current

The capacitors may be charged from a source without internal resistance and they may be discharged by short-circuiting. If the capacitors are charged and discharged continuously several times per minute, the charge and discharge currents have to be considered as ripple currents flowing through the capacitors. The r.m.s. value of these currents should be determined and the value thus found must not exceed the applicable limit.

Leakage current

Maximum leakage current **1 min** after application of the rated voltage at T_{amb} = 20 °C	
case sizes 4 to 7	see Table 2 (0,05 CU or 5 μA for CU $\leqslant$ 1000 μC; 0,03 CU + 20 μA for CU > 1000 μC)
case sizes 00 to 05	see Table 2 (0,009 CU + 10 μA)
Maximum leakage current **5 min** after application of the rated voltage at T_{amb} = 20 °C; all case sizes	0,01 CU or 1 μA (whichever is greater) for CU $\leqslant$ 1000 μC; 0,006 CU + 4 μA for CU > 1000 μC

If owing to prolonged storage and/or storage at an excessive temperature (> 40 °C) the leakage current is too high, application of the rated voltage for some hours will cause the leakage current to fall to a value lower than specified in Table 2.

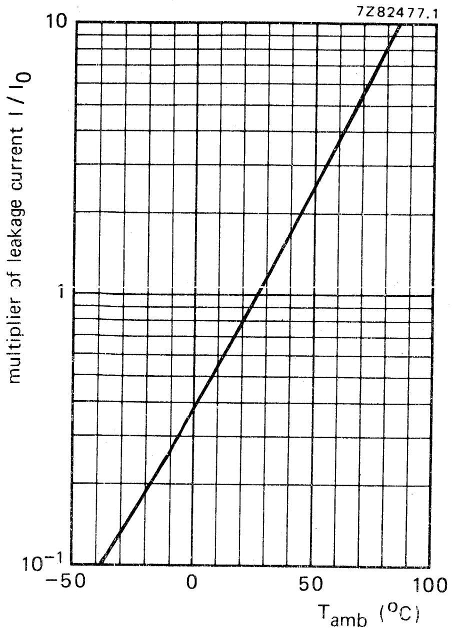


Fig. 10 Multiplier of leakage current as a function of ambient temperature; I_0 = leakage current during continuous operation at 25 °C and U_R.

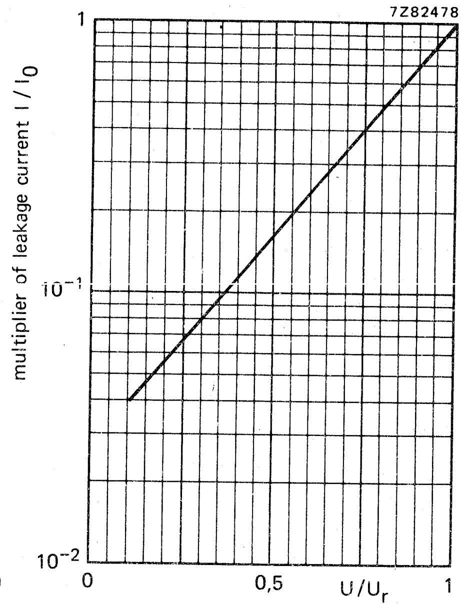


Fig. 11 Multiplier of leakage current as a function of U/U_R; I_0 = leakage current during continuous operation at 25 °C and U_R.

Equivalent series resistance (ESR)

Maximum ESR at 100 Hz, measured by means of a four-terminal circuit (Thomson circuit)

see Table 2

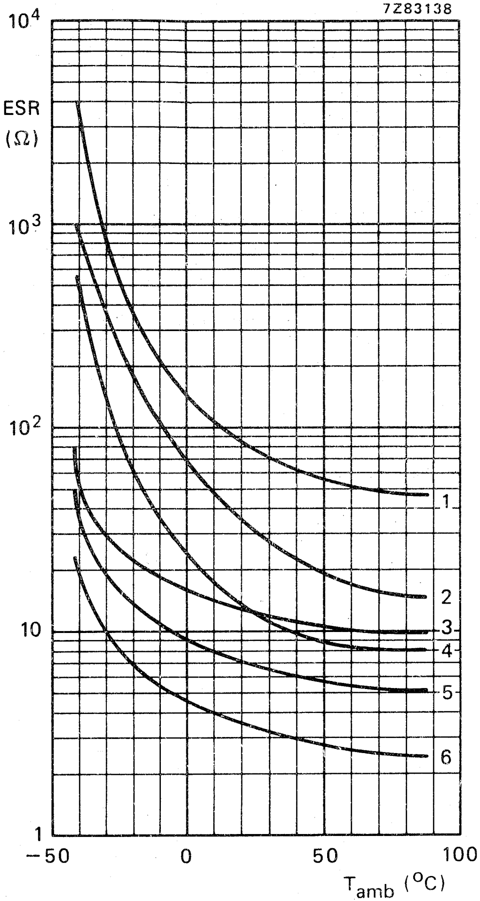


Fig. 12 Typical ESR as a function of ambient temperature at 100 Hz; **case sizes 4 to 7.**
Curve 1 = case size 4, 385 V;
curve 2 = case size 5, 385 V;
curve 3 = case size 4, 160 V;
curve 4 = case size 7, 385 V;
curve 5 = case size 5, 160 V;
curve 6 = case size 7, 160 V.

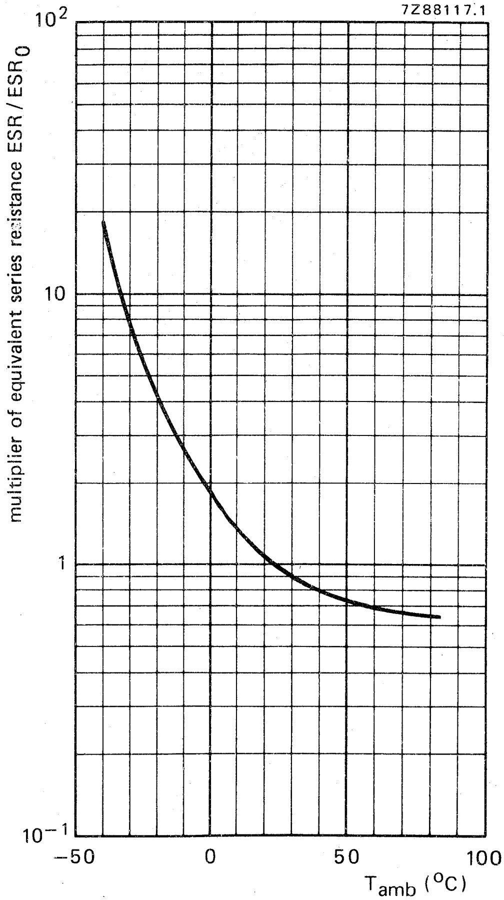


Fig. 13 Multiplier of ESR as a function of ambient temperature; **case sizes 00 to 05**;
ESR_0 = typ. ESR at 25 °C, 100 Hz.

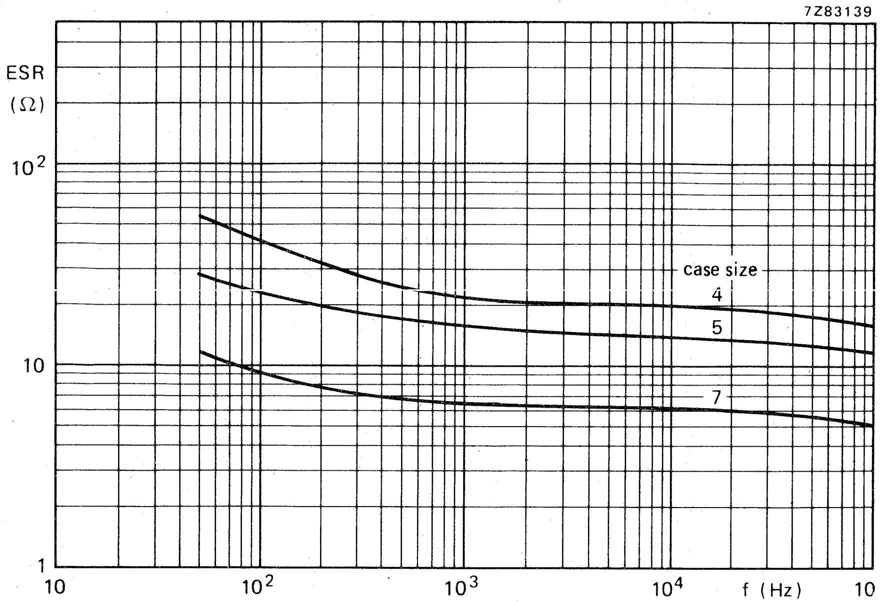


Fig. 14 Typical ESR as a function of frequency at 20 °C; U_R = 250 V; **case sizes 4 to 7.**

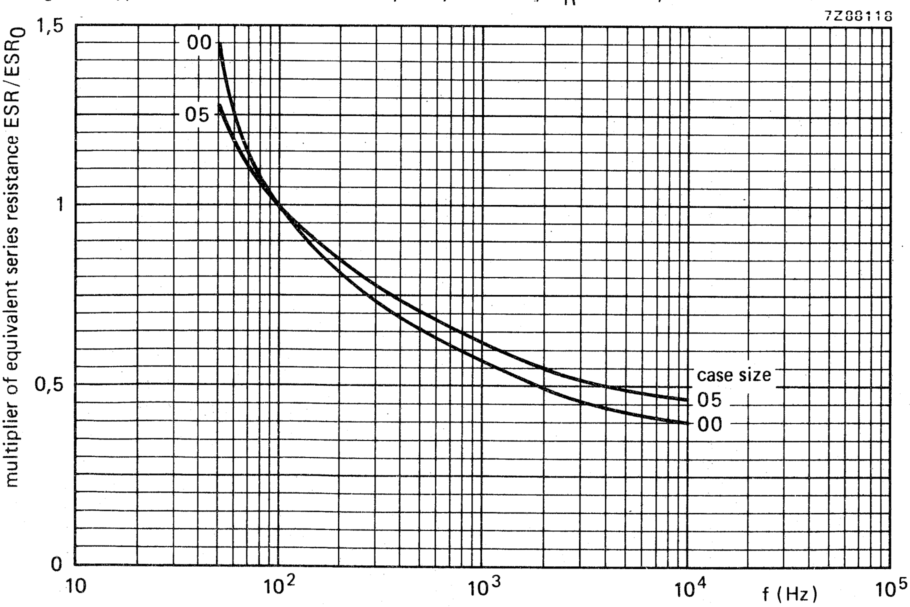


Fig. 15 Multiplier of ESR as a function of frequency; **case sizes 00 to 05**; ESR_0 = typ. ESR at 25 °C, 100 Hz.

Impedance

Typical impedance at 10 kHz, measured by a four-terminal circuit (Thomson circuit)

see Table 2

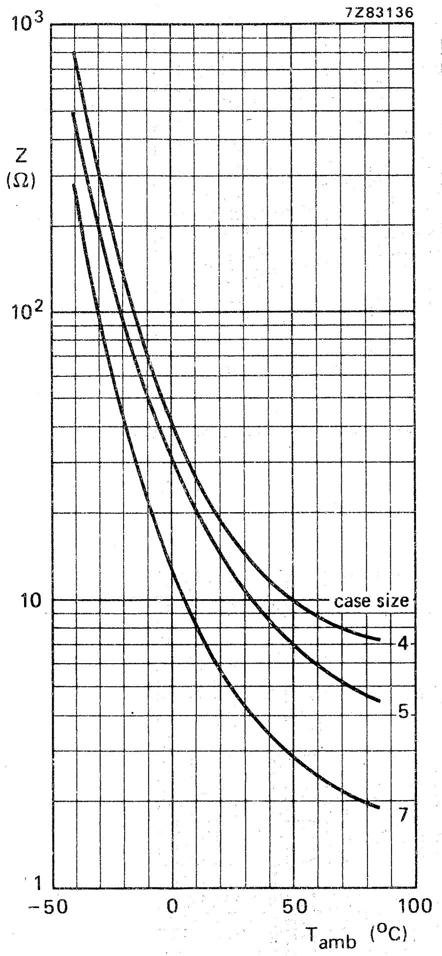


Fig. 16 Typical impedance as a function of ambient temperature at 10 kHz; U_R = 250 V; **case sizes 4 to 7.**

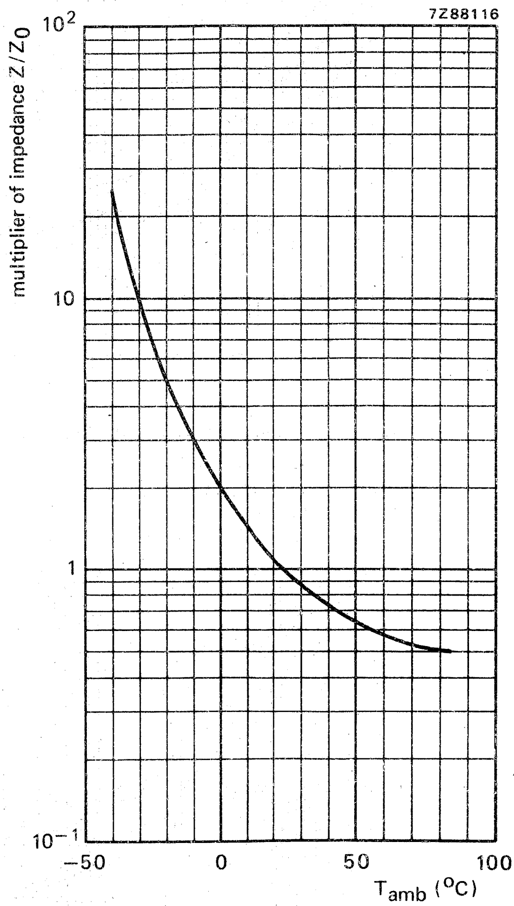


Fig. 17 Multiplier of impedance as a function of ambient temperature; **case sizes 00 to 05;** Z_0 = typ. impedance at 25 °C, 10 kHz (see Table 2).

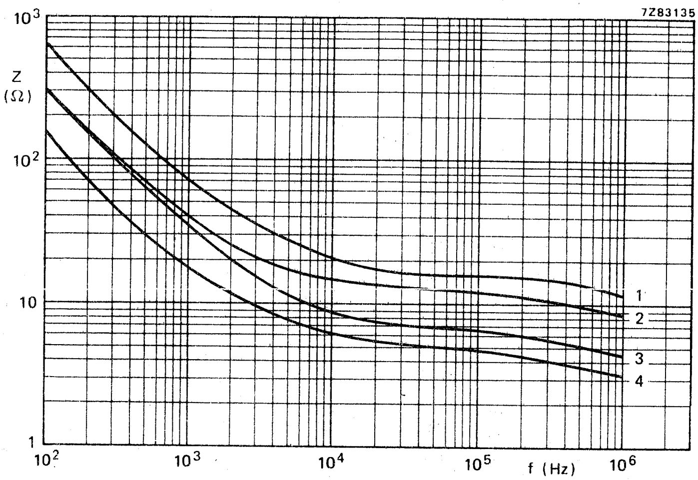


Fig. 18 Typical impedance as a function of frequency at 20 °C. **Case sizes 4 to 7.**
Curve 1 = case size 4, 250 V;
curve 2 = case size 5, 250 V;
curve 3 = case size 6, 350 V;
curve 4 = case size 7, 250 V.

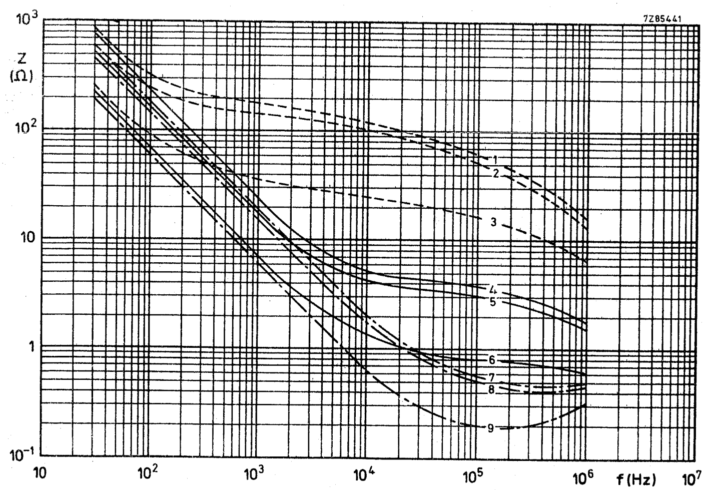


Fig. 19 Typical impedance as a function of frequency at different temperatures. **Case size 00.**
Curve 1 = 6,8 μF, 350/385 V; –40 °C;
curve 2 = 10 μF, 250 V; –40 °C;
curve 3 = 22 μF, 160 V; –40 °C;
curve 4 = 6,8 μF, 350/385 V; + 20 °C;
curve 5 = 10 μF, 250 V; + 20 °C;
curve 6 = 22 μF, 160 V; + 20 °C;
curve 7 = 6,8 μF, 350/385 V; + 85 °C;
curve 8 = 10 μF, 250 V; + 85 °C;
curve 9 = 22 μF, 160 V; + 85 °C.

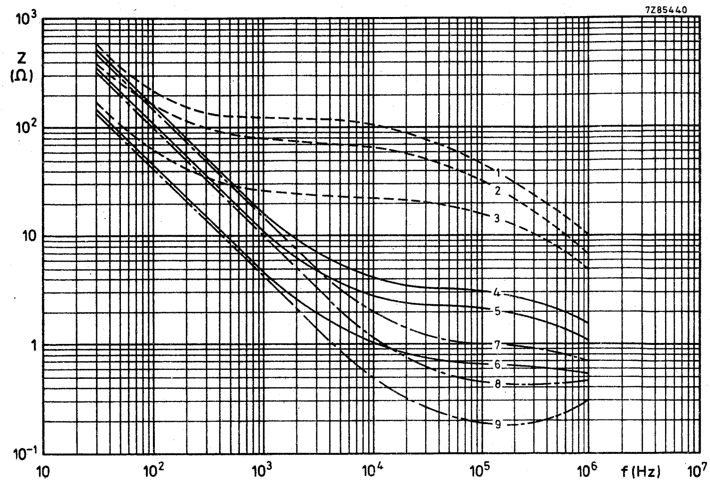


Fig. 20 Typical impedance as a function of frequency at different temperatures. **Case size 01.**

Curve 1 = 10 μF, 350/385 V; –40 °C;
curve 2 = 15 μF, 250 V; –40 °C;
curve 3 = 33 μF, 160 V; –40 °C;
curve 4 = 10 μF, 350/385 V; + 20 °C;
curve 5 = 15 μF, 250 V; + 20 °C;
curve 6 = 33 μF, 160 V; + 20 °C;
curve 7 = 10 μF, 350/385 V; + 85 °C;
curve 8 = 15 μF, 250 V; + 85 °C;
curve 9 = 33 μF, 160 V; + 85 °C.

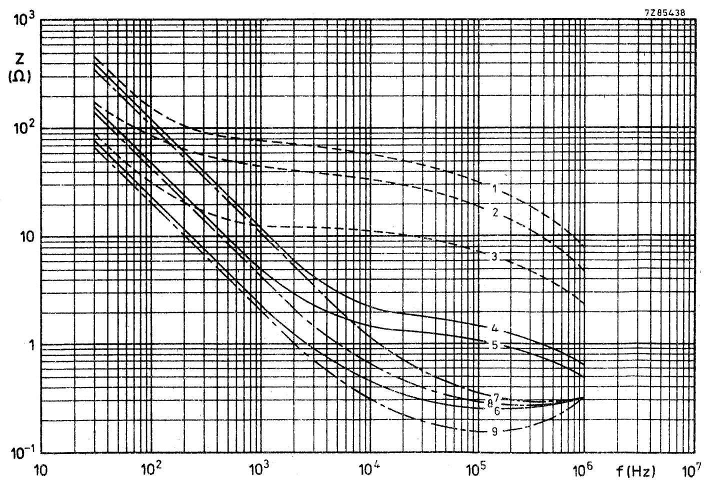


Fig. 21 Typical impedance as a function of frequency at different temperatures. **Case size 02.**

Curve 1 = 15 μF, 385 V; –40 °C;
curve 2 = 22 μF, 250 V; –40 °C;
curve 3 = 68 μF, 160 V; –40 °C;
curve 4 = 15 μF, 385 V; +20 °C;
curve 5 = 22 μF, 250 V; +20 °C;
curve 6 = 68 μF, 160 V; + 20 °C;
curve 7 = 15 μF, 385 V; + 85 °C;
curve 8 = 22 μF, 250 V; + 85 °C;
curve 9 = 68 μF, 160 V; + 85 °C.

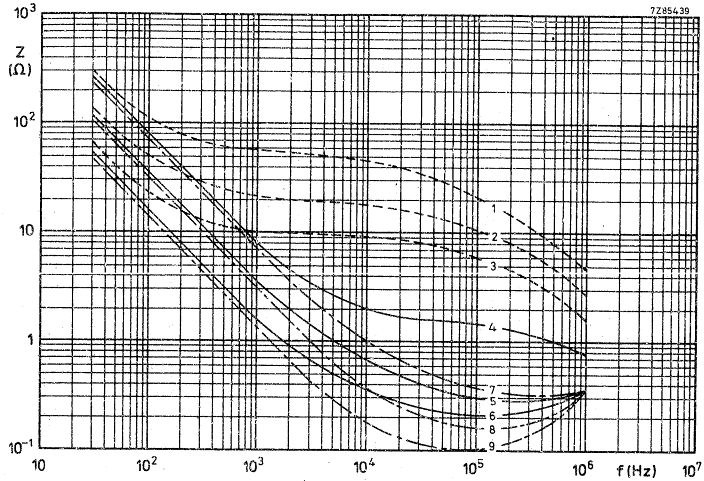


Fig. 22 Typical impedance as a function of frequency at different temperatures. **Case size 03.**

Curve 1 = 22 μF, 385 V; –40 °C;
curve 2 = 47 μF, 250 V; –40 °C;
curve 3 = 100 μF, 160 V; –40 °C;
curve 4 = 22 μF, 385 V; + 20 °C;
curve 5 = 47 μF, 250 V; + 20 °C;
curve 6 = 100 μF, 160 V; + 20 °C;
curve 7 = 22 μF, 385 V; + 85 °C;
curve 8 = 47 μF, 250 V; + 85 °C;
curve 9 = 100 μF, 160 V; + 85 °C.

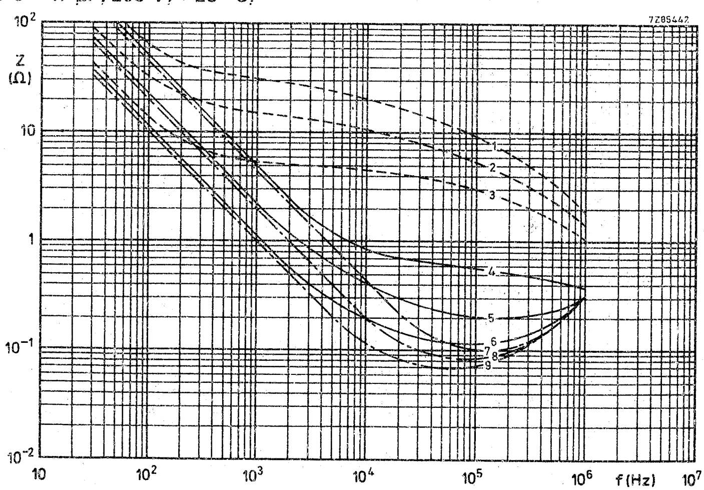


Fig. 23 Typical impedance as a function of frequency at different temperatures. **Case size 04.**

Curve 1 = 33 μF, 385 V; –40 °C;
curve 2 = 68 μF, 250 V; –40 °C;
curve 3 = 150 μF, 160 V; –40 °C;
curve 4 = 33 μF, 385 V; + 20 °C;
curve 5 = 68 μF, 250 V; + 20 °C;
curve 6 = 150 μF, 160 V; + 20 °C;
curve 7 = 33 μF, 385 V; + 85 °C;
curve 8 = 68 μF, 250 V; + 85 °C;
curve 9 = 150 μF, 160 V; + 85 °C.

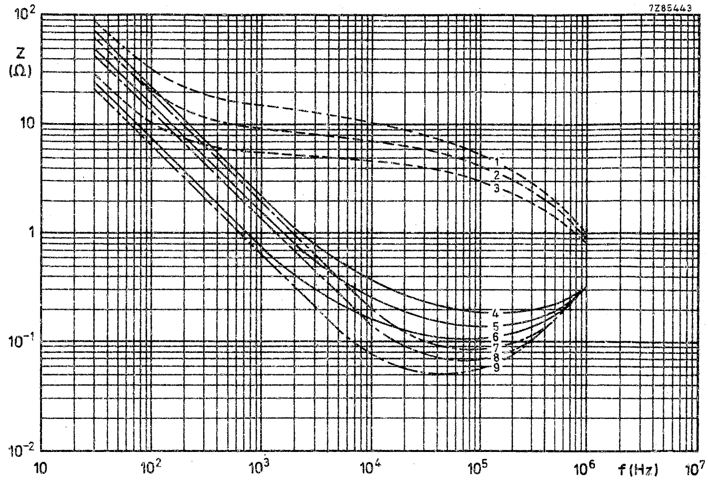


Fig. 24 Typical impedance as a function of frequency at different temperatures. **Case size 05.**

Curve 1 = 68 μF, 350/385 V; –40 °C;
curve 2 = 100 μF, 250 V; –40 °C;
curve 3 = 220 μF, 160 V; –40 °C;
curve 4 = 68 μF, 350/385 V; + 20 °C;
curve 5 = 100 μF, 250 V; + 20 °C;
curve 6 = 220 μF, 160 V; + 20 °C;
curve 7 = 68 μF, 350/385 V; + 85 °C;
curve 8 = 100 μF, 250 V; + 85 °C;
curve 9 = 220 μF, 160 V; + 85 °C.

Inductance (ESL)

Case sizes 00 and 01	50 nH	typical values
Case size 02	55 nH	
Case sizes 03, 04 and 05	60 nH	

OPERATIONAL DATA

Category temperature range	–40 to + 85 °C
Typical life time at T_{amb} = 85 °C	
case sizes 4 to 7	5000 h
case sizes 00 to 05	10 000 h

PACKING

All capacitors are supplied in boxes; case sizes 4 to 7 of style 1 are on bandoliers in boxes or on reels. The number of capacitors per box or per reel is shown in Table 3.

Table 3

case size	number of capacitors	
	per box	per box or per reel (style 1, on bandoliers)
4	1000	1000
5	1000	500
6	1000	500
7	500	500
00	200	
01	200	
02	200	
03	200	
04	100	
05	100	

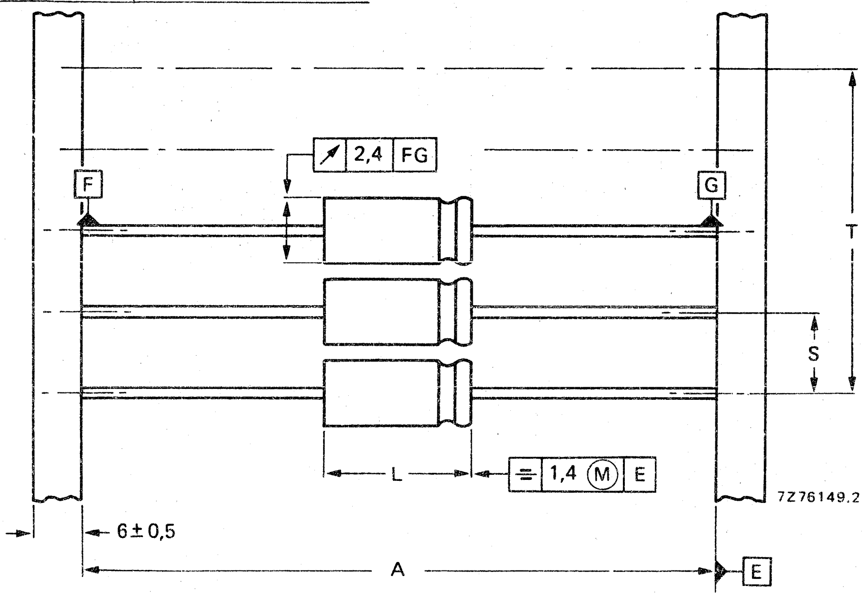


Fig. 25 Style 1 capacitors (case sizes 4 to 7) on bandoliers: the bandolier to which the negative capacitor terminals are connected is blue. See Table 4 for dimensions A, S, T and L.

Table 4

Dimensions in mm

case size	A	S	T for number (n) of capacitors		L_{max}
			$n < 50$	$50 < n < 100$	
4	73 ± 1,6	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	18,5
5	73 ± 1,6	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	18,5
6	73 ± 1,6	15 ± 0,75	15 (n-1) ± 2	15 (n-1) ± 4	18,5
7	73 ± 1,6	15 ± 0,75	15 (n-1) ± 2	15 (n-1) ± 4	25,0

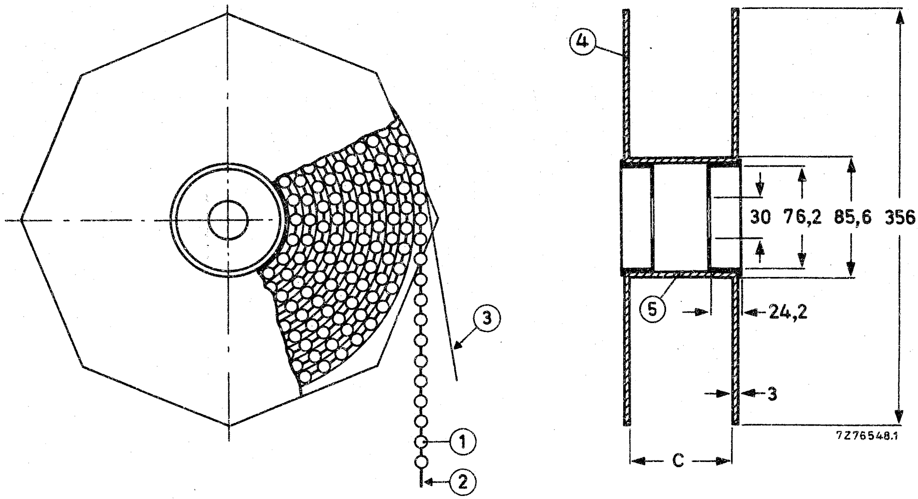


Fig. 26 Style 1 capacitors (case sizes 4 to 7) on bandoliers on reel; dimension C is 88,5 mm; the overall width of the reel is 99,5 mm.

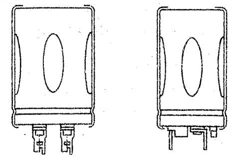
1 = capacitor
2 = bandolier
3 = paper
4 = flange
5 = cylinder

TESTS AND REQUIREMENTS

See Introduction, section 9, under aluminium electrolytic capacitors.

Note: Capacitors 2222 041 are miniature types, long-life grade.
Capacitors 2222 042 and 2222 043 are small types, long-life grade.

ALUMINIUM ELECTROLYTIC CAPACITORS



- Large type with solder tags or printed-wiring pins
- Long life
- Industrial applications

QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	47 to 68 000 μF
Tolerance on nominal capacitance	−10 to + 30%
Rated voltage, U_R	10 to 385 V
Category temperature range	−40 to + 85 °C
Endurance test at 85 °C, at U_R	2000 h
Basic specification	IEC 384-4, long-life grade; DIN 41240
Dimensional specification	DIN 41238
Climatic category, IEC 68	40/085/56
DIN40040	GPF (56 days)

Selection chart for C_{nom}-U_R and relevant case sizes.

C_{nom} μF	U_R (V) 10	16	25	40	63	100	250	385
47								1
68								2
100							1	3
150							2	4
220							3	5/6
330							4	7
470						1	5/6	8
680						2	7	
1 000					1	3	8	
1 500				1	2	4		
2 200			1	2	3	5/6		
3 300		1	2	3	4	7		
4 700	1	2	3	4	5/6	8		
6 800	2	3	4	5/6	7	9		
10 000	3	4	5/6	7	8			
15 000	4	5/6	7	8	9			
22 000	5/6	7	8	9				
33 000	7	8	9					
47 000	8	9						
68 000	9							

case size	nominal dimensions (mm) versions with solder tags	versions with printed-wiring pins
1	ϕ 25 x 35	ϕ 25 x 35
2	ϕ 25 x 45	ϕ 25 x 45
3	ϕ 30 x 45	ϕ 30 x 45
4	ϕ 35 x 45	ϕ 35 x 45
5	ϕ 35 x 55	ϕ 35 x 55
6		ϕ 40 x 45
7	ϕ 40 x 55	ϕ 40 x 55
8	ϕ 40 x 75	ϕ 40 x 75
9	ϕ 40 x 105	ϕ 40 x 105

APPLICATION

These capacitors have low ESR and ESL values and a high resistance to shock and vibration which render them suitable for application such as:

- switched-mode power supplies;
- power supplies in digital equipment;
- energy storage in pulse systems;
- filters in measuring and control apparatus.

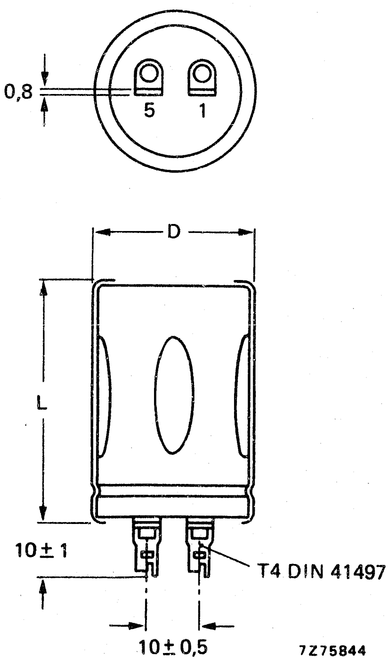
DESCRIPTION

The resistance to shock and vibration is achieved by a special internal construction.
The capacitors are completely cold welded and charge/discharge proof. The aluminium case is fully insulated. The solder tag versions have a safety vent in the discs, the printed-wiring versions have a safety vent in the case bottom.

MECHANICAL DATA

Dimensions in mm

Capacitors with solder tags



1 = plus
5 = minus

Fig. 1.

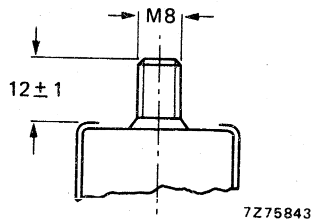


Fig. 2 Bolt version.

Table 1a

case size	D		L		mass approx. g
1	25		35		25
2	25		45		30
3	30		45		40
4	35	+ 0,6	45	+ 1,3	55
5	35		55		65
7	40		55		85
8	40		75		115
9	40		105		160

Capacitors with printed-wiring pins

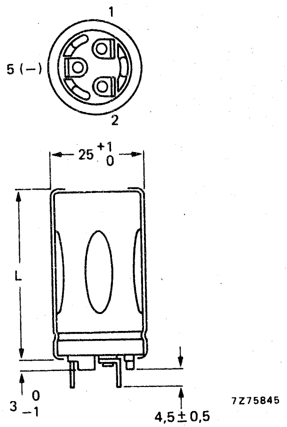


Fig. 3a.

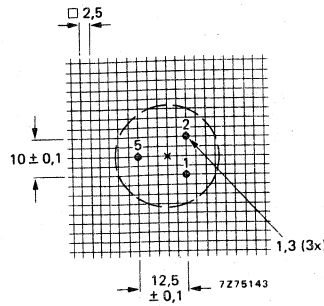


Fig. 3b Piercing diagram viewed from component side.

Table 1b

case size	L	mass approx. g
1	35 } + 1,3	25
2	45 } + 1,3	30

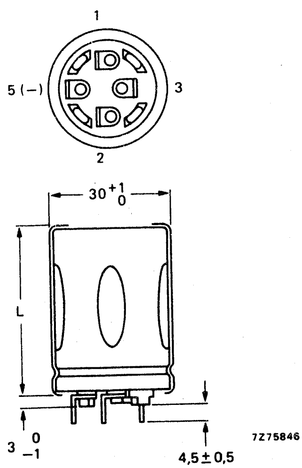


Fig. 4a.

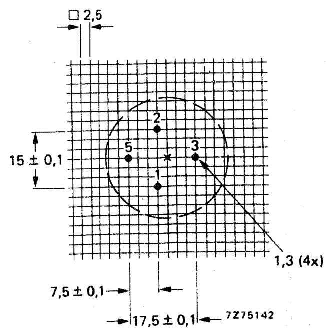


Fig. 4b Piercing diagram viewed from component side.

Table 1c

case size	L	mass approx. g
3	45 + 1,3	40

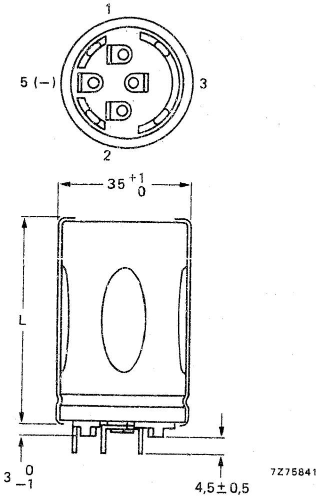


Fig. 5a.

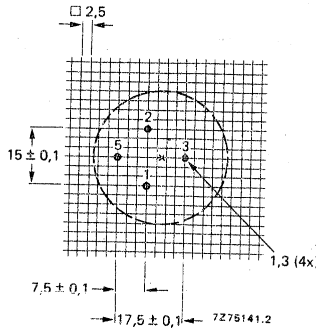


Fig. 5b Piercing diagram viewed from component side.

Table 1d

case size	L		mass approx. g
4	45	+ 1,3	55
5	55		65

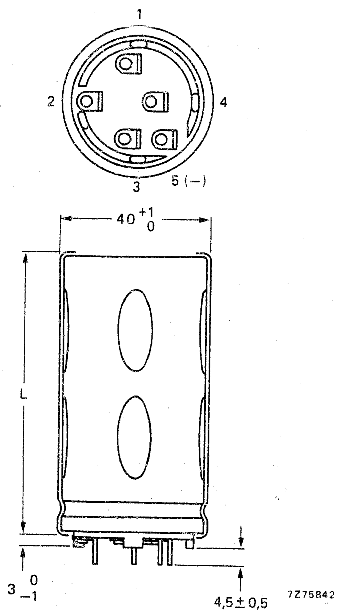


Fig. 6a.

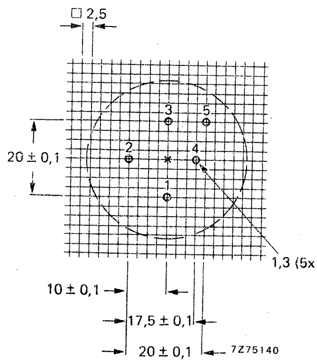


Fig. 6b Piercing diagram viewed from component side.

Table 1e

case size	L		mass approx. g
6	45	+ 1,3	70
7	55		85
8	75		115
9	105		160

Marking

The capacitors are marked with: nominal capacitance, tolerance on capacitance, rated voltage, temperature range, IEC grade, catalogue number, date code (year, month) according to IEC 62, name of manufacturer, indication of production centre, polarity of the terminals and dimensional specification DIN 41238.

The terminals are marked as shown in the dimensional figures.

Mounting

The capacitors may be mounted in any position with or without a mounting clamp. When a number of capacitors are connected in a bank, they must not be closer together than 15 mm, when no derating of ripple current and/or temperature is applied.
If the case has to be at a specified potential, it should be connected to the negative terminal only.

Minimum atmospheric pressure 8,5 kPa

ELECTRICAL DATA

Unless otherwise specified all electrical values apply at an ambient temperature of 20 °C, a frequency of 100 Hz, an atmospheric pressure of 86 to 106 kPa and a relative humidity of 45 to 75%.

Table 2 (note is at the end of the table)

U_R	nom. cap.	max. r.m.s. ripple current (A) at		max. leakage current at U_R after 5 min (mA)	typ. tan δ	max. ESR	max. impedance at 10 kHz	case size	catalogue number* 2222 followed by
		100 Hz, 85 °C	20 kHz, 70 °C						
V	µF					mΩ	mΩ		
10	4 700	2,4	4,6	0,28	0,19	74	50	1	050 .4472
	6 800	3,2	6,1	0,41	0,18	51	37	2	.4682
	10 000	3,8	7,2	0,60	0,24	39	29	3	.4103
	15 000	4,1	7,8	0,90	0,33	35	26	4	.4153
	22 000	5,0	9,5	1,32	0,37	27	21	5	.4223
	22 000	4,2	8,0	1,32	0,48	36	27	6	.4223
	33 000	5,0	9,5	1,98	0,58	29	22	7	.4333
	47 000	6,8	12,9	2,82	0,58	20	17	8	.4473
	68 000	9,2	17,5	4,08	0,62	15	14	9	.4683
16	3 300	2,4	4,6	0,32	0,13	75	50	1	.5332
	4 700	3,1	5,9	0,45	0,14	52	37	2	.5472
	6 800	3,7	7,0	0,65	0,17	40	30	3	.5682
	10 000	4,1	7,8	0,96	0,22	36	27	4	.5103
	15 000	5,0	9,5	1,44	0,25	28	21	5	.5153
	15 000	4,2	8,0	1,44	0,33	36	27	6	.5153
	22 000	5,0	9,5	2,12	0,38	29	22	7	.5223
	33 000	6,7	12,7	3,17	0,41	20	17	8	.5333
	47 000	9,1	17,3	4,51	0,42	15	14	9	.5473
25	2 200	2,3	4,4	0,33	0,10	78	52	1	.6222
	3 300	3,1	5,9	0,49	0,11	53	38	2	.6332
	4 700	3,7	7,0	0,70	0,12	42	31	3	.6472
	6 800	4,1	7,8	1,02	0,15	37	28	4	.6682
	10 000	5,0	9,5	1,50	0,17	28	21	5	.6103
	10 000	4,2	8,0	1,50	0,22	36	27	6	.6103
	15 000	5,0	9,5	2,25	0,26	29	22	7	.6153
	22 000	6,8	12,9	3,30	0,27	20	17	8	.6223
	33 000	9,2	17,5	4,95	0,30	15	14	9	.6333
40	1 500	2,0	3,8	0,36	0,085	112	68	1	.7152
	2 200	2,7	5,1	0,53	0,087	76	51	2	.7222
	3 300	3,3	6,3	0,79	0,10	57	41	3	.7332
	4 700	3,8	7,2	1,13	0,12	48	35	4	.7472
	6 800	4,7	8,9	1,64	0,13	36	27	5	.7682
	6 800	4,1	7,8	1,64	0,17	45	33	6	.7682
	10 000	4,9	9,3	2,40	0,19	35	27	7	.7103
	15 000	6,6	12,5	3,60	0,21	25	20	8	.7153
	22 000	9,0	17,1	5,28	0,22	18	16	9	.7223

Table 2 (continued)

U_R	nom cap.	max. r.m.s. ripple current (A) at		max. leakage current at U_R after 5 min (mA)	typ. tan δ	max. ESR	max. impedance at 10 kHz	case size	catalogue number* 2222 followed by
V	μF	100 Hz, 85 °C	20 kHz, 70 °C			mΩ	mΩ		
63	1 000	1,8	3,4	0,38	0,064	122	74	1	050 . 8102
	1 500	2,5	4,7	0,57	0,065	83	54	2	. 8152
	2 200	3,1	5,9	0,83	0,076	57	41	3	. 8222
	3 300	3,6	6,8	1,25	0,094	48	35	4	. 8332
	4 700	4,4	8,3	1,78	0,10	36	27	5	. 8472
	4 700	3,8	7,2	1,78	0,13	45	33	6	. 8472
	6 800	4,7	8,9	2,57	0,14	35	27	7	. 8682
	10 000	6,2	11,8	3,78	0,15	25	20	8	. 8103
	15 000	8,5	16,1	5,67	0,16	18	16	9	. 8153
100	470	1,2	2,3	0,28	0,086	342	300	1	. 9471
	680	1,7	3,2	0,41	0,087	229	210	2	. 9681
	1 000	2,2	4,2	0,60	0,092	160	150	3	. 9102
	1 500	2,6	4,9	0,90	0,10	117	120	4	. 9152
	2 200	3,2	6,1	1,32	0,11	84	90	5	. 9222
	2 200	3,0	5,7	1,32	0,12	96	110	6	. 9222
	3 300	3,6	6,8	1,98	0,14	70	75	7	. 9332
	4 700	5,0	9,5	2,82	0,13	49	55	8	. 9472
	6 800	6,9	13,1	4,08	0,14	34	40	9	. 9682
250	100	0,6	1,15	150	0,085	1800	1300	1	052 . 3101
	150	0,8	1,5	230	0,08	1100	850	2	. 3151
	220	1,0	1,9	330	0,08	750	550	3	. 3221
	330	1,4	2,65	490	0,08	500	400	4	. 3331
	470	1,8	3,4	700	0,08	360	290	5	. 3471
	470	1,8	3,4	700	0,095	420	350	6	. 3471
	680	2,3	4,4	1020	0,08	250	190	7	. 3681
	1 000	3,0	5,7	1500	0,08	170	140	8	. 3102
385	47	0,4	0,75	110	0,065	2800	2200	1	. 8479
	68	0,6	1,15	160	0,055	1700	1350	2	. 8689
	100	0,8	1,5	230	0,055	1100	850	3	. 8101
	150	1,0	1,9	340	0,055	725	525	4	. 8151
	220	1,3	2,45	500	0,055	500	350	5	. 8221
	220	1,3	2,45	500	0,065	600	420	6	. 8221
	330	1,7	3,2	750	0,055	340	230	7	. 8331
	470	2,8	5,3	1060	0,055	240	160	8	. 8471

* To complete the catalogue number, replace dot (8th digit) by:
1 = solder tag version;
4 = printed-wiring version, case size 6 only;
5 = printed-wiring version, except case size 6;
6 = solder tag, bolt version.

Capacitance

Nominal capacitance values at 100 Hz and T_{amb} = 20 °C	see Table 2
Tolerance on nominal capacitance at 100 Hz	−10 to + 30%

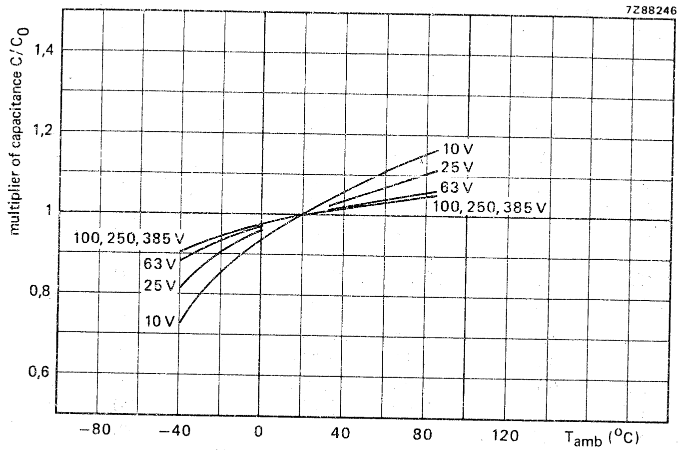


Fig. 7 Multiplier of capacitance as a function of ambient temperature; C_0 = capacitance at 25 °C, 100 Hz.

Voltage

	< 50 °C	50 to 85 °C
Rated voltage = max. permissible voltage	1,1 x U_R	U_R
Ripple voltage* = max. permissible a.c. voltage providing the following conditions are met:		
(a) max. positive voltage on anode (d.c. + peak a.c.)	⩽ 1,1 x U_R	⩽ U_R
(b) max. positive voltage on cathode (reverse voltage)	2 V	
Surge voltage = max. permissible voltage at the maximum category temperature for short periods		
10 to 100 V versions	1,25 x U_R	1,15 x U_R
250 V version	1,15 x U_R	1,15 x U_R
385 V version	1,1 x U_R	1,1 x U_R
Reverse voltage = max. d.c. voltage applied in the reverse polarity at the maximum category temperature for short periods	2 V	

* Ripple voltages are not applicable if the maximum permissible ripple current is exceeded. In that case the ripple current is decisive.

Ripple current*

Maximum permissible r.m.s. ripple current

at 100 Hz and T_{amb} = 85 °C	see Table 2
at 20 kHz and T_{amb} = 70 °C	see Table 2
at 100 Hz and other temperatures	see Table 3
at other frequencies and T_{amb} = 85 °C	see Table 4

Table 3

ambient temperature °C	multiplier of max. ripple current
85	1,00
80	1,22
75	1,41
70	1,58
65	1,73
60	1,87
55	2,00
50	2,12
45	2,24
≤ 40	2,35

Table 4

frequency Hz	multiplier of max. ripple current, $\sqrt{r}$
50	0,83
100	1,00
200	1,10
400	1,15
1000	1,19
≥ 2000	1,20

Non-sinusoidal ripple currents have to be analyzed into a number of sinusoidal currents and the following requirements shall then be satisfied:

$$\sum_n \frac{I_n^2}{r_n} \leq I_{r\,max}^2$$

$I_{r\,max}$ = maximum ripple current at 100 Hz and applicable ambient temperature

I_n = ripple current at a certain frequency

$\sqrt{r_n}$ = multiplying factor at same frequency (Table 4).

Charge and discharge current

The capacitors may be charged from a source without internal resistance and they may be discharged by short-circuiting. If the capacitors are charged and discharged continuously, the charge and discharge currents have to be considered as ripple currents flowing through the capacitor. The r.m.s. value of these currents should be determined and the value thus found must not exceed the applicable limit.

* Ripple currents are not applicable if the maximum permissible ripple voltage is exceeded. In that case the ripple voltage is decisive.

Leakage current

Maximum leakage current 5 min after application of the rated voltage at T_{amb} = 20 °C	see Table 2 (0,006 CU + 4 μA)
Maximum leakage current 15 min after application of the rated voltage	
at T_{amb} = 20 °C	0,125 x value stated in Table 2
at T_{amb} = 85 °C	0,625 x value stated in Table 2

If owing to prolonged storage and/or storage at an excessive temperature the leakage current is too high, application of the rated voltage for some hours will cause the leakage current to fall to a value lower than specified in Table 2.

Tan δ (dissipation factor)

Tan δ at 100 Hz and T_{amb} = 20 °C, measured by means of a four-terminal circuit (Thomson circuit)	see Table 2

Equivalent series inductance (ESL)

Case sizes 1 and 2	max. 20 nH
Case sizes 3, 4 and 5	max. 35 nH
Case sizes 6, 7 and 8	max. 50 nH

Equivalent series resistance (ESR)

Maximum ESR at 100 Hz and T_{amb} = 20 °C	see Table 2

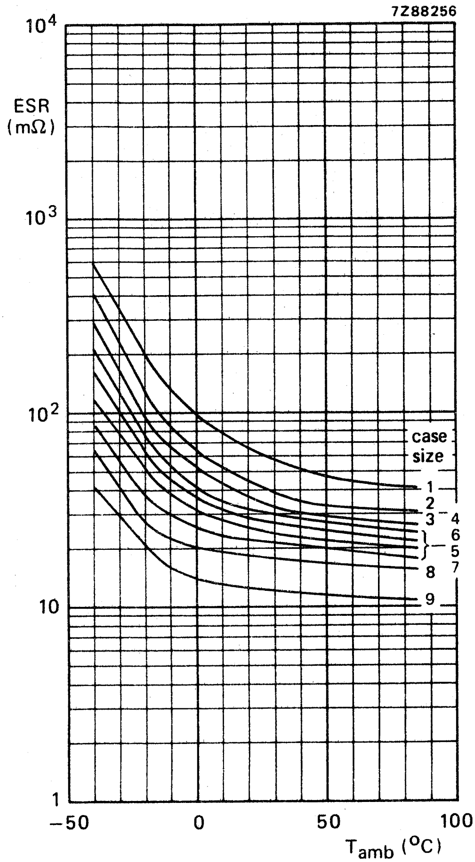


Fig. 8 Typical ESR as a function of temperature at 100 Hz, U_R = 10 V.

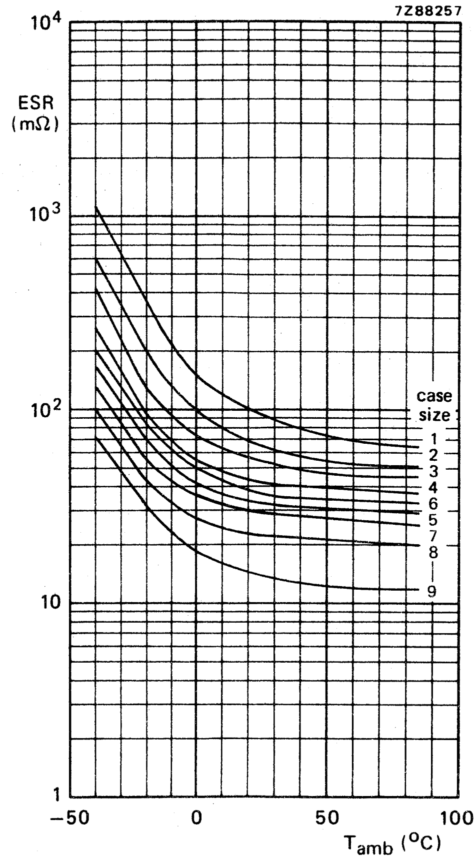


Fig. 9 Typical ESR as a function of temperature at 100 Hz, U_R = 63 V.

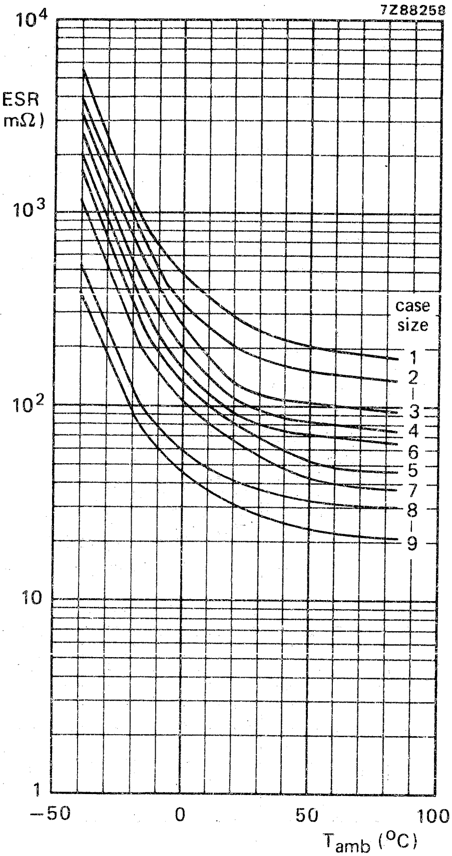


Fig. 10 Typical ESR as a function of temperature at 100 Hz, U_R = 100 V.

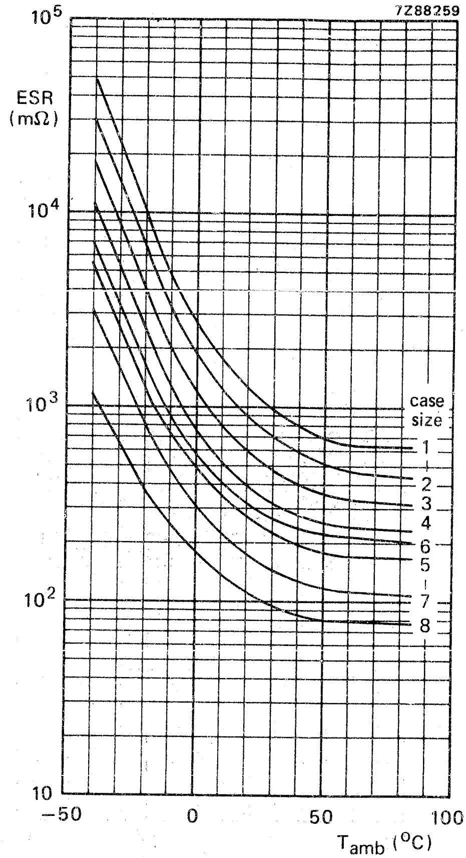


Fig. 11 Typical ESR as a function of temperature at 100 Hz, U_R = 250 V.

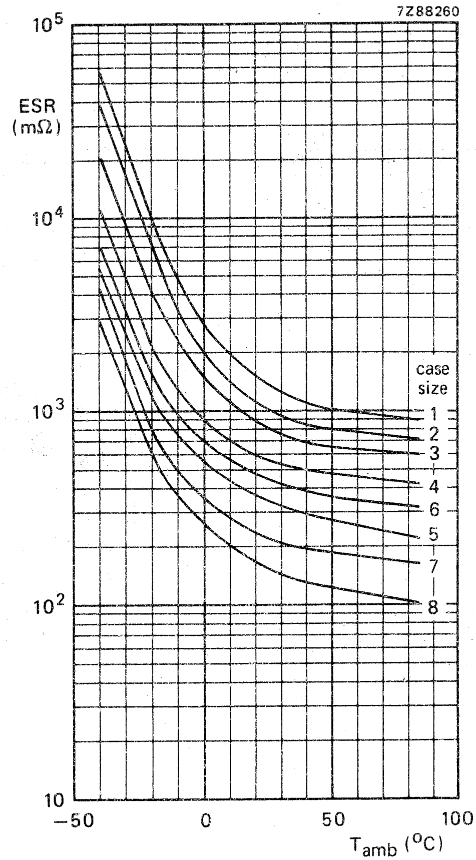


Fig. 12 Typical ESR as a function of temperature at 100 Hz, U_R = 385 V.

Impedance

Maximum impedance at 10 kHz and T_{amb} = 20 °C, measured by means of a four-terminal circuit (Thomson circuit) — see Table 2

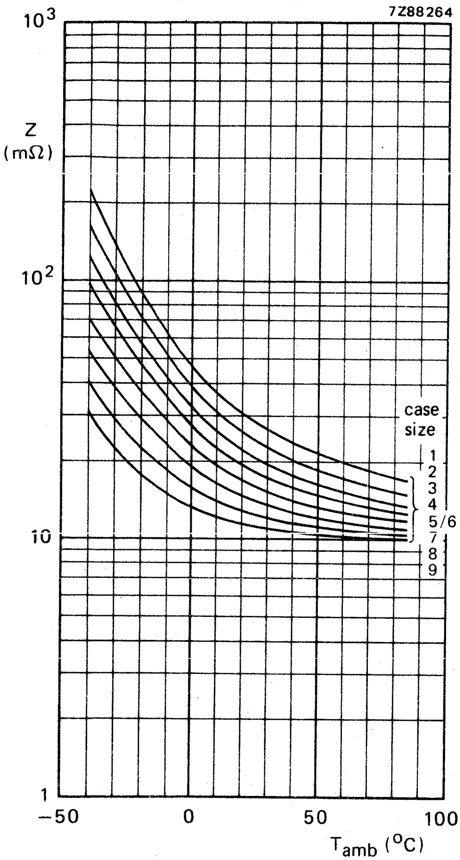


Fig. 13 Typical impedance as a function of temperature at 10 kHz, U_R = 10 V.

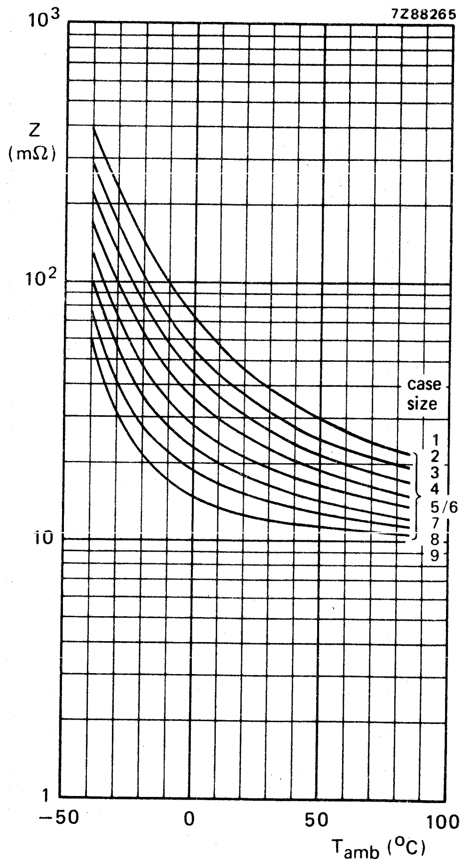


Fig. 14 Typical impedance as a function of temperature at 10 kHz, U_R = 63 V.

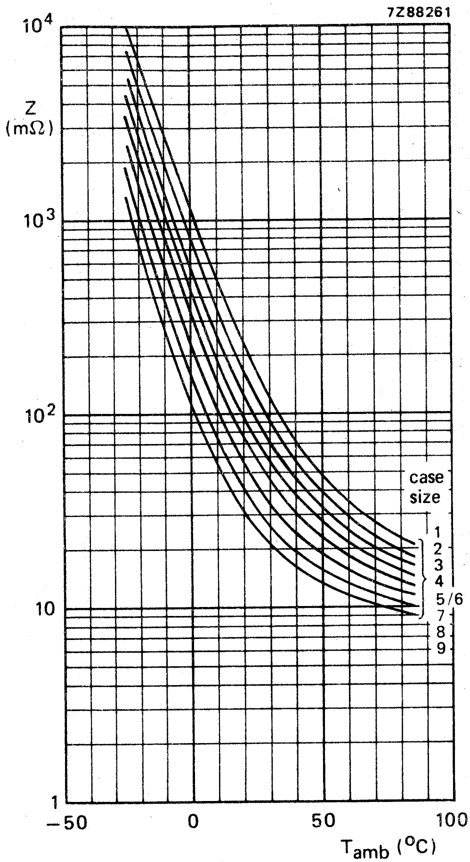


Fig. 15 Typical impedance as a function of temperature at 10 kHz, U_R = 100 V.

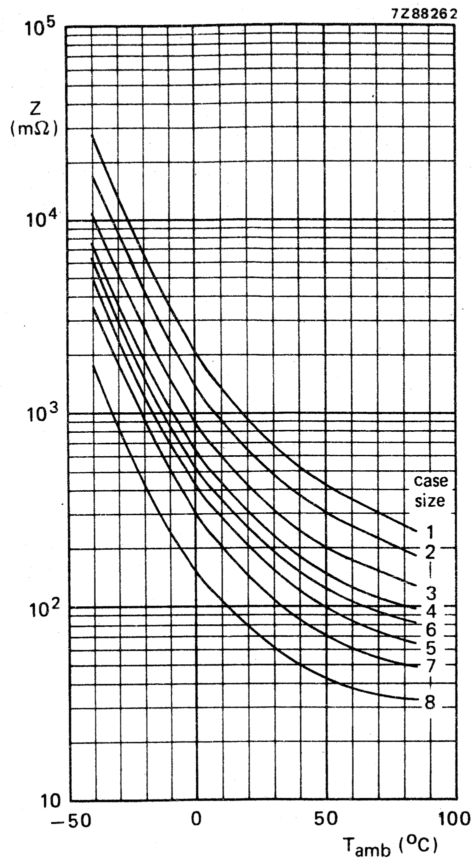


Fig. 16 Typical impedance as a function of temperature at 10 kHz, U_R = 250 V.

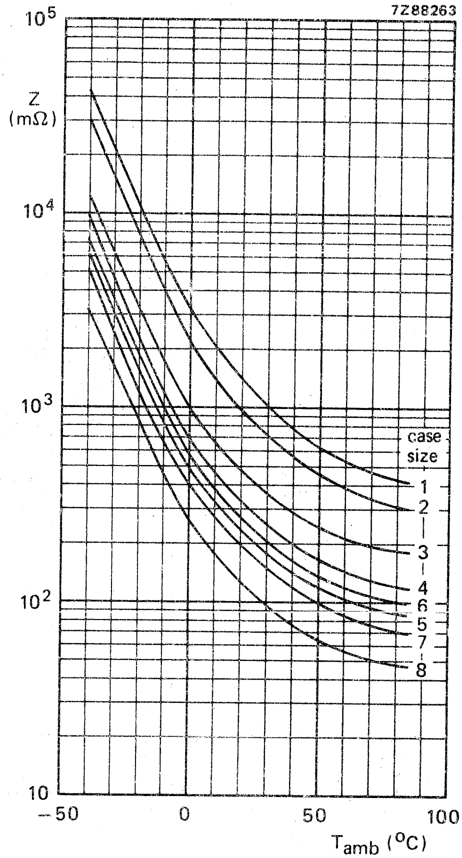


Fig. 17 Typical impedance as a function of temperature at 10 kHz, U_R = 385 V.

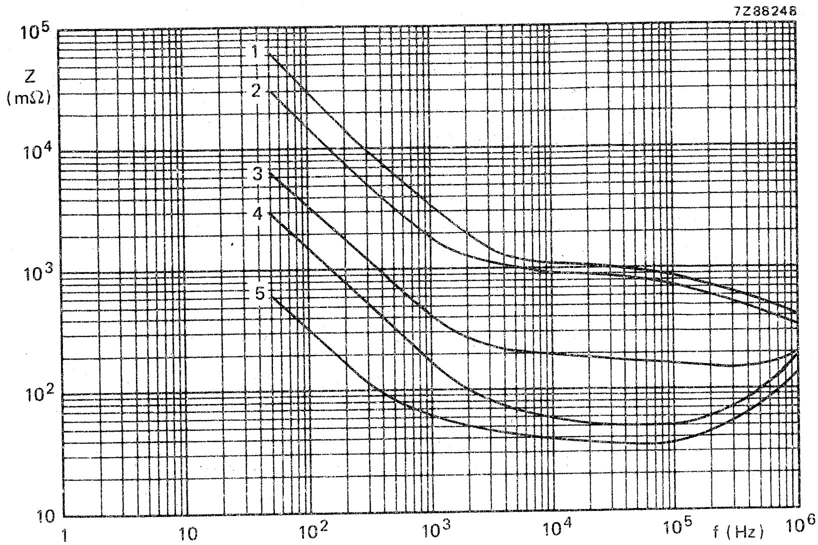


Fig. 18 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 1:**
curve 1 = 47 μF, 385 V;
curve 2 = 100 μF, 250 V;
curve 3 = 470 μF, 100 V;
curve 4 = 1000 μF, 63 V;
curve 5 = 4700 μF, 10 V.

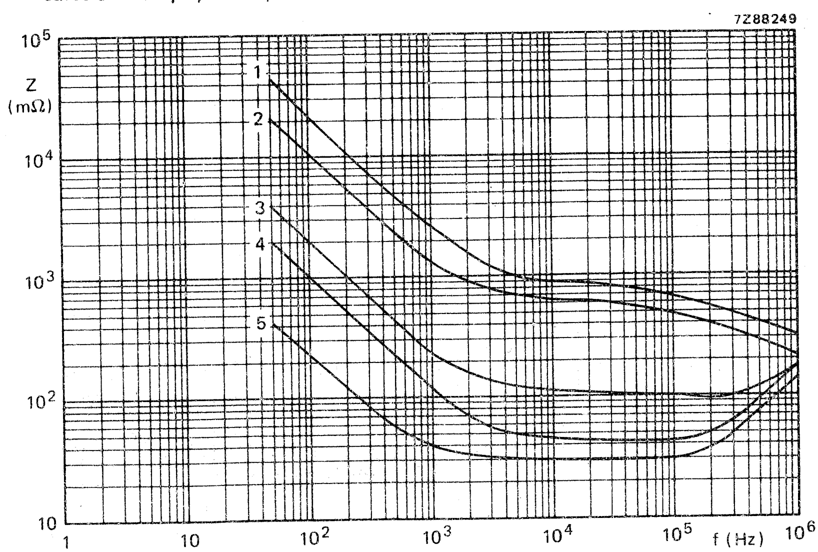


Fig. 19 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 2:**
curve 1 = 68 μF, 385 V;
curve 2 = 150 μF, 250 V;
curve 3 = 680 μF, 100 V;
curve 4 = 1500 μF, 63 V;
curve 5 = 6800 μF, 10 V.

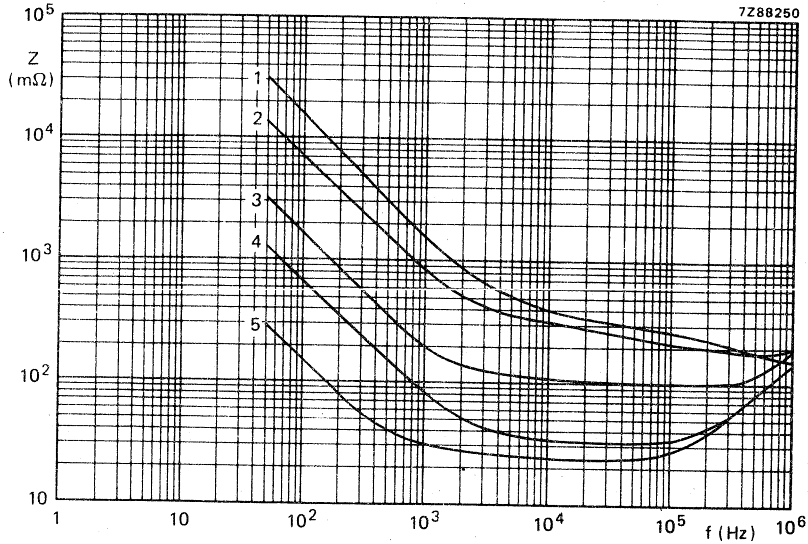


Fig. 20 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 3:**
curve 1 = 100 μF, 385 V;
curve 2 = 220 μF, 250 V;
curve 3 = 1000 μF, 100 V;
curve 4 = 2200 μF, 63 V;
curve 5 = 10 000 μF, 10 V.

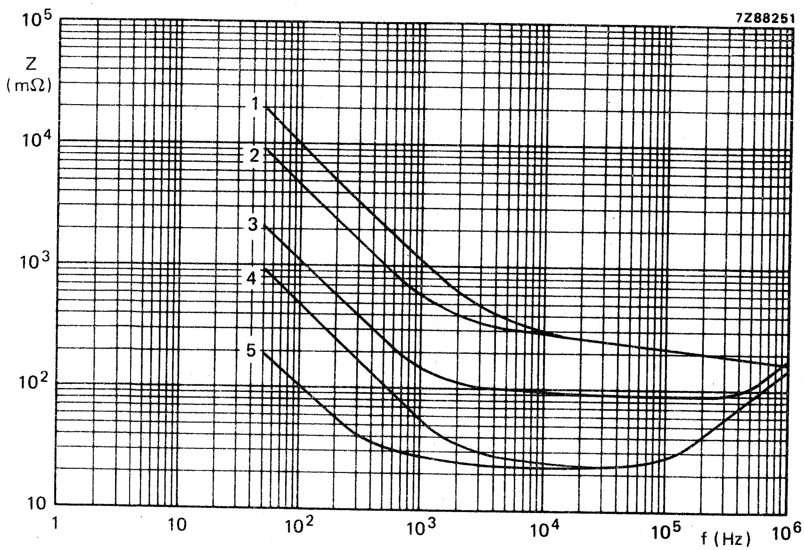


Fig. 21 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 4:**
curve 1 = 150 μF, 385 V;
curve 2 = 330 μF, 250 V;
curve 3 = 1500 μF, 100 V;
curve 4 = 3300 μF, 63 V;
curve 5 = 15 000 μF, 10 V.

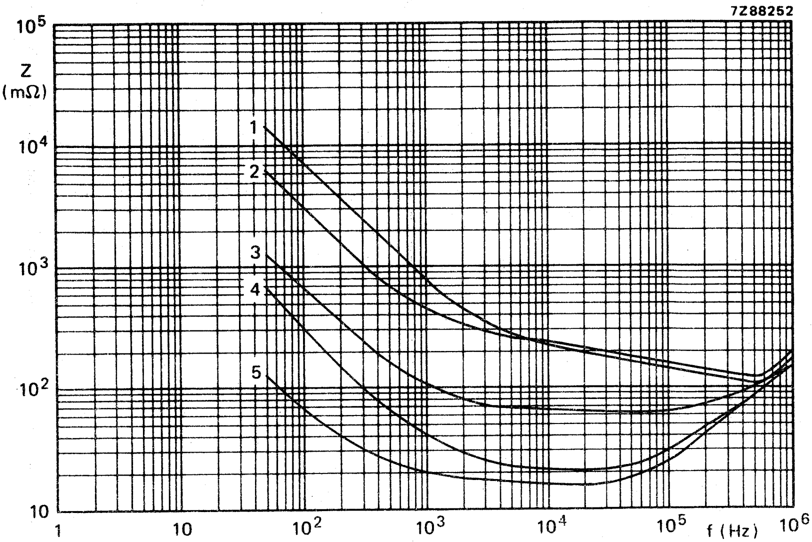


Fig. 22 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 5:**
curve 1 = 220 μF, 385 V;
curve 2 = 470 μF, 250 V;
curve 3 = 2200 μF, 100 V;
curve 4 = 4700 μF, 63 V;
curve 5 = 22 000 μF, 10 V.

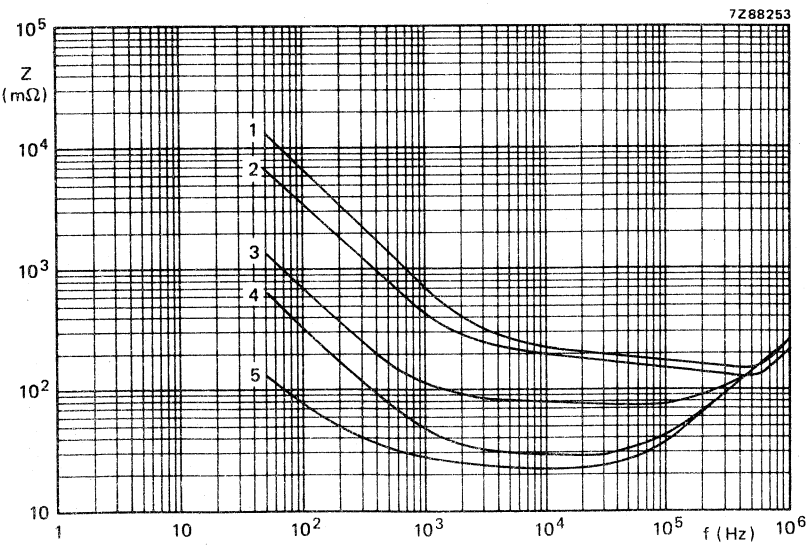


Fig. 23 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 6:**
curve 1 = 220 μF, 385 V;
curve 2 = 470 μF, 250 V;
curve 3 = 2200 μF, 100 V;
curve 4 = 4700 μF, 63 V;
curve 5 = 22 000 μF, 10 V.

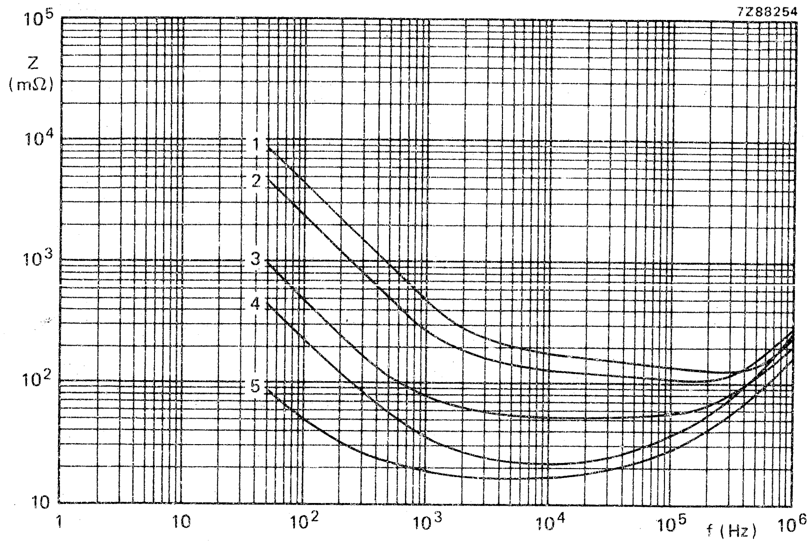


Fig. 24 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 7:**
curve 1 = 330 μF, 385 V;
curve 2 = 680 μF, 250 V;
curve 3 = 3300 μF, 100 V;
curve 4 = 6800 μF, 63 V;
curve 5 = 33 000 μF, 10 V.

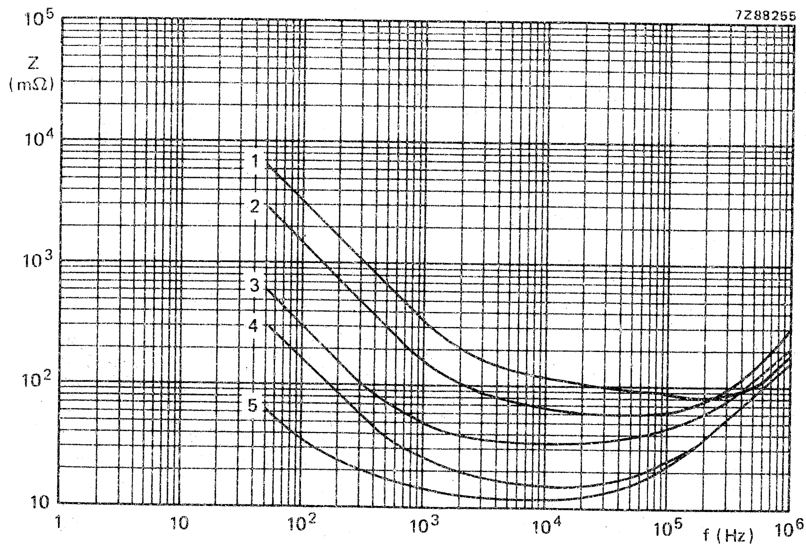


Fig. 25 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 8:**
curve 1 = 470 μF, 385 V;
curve 2 = 1000 μF, 250 V;
curve 3 = 4700 μF, 100 V;
curve 4 = 10 000 μF, 63 V;
curve 5 = 47 000 μF, 10 V.

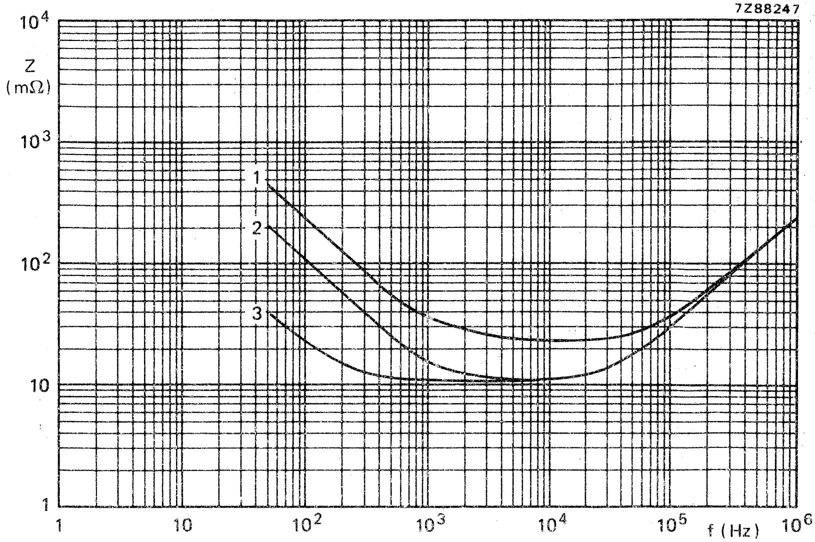


Fig. 26 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 9:**
curve 1 = 6800 μF, 100 V;
curve 2 = 15 000 μF, 63 V;
curve 3 = 68 000 μF, 10 V.

OPERATIONAL DATA

Category temperature range — −40 to + 85 °C

Life expectancy

Typical life time
at T_{amb} = 85 °C — > 5000 h
at T_{amb} = 40 °C — > 200 000 h

Guaranteed life time at maximum ripple current and different temperatures — see Table 5

Table 5

ambient temperature °C	guaranteed life time (h) at maximum ripple current
85	2 000
80	3 100
75	4 800
70	7 500
65	12 000
60	18 000
55	27 000
50	42 000
45	65 000
⩽40	100 000

Failure rate

Failure rate, catastrophic, at rated voltage, T_{amb} = 40 °C and confidence level 60% — $< 0,5 \times 10^{-7}$

PACKING

The capacitors are packed in boxes containing 100 pieces.

TESTS AND REQUIREMENTS

See Introduction, section 9, under aluminium electrolytic capacitors.
For the 385 V version the leakage current and tan δ measurements of the reverse voltage test (sub clause 9 . 16 IEC 384-4) should be carried out after 250 h, U_R in forward polarity.
Note: Capacitors 2222 050 and 2222 052 are large types, long-life grade.

MOUNTING ACCESSORIES

Dimensions in mm

Clamps

To facilitate vertical mounting, a series of rigid clamps made of cadmium-plated steel are available. They can easily be slid over the capacitor and then fixed to it with a nut and bolt. The clamps have two mounting lugs. Four types are available, one for each case diameter of the capacitor range. They are delivered without nuts or bolts.

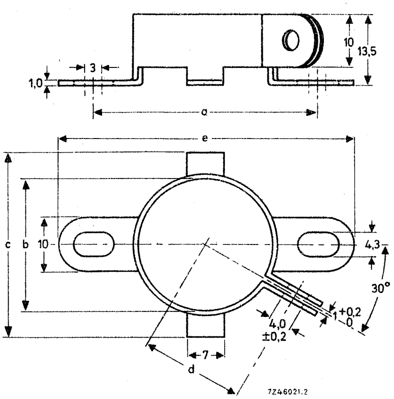


Fig. 27 Clamp for case sizes 1, 2, 3, 7, 8 and 9.

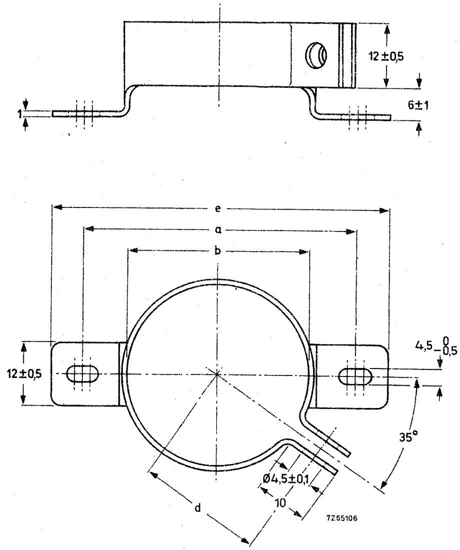


Fig. 28 Clamp for case sizes 4 and 5.

case size	dimensions (mm)					catalogue number
	a	b	c	d	e	
1, 2	41,5 ± 0,2	25	35	18,5	56	4322 043 03301
3	46,5 ± 0,2	30	40	21	61	03311
4, 5	51,5 ± 0,2	35	—	23,5	63	04272
7, 8, 9	56,5 ± 0,2	40	50	26	71	03331

Bolt/nut

When mounting by means of the bolt, which is an integral part of the case, normal metal M8 nuts and washers can be used. If an insulated mounting is required a synthetic nut and rubber washers are available.

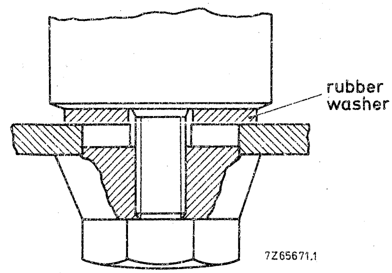


Fig. 29.

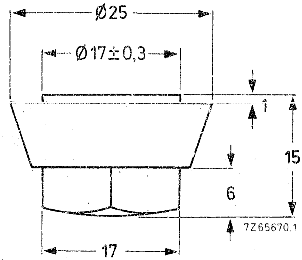


Fig. 30 Synthetic cap nut M8,
threaded depth min 11,5 mm.
Catalogue number 4322 043 05561.

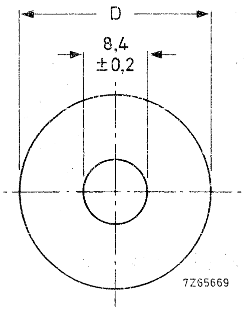
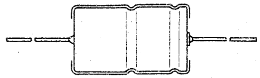


Fig. 31 Rubber washer (thickness 2 mm).

D mm	catalogue number
24	4322 043 05611
29	4322 043 05601
34	4322 043 05591
39	4322 043 05581

ALUMINIUM ELECTROLYTIC CAPACITORS

- Small type
- Long life
- Industrial applications



QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	2,2 to 2200 μF	
Tolerance on nominal capacitance	−10 to + 50%	
Rated voltage range (U_R) (R5 series)	6,3 to 63 V	
Category temperature range	−40 to + 85 °C	
	case sizes 5,6	case sizes 00 to 03
Typical life time at 85 °C	> 6000 h	> 10 000 h
Basic specification	IEC 384–4, long-life grade DIN 41240 (IA) NF C93–110 (type 1)	
Climatic category		
IEC 68	40/085/56	
DIN 40040	GPF (56 days)	
NF C93–001	554	
Approval	CECC 30 301-027	

Selection chart for C–U_R and relevant case sizes.

C_{nom} μF	U_R (V) 6,3	10	16	25	40	63
2,2						5
3,3						5
4,7						5
6,8						5
10						5
15					5	6
22					5	6
33				5	6	00
47				5	6	00
68			5		00	01
100		5		6	01	02
150	5		6	00	01	03
220		6	00	01	02	
330	6	00			03	
470	00		01	02		
680		01	02	03		
1000	01	02	03			
1500	02	03				
2200	03					

case size	nominal dimensions (mm)
5	Ø 8 x 18
6	Ø 10 x 18
00	Ø 10 x 30
01	Ø 12,5 x 30
02	Ø 15 x 30
03	Ø 18 x 30

APPLICATION

These axial-type capacitors are especially designed for those applications where extreme requirements have to be met concerning reliability and long lifetime both at high and low temperatures, such as in computer telecommunication and telephone apparatus.

DESCRIPTION

The capacitor has etched aluminium foil electrodes rolled up with a porous paper spacer, which separates the anode and the cathode. The spacer is impregnated with an electrolyte which retains its good characteristics both at low and high temperatures. The capacitor is housed in an aluminium case with axial leads, sealed with a synthetic disc and is insulated with a blue synthetic sleeve. The all-welded construction, the built-in voltage derating, and the close quality control during manufacture ensure a reliability and a life expectancy far superior to normal grade electrolytic capacitors.

MECHANICAL DATA

Dimensions in mm

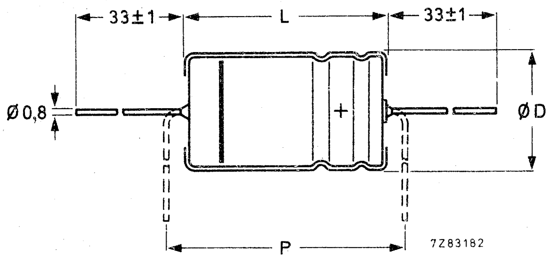


Fig. 1 Case sizes 5 and 6. For dimensions D, L and P, see Table 1.

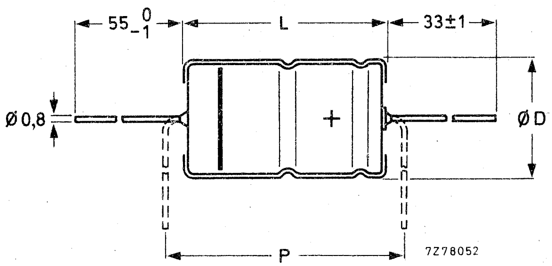


Fig. 2 Case sizes 00, 01, 02 and 03. For dimensions D, L and P, see Table 1.

Table 1

case size	dimensions D		dimensions L		dimensions P_{min}	approx. mass g
5	8,0	+ 0,5	18,0	+ 0,5	25	1,8
6	10,0		18,0		25	2,5
00	10,0		30,0		35	4,3
01	12,5		30,0		35	6,6
02	15,0		30,0		35	8,5
03	18,0		30,0		35	11,2

Marking

The capacitors are marked with: nominal capacitance, rated voltage, tolerance on capacitance, group number 108.3, maximum temperature, date code, a band to identify the negative terminal and "+" signs for positive terminal.

Mounting

The capacitors may be mounted in any position by their leads (see also Tests and requirements in the Introduction).

Minimum atmospheric pressure 8,5 kPa

ELECTRICAL DATA

Table 2

Unless otherwise specified all electrical values in Table 2 apply at an ambient temperature of 20 to 25 °C, a frequency of 100 Hz, an atmospheric pressure of 86 to 106 kPa and a relative humidity of 45 to 75%.

U_R V	nom. cap. µF	max. r.m.s. ripple current at T_{amb} = 85 °C (mA) *	max. leakage current at U_R after 5 min µA	max. tan δ *	typ. ESR * Ω	impedance at 100 kHz Ω		case size	catalogue number
						max.	typ.		
6,3	150	130	10	0,20	1,06	1,60	0,70	5	2222 108 33151
	330	220	17	0,20	0,49	0,84	0,36	6	33331
	470	325	22	0,20	0,34	0,42	0,18	00	33471
	1000	470	42	0,20	0,16	0,30	0,13	01	33102
	1500	630	60	0,20	0,11	0,22	0,10	02	33152
	2200	920	85	0,20	0,09	0,19	0,09	03	33222
10	100	120	10	0,15	1,27	1,60	0,70	5	34101
	220	205	17	0,15	0,57	0,84	0,36	6	34221
	330	325	24	0,15	0,38	0,42	0,18	00	34331
	680	470	45	0,15	0,19	0,30	0,13	01	34681
	1000	630	65	0,15	0,13	0,22	0,10	02	34102
	1500	920	95	0,15	0,09	0,19	0,09	03	34152
16	68	110	11	0,12	1,40	1,60	0,70	5	35689
	150	190	18	0,12	0,63	0,84	0,36	6	35151
	220	270	25	0,12	0,44	0,42	0,18	00	35221
	470	360	50	0,12	0,21	0,30	0,13	01	35471
	680	500	70	0,12	0,14	0,22	0,10	02	35681
	1000	650	100	0,12	0,10	0,19	0,09	03	35102
25	33	85	8	0,10	2,41	1,60	0,70	5	36339
	47	100	11	0,10	1,70	1,60	0,70	5	36479
	100	170	19	0,10	0,80	0,84	0,36	6	36101
	150	270	26	0,10	0,53	0,42	0,18	00	36151
	220	360	37	0,10	0,36	0,30	0,13	01	36221
	470	500	75	0,10	0,17	0,22	0,10	02	36471
	680	650	105	0,10	0,12	0,19	0,09	03	36681
40	15	65	6	0,08	4,24	1,60	0,70	5	37159
	22	80	9	0,08	2,89	1,60	0,70	5	37229
	33	110	12	0,08	1,93	0,84	0,36	6	37339
	47	130	15	0,08	1,36	0,84	0,36	6	37479
	68	195	20	0,08	0,93	0,42	0,18	00	37689
	100	245	28	0,08	0,63	0,30	0,13	01	37101
	150	280	40	0,08	0,43	0,30	0,13	01	37151
	220	360	55	0,08	0,34	0,22	0,10	02	37221
	330	495	85	0,08	0,20	0,19	0,09	03	37331
63	2,2	25	1,5	0,08	28,9	1,60	0,70	5	38228
	3,3	30	2	0,08	19,3	1,60	0,70	5	38338
	4,7	35	3	0,08	13,5	1,60	0,70	5	38478
	6,8	45	4	0,08	9,36	1,60	0,70	5	38688
	10	50	6	0,08	6,37	1,60	0,70	5	38109
	15	75	10	0,08	2,90	0,84	0,36	6	38159
	22	90	12	0,08	4,25	0,84	0,36	6	38229
	33	125	17	0,08	1,93	0,42	0,18	00	38339
	47	150	22	0,08	1,36	0,42	0,18	00	38479
	68	195	30	0,08	0,93	0,30	0,13	01	38689
	100	275	42	0,08	0,63	0,22	0,10	02	38101
	150	355	60	0,08	0,43	0,19	0,09	03	38151

* See also corresponding paragraph.

Capacitance

Nominal capacitance value at 100 Hz at T_{amb} = 20 °C	see Table 2
Tolerance on nominal capacitance at 100 Hz	−10 to + 50%

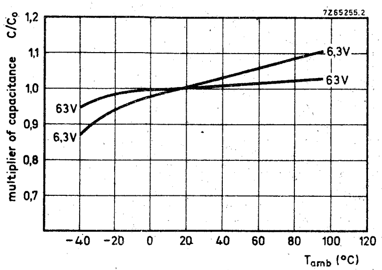


Fig. 3 Typical capacitance as a function of temperature; C_o = capacitance at 20 °C, 100 Hz.

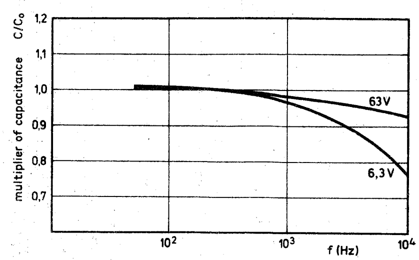


Fig. 4 Typical capacitance as a function of frequency; C_o = capacitance at 20 °C, 100 Hz.

Voltage

Max. permissible voltage	1,1 x U_R
Ripple voltage * = max. permissible a.c. voltage providing the following three conditions are met:	
a) max. (d.c. + peak a.c.) voltage	≤ 1,1 x U_R
b) max. peak a.c. voltage, with d.c. voltage applied	≤ applied d.c. voltage + 1 V
c) max. peak a.c. voltage, without d.c. voltage applied	1 V
Surge voltage = max. permissible voltage for short periods (see also **Tests and requirements** in the Introduction)	1,15 x U_R
Reverse voltage = max. d.c. voltage applied in the reverse polarity at 85 °C	1 V

Ripple current

Maximum permissible r.m.s. ripple current at 100 Hz and

T_{amb} = 85 °C	see Table 2
T_{amb} = 75 °C	1,7 x values of Table 2
T_{amb} ≤ 65 °C	2,2 x values of Table 2

* Ripple voltages are not applicable if the max. permissible ripple current is exceeded. In that case the ripple current is decisive.

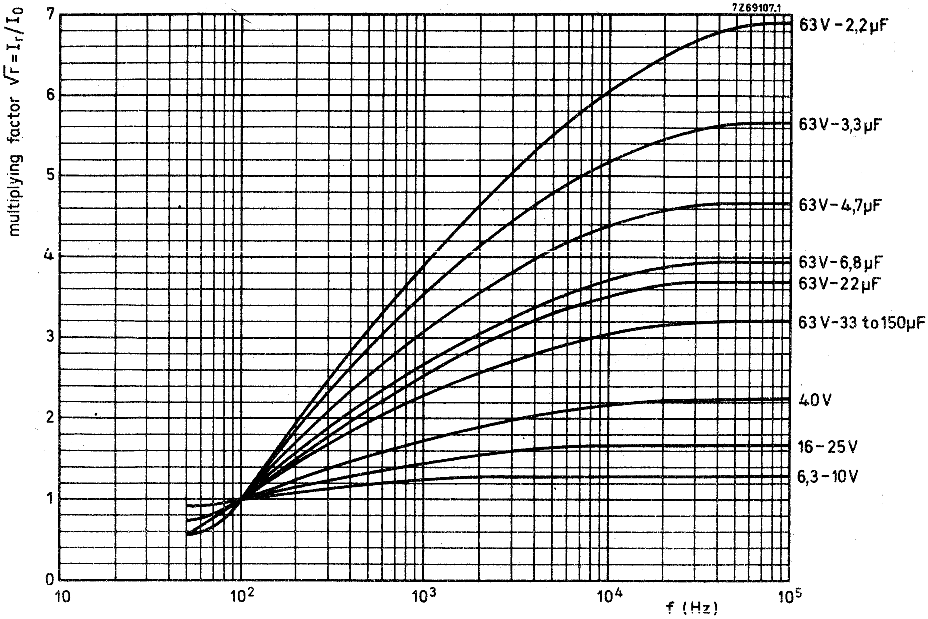


Fig. 5 Multiplying factor as a function of frequency. I_0 = maximum ripple current at 85 °C, 100 Hz.

Non-sinusoidal currents

Non-sinusoidal ripple currents have to be analyzed into a number of sinusoidal currents and the following requirements shall then be satisfied:

$$\sum_n \frac{I_n^2}{r_n} \leqslant I_r^2 \text{ max.}$$

$I_{r\,max}$ = max. ripple current at 100 Hz and applicable ambient temperature;
I_n = ripple current at a certain frequency;
$\sqrt{r_n}$ = multiplying factor at same frequency.

Note
These ripple currents are not applicable if the max. permissible ripple voltage is exceeded. In that case the ripple voltage is decisive (see Ripple voltage).

Charge and discharge current

The capacitors may be charged from a source with a source impedance of 0 Ω, and they may be discharged by short-circuiting. If the capacitors are charged and discharged continuously at a rate of several times per minute, the charge and discharge currents have to be considered as ripple currents flowing through the capacitor. The r.m.s. value of these currents should be determined and the value thus found must not exceed the applicable limit.

Leakage current

Maximum leakage current 5 min after application of the rated voltage at T_{amb} = 20 °C	see Table 2
Leakage current during continuous operation at U_R	
at 20 °C	approx. 0,2 of value stated in Table 2
at 85 °C	⩽ value stated in Table 2

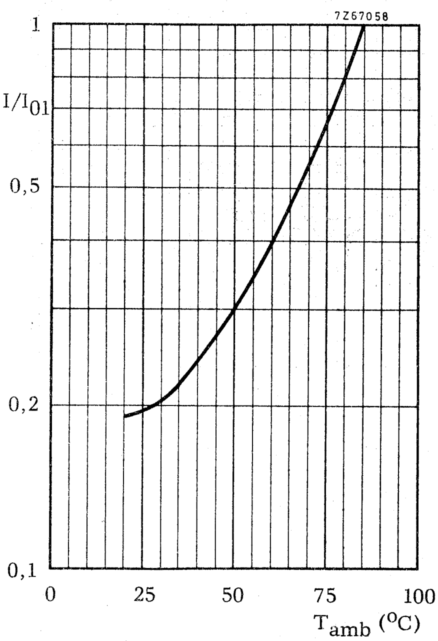


Fig. 6 Multiplier I/I_{01} as a function of temperature. I_{01} = leakage current during continuous operation at T_{amb} = 85 °C at U_R.

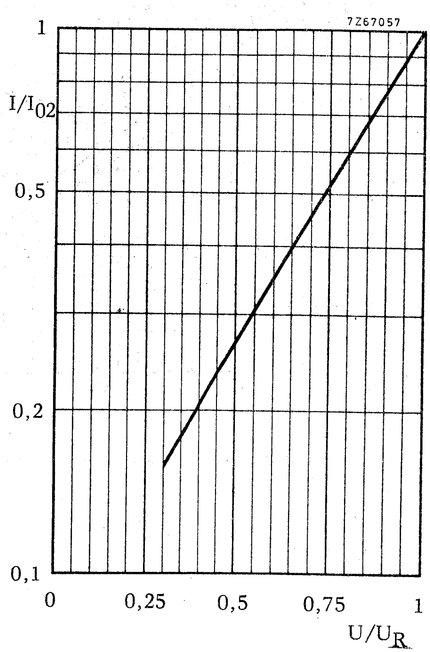


Fig. 7 Multiplier I/I_{02} as a function of U/U_R. I_{02} = leakage current at U_R at a discrete constant temperature within category temperature range.

If owing to prolonged storage and/or storage at an excessive temperature (> 40 °C) the leakage current is too high, application of the rated voltage for some hours will cause the leakage current to fall to a value lower than specified in Table 2.

Tan δ (dissipation factor)

Tan δ at 100 Hz and T_{amb} = 20 °C, measured by means of a four-terminal circuit (Thomson circuit) — see Table 2

Impedance

Impedance at 100 kHz and T_{amb} = 20 °C, measured by means of a four-terminal circuit (Thomson circuit) — see Table 2

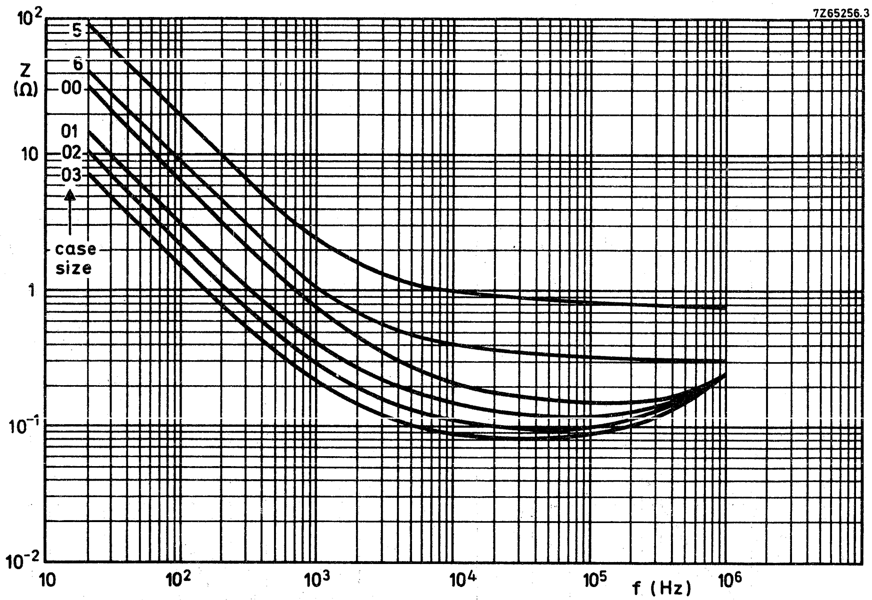


Fig. 8 Typical impedance as a function of frequency at 20 °C, for 16 V versions.

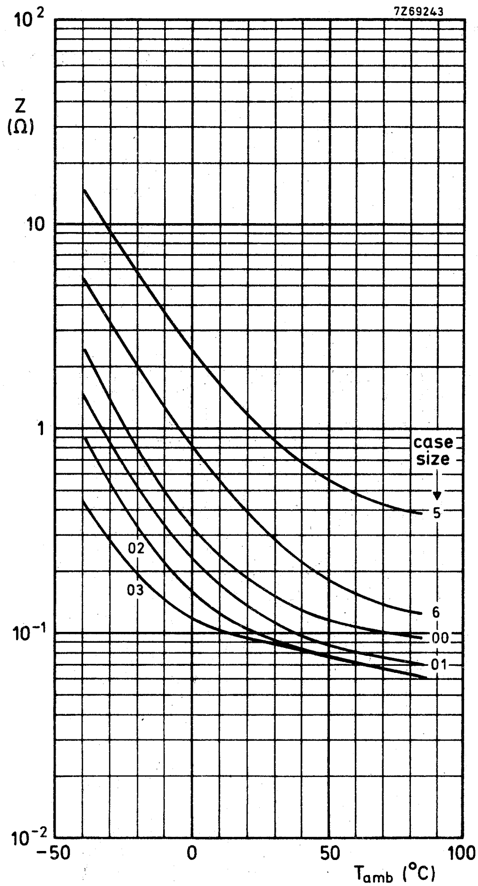


Fig. 9 Typical impedance as a function of temperature at 100 kHz.

Equivalent series resistance (ESR = tan $\delta/\omega C$)

ESR at 100 Hz and T_{amb} = 20 °C — see Table 2

Inductance — ⩽ 40 nH

OPERATIONAL DATA

Category temperature range

for rated voltage: −40 to + 85 °C

Life expectancy

Guaranteed lifetime

at + 85 °C	5000 h
at + 105 °C	1000 h

Typical lifetime

	case sizes 5 and 6	case sizes 00 to 03
at + 40 °C	> 120 000 h	> 160 000 h
at + 85 °C	> 6 000 h	> 10 000 h
at + 105 °C	> 1 200 h	> 2 000 h

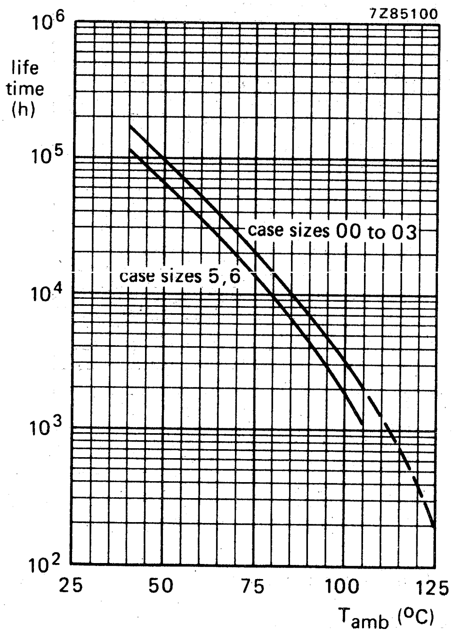


Fig. 10 Typical lifetime as a function of temperature.

PACKING

Case sizes 5 and 6: on bandoliers in boxes of 500.
Case sizes 00 to 03: in boxes of 200.

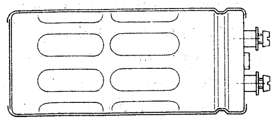
TESTS AND REQUIREMENTS

See Introduction, section 9, under aluminium electrolytic capacitors, with the exception of IEC 384–4 sub clause 9. 14, for which the following is valid.

IEC 384–4 sub clause 9. 14.
IEC 68–2 test method: no reference.
Name of test: Endurance.
Procedure: 5000 h at 85 ^{o}C, rated voltage and ripple current applied.
Requirements: No visible damage, no leakage of electrolyte, insulation resistance $>$ 100 MΩ, no breakdown or flashover, leakage current $\leqslant$ stated limit, tan $\delta \leqslant$ 1,3 x stated limit, impedance at 100 kHz $\leqslant$ 2 x stated limit, $\Delta C/C \leqslant 15\%$.

Note
Capacitors 2222 108 belong to the small types, long-life grade.

ALUMINIUM ELECTROLYTIC CAPACITORS



- **Large type with screw terminals**
- **Long life**
- **Industrial applications**

QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	150 to 220 000 μF
Tolerance on nominal capacitance	–10 to + 30%
Rated voltage range, U_R	10 to 385 V
Category temperature range	–40 to + 85 °C
Endurance test at 85 °C	5000 h
Basic specification	IEC 384-4, long-life grade DIN 41240
Detail specification	DIN 41248
Climatic category	
IEC 68	40/085/56
DIN 40040	GPF (56 days)
NF C93-001	554

Selection chart for C_{nom}-U_R and relevant case sizes.

C_{nom} μF	U_R (V)								
	10	16	25	40	63	100	250	350	385
150									10
220									11
330							10		12a
470							11		14
680							12a	14	15a
1 000						10	14	15a	16a
1 500						10	15a		16a
2 200					10	11	16a		17
3 300				10	10	12a	16a		
4 700			10	10	11	14	17		
6 800			10	11	12a	15a			
10 000		10	11	12a	14	16a			
15 000	10	11	12a	14	15a	16a			
22 000	11	12a	14	15a	16a	17			
33 000	12a	14	15a	16a	16a				
47 000	14	15a	16a	16a	17				
68 000	15a	16a	16a	17					
100 000	16a	16a	17						
150 000	16a	17							
220 000	17								

case size	nominal dimensions (mm)
10	Ø 35 x 60
11	Ø 35 x 80
12a	Ø 35 x 105
14	Ø 50 x 80
15a	Ø 50 x 105
16a	Ø 65 x 105
17	Ø 75 x 105

APPLICATION

These capacitors have extremely low impedance and inductance values and high resistance to shock and vibration which render them very suitable for applications such as:

- switched-mode power supplies;
- power supplies in digital equipment;
- energy storage in pulse systems;
- filters in measuring and control apparatus.

DESCRIPTION

The low impedance and inductance are achieved by a special construction with multiple internal anode and cathode connections. The high resistance to shock and vibration is achieved by the longitudinal rills and special internal construction. The capacitors are completely cold-welded and there are no limitations on charge/discharge rate (see paragraph "Charge and discharge current"). The aluminium cases are fully insulated and sealed by a synthetic disc with a vent. The capacitors are delivered with screws and washers.

MECHANICAL DATA

Dimensions in mm

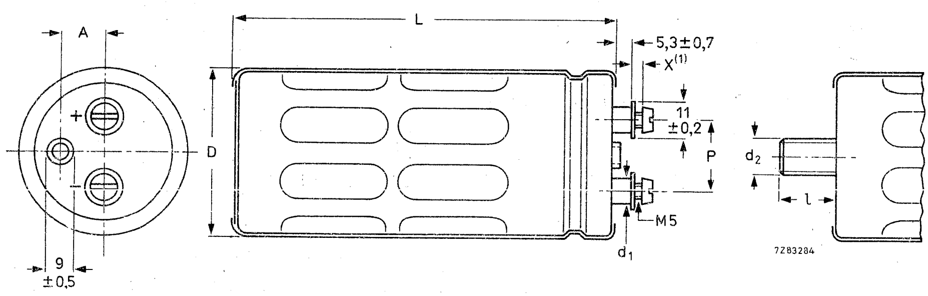


Fig. 1 See Table 1 for dimensions D, L, P, A, d_1, d_2, and l.

(1) Maximum permissible torque which may be applied to the termination screws at various heights (dimension x in drawing):

x	max. permissible torque (Nm)
2	1,5
4	1
6	0,5

Table 1

case size	D		L		P		A	d1		d2 x l
10	35	+ 1,5	60	+ 3	13,0	± 0,1	8,4	8	± 0,2	M8 x 12
11	35		80		13,0		8,4	8		M8 x 12
12a	35		105		13,0		8,4	8		M8 x 12
14	50		80		22,0		14,3	8		M12 x 16
15a	50		105		22,0		14,3	8		M12 x 16
16a	65		105		28,5		19,0	11		M12 x 16
17	75		105		32,0		21,0	11		M12 x 16

Marking

The capacitors are marked with: nominal capacitance, tolerance on nominal capacitance, rated voltage, temperature range, IEC grade, maximum r.m.s. ripple current at 70 °C and 20 kHz, catalogue number, date code (year/month), name of manufacturer.

Mounting

The capacitors may be mounted vertically or horizontally, with or without mounting clamp. The vent, should be on the upper side when the capacitor is mounted horizontally. When a number of capacitors are connected in a bank, they must not be closer together than 15 mm when no derating of ripple current and/or temperature is applied. See also Mounting Accessories, at the end of this data sheet.

Minimum atmospheric pressure 8,5 kPa

ELECTRICAL DATA

Unless otherwise specified all electrical values in Table 2 apply at an ambient temperature of 20 °C, a frequency of 100 Hz, an atmospheric pressure of 86 to 106 kPa and a relative humidity of 45 to 75%.

Table 2

U_R V	nom. cap. µF	max. r.m.s.* ripple current (A) at T_{amb} = 85 °C 100 Hz	at T_{amb} = 70 °C 20 kHz	max. leakage current at U_R after 5 min mA	typ.* ESR mΩ	max. tan δ*	impedance at 20 kHz* mΩ typ.	max.	case size	catalogue number**
10	15 000	6	11,4	0,90	20	0,32	13	20	10	2222 114 14153
	22 000	7,5	14,2	1,32	14	0,33	9,5	14	11	14223
	33 000	10	19	1,98	10	0,35	7,5	10	12a	14333
	47 000	14	26,5	2,82	7,5	0,36	5,0	8,0	14	14473
	68 000	18	34	4,08	5,5	0,38	4,0	6,5	15a	14683
	100 000	30	50	6,00	3,5	0,34	3,0	5,0	16a	14104
	150 000	30	50	9,00	3,0	0,45	3,0	5,0	16a	14154
	220 000	37	50	13,20	2,0	0,45	2,5	4,0	17	14224
16	10 000	6	11,4	0,96	22	0,22	13	20	10	15103
	15 000	7,5	14,2	1,44	15	0,23	9,5	14	11	15153
	22 000	10	19	2,12	11	0,25	7,0	10	12a	15223
	33 000	13	24,6	3,17	7,5	0,26	5,0	8,0	14	15333
	47 000	18	34	4,52	5,5	0,27	4,0	6,5	15a	15473
	68 000	28	50	6,53	3,5	0,24	3,0	5,0	16a	15683
	100 000	28	50	9,60	3,0	0,31	3,0	5,0	16a	15104
	150 000	37	50	14,40	2,0	0,31	2,5	4,0	17	15154
25	4 700	5,2	10	0,71	30	0,14	15	23	10	16472
	6 800	5,2	10	1,02	25	0,18	14	21	10	16682
	10 000	6,7	12,7	1,50	18	0,18	10	15	11	16103
	15 000	9,7	18,4	2,25	12	0,19	7,5	11	12a	16153
	22 000	12,5	23,7	3,30	8,5	0,19	5,5	8,0	14	16223
	33 000	18	34	4,95	6,0	0,21	4,0	6,5	15a	16333
	47 000	27	50	7,05	4,0	0,18	3,0	5,0	16a	16473
	68 000	27	50	10,20	3,5	0,23	3,0	5,0	16a	16683
	100 000	37	50	15,00	2,5	0,23	2,5	4,0	17	16104
40	3 300	4,5	8,5	0,80	37	0,13	21	32	10	17332
	4 700	4,5	8,5	1,13	35	0,17	22	33	10	17472
	6 800	6	11,4	1,64	25	0,17	15	23	11	17682
	10 000	7,5	14,2	2,40	17	0,18	11	17	12a	17103
	15 000	10	19	3,60	11	0,17	7,5	11	14	17153
	22 000	15	28,5	5,28	8,0	0,18	5,5	8,5	15a	17223
	33 000	21	40	7,92	5,0	0,16	3,5	6,0	16a	17333
	47 000	22	42	11,28	4,5	0,21	3,5	6,0	16a	17473
	68 000	30	50	16,32	3,0	0,21	3,0	4,5	17	17683

* See also corresponding paragraph.
** Replace 8th digit by 5 for bolt version.

U_R V	nom. cap. μF	max. r.m.s.* ripple current (A) at T_{amb} = 85 °C 100 Hz	max. r.m.s.* ripple current (A) at T_{amb} = 70 °C 20 kHz	max. leakage current at U_R after 5 min mA	typ.* ESR mΩ	max. tan δ*	impedance at 20 kHz* mΩ typ.	impedance at 20 kHz* mΩ max.	case size	catalogue number**
63	2 200	3,7	7	0,84	39	0,09	22	33	10	2222 114 18223
	3 300	3,7	7	1,25	32	0,11	20	30	10	18332
	4 700	5,2	10	1,78	23	0,11	14	21	11	18472
	6 800	7,5	14,2	2,57	17	0,11	10	15	12a	18682
	10 000	9,5	18	3,78	12	0,12	7,5	12	14	18103
	15 000	13,5	25,6	5,67	8,5	0,13	5,5	8,5	15a	18153
	22 000	21	40	8,32	5,0	0,11	3,5	6,0	16a	18223
	33 000	22	42	12,48	4,5	0,14	3,5	6,0	16a	18333
	47 000	30	50	17,77	3,0	0,14	3,0	4,5	17	18473
100	1 000	2,2	4,2	0,60	220	0,22	160	240	10	19102
	1 500	2,2	4,2	0,90	220	0,33	160	240	10	19152
	2 200	3,3	6,3	1,32	150	0,33	110	165	11	19222
	3 300	4,5	8,5	1,98	100	0,33	75	115	12a	19332
	4 700	5,7	10,8	2,82	70	0,33	55	85	14	19472
	6 800	8,0	15,2	4,08	50	0,33	35	55	15a	19682
	10 000	13,5	25,6	6,00	22	0,22	16	25	16a	19103
	15 000	13,5	25,6	9,00	22	0,33	16	25	16a	19153
	22 000	15,0	28,5	13,20	15	0,33	11	17	17	19223
250	330	1,8	3,4	0,50	300	0,15	275	500	10	2222 115 13331
	470	2,5	4,7	0,71	250	0,15	140	375	11	13471
	680	3,5	6,6	1,02	180	0,15	125	300	12a	13681
	1 000	4,2	8	1,50	110	0,15	60	130	14	13102
	1 500	6,3	12	2,25	60	0,15	40	100	15a	13152
	2 200	8,8	16,7	3,30	45	0,15	30	60	16a	13222
	3 300	10,5	20	4,95	30	0,15	25	50	16a	13332
	4 700	14	26,5	7,05	25	0,15	20	40	17	13472
350	680	2,7	5,1	1,47	140	0,10	60	130	14	15681
	1 000	4,8	9,1	2,14	65	0,10	50	100	15a	15102
385	150	1,2	2,3	0,34	425	0,10	250	500	10	18151
	220	1,6	3	0,50	275	0,10	200	380	11	18221
	330	2,2	4,2	0,75	175	0,10	140	300	12a	18331
	470	2,7	5,1	1,06	110	0,10	75	130	14	18471
	680	4,8	9,1	1,53	90	0,10	60	130	15a	18681
	1 000	7	13,3	2,25	70	0,10	45	60	16a	18102
	1 500	7	13,3	3,38	45	0,10	30	50	16a	18152
	2 200	9	17	4,95	35	0,10	20	45	17	18222

* See also corresponding paragraph.
** Replace 8th digit by 5 for bolt version.

Capacitance

Nominal capacitance at 100 Hz and T_{amb} = 20 °C	see Table 2
Tolerance on nominal capacitance at 100 Hz	−10 to + 30%

Voltage

		< 50 °C	50 to 85 °C
Rated voltage	= max. permissible voltage	1,1 x U_R	U_R
Ripple voltage	= max. permissible a.c. voltage providing the following three conditions are met:		
	(a) max. positive voltage on anode (d.c. + peak a.c.)	1,1 x U_R	U_R
	(b) max. positive voltage on cathode (reverse voltage)	1 V	1 V
	(c) max. ripple current is not exceeded		
Surge voltage	= max. permissible voltage for short periods (see also "Tests and requirements")		
	U_R = 10 to 100 V	1,25 x U_R	1,15 x U_R
	U_R = 250 V	1,15 x U_R	1,15 x U_R
	U_R = 350 V and 385 V	1,1 x U_R	1,1 x U_R
Reverse voltage	= max. d.c. voltage applied in the reverse polarity at the maximum category temperature (for short periods)	1 V	1 V

Ripple current

Maximum permissible r.m.s. ripple current	
at 100 Hz and T_{amb} = 85 °C	see Table 2
at 20 kHz and T_{amb} = 70 °C	see Table 2
at other frequencies and temperatures	see Tables 3 and 4*

Table 3

ambient temperature °C	multiplier of max. ripple current
85	1,00
80	1,22
75	1,41
70	1,58
65	1,73
60	1,87
55	2,00
50	2,12
45	2,24
≤ 40	2,35

Table 4

frequency Hz	multiplier of max. ripple current ($\sqrt{r}$)
50	0,83
100	1,00
200	1,10
400	1,15
1000	1,19
≥ 2000	1,20

*With an absolute maximum of 50 A.

Non-sinusoidal ripple currents have to be analyzed into a number of sinusoidal currents and the following requirements shall then be satisfied:

$$\sum_n \frac{I_n^2}{r_n} \leq I_r^2\,\text{max.}$$

$I_{r\,max}$ = max. ripple current at 100 Hz and applicable ambient temperature;
I_n = ripple current at a certain frequency;
$\sqrt{r_n}$ = multiplying factor at same frequency (Table 4)

Note
Ripple currents are not applicable if the maximum permissible ripple voltage is exceeded. In that case the ripple voltage is decisive.

Charge and discharge current

The capacitors may be charged from a source without internal resistance and they may be discharged by short-circuiting. If the capacitors are charged and discharged continuously at a rate of several times per minute, the charge and discharge currents have to be considered as ripple currents flowing through the capacitor. The r.m.s. value of these currents should be determined and the value thus found must not exceed the applicable limit.

Leakage current

Maximum leakage current 5 min after application of the rated voltage at T_{amb} = 20 °C	see Table 2 (0,006 CU + 4 μA)
Leakage current after 15 min at U_R,	
at T_{amb} = 20 °C	0,125 x value stated in Table 2
at T_{amb} = 85 °C	0,625 x value stated in Table 2

If owing to prolonged storage and/or storage at an excessive temperature the leakage current is too high, application of the rated voltage for some hours will cause the leakage current to fall to a value lower than specified in Table 2.

Tan δ (dissipation factor)

Maximum tan δ at 100 Hz and T_{amb} = 20 °C, measured by means of a four-terminal circuit (Thomson circuit) — see Table 2

Equivalent series resistance (ESR)

Typical ESR at 100 Hz and T_{amb} = 20 °C — see Table 2

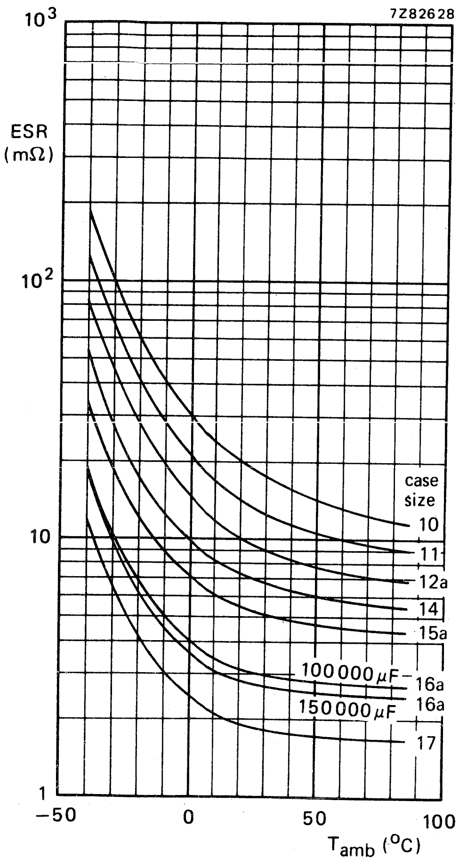


Fig. 2 Typical ESR as a function of temperature at 100 Hz, U_R = 10 V.

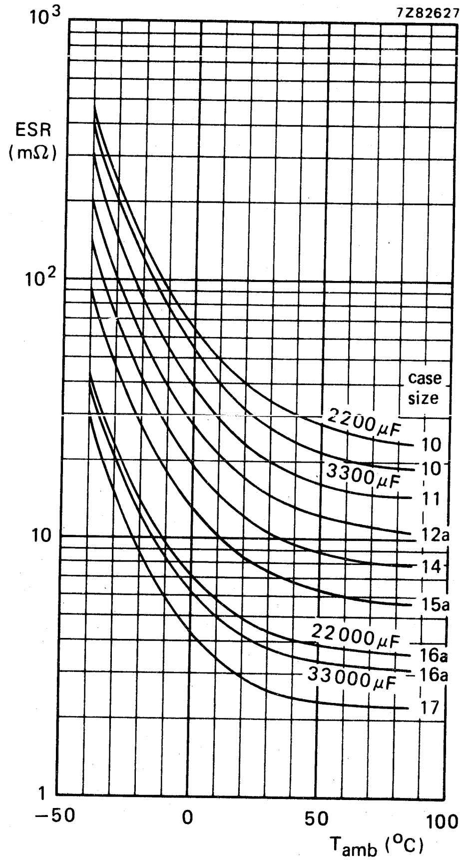


Fig. 3 Typical ESR as a function of temperature at 100 Hz, U_R = 63 V.

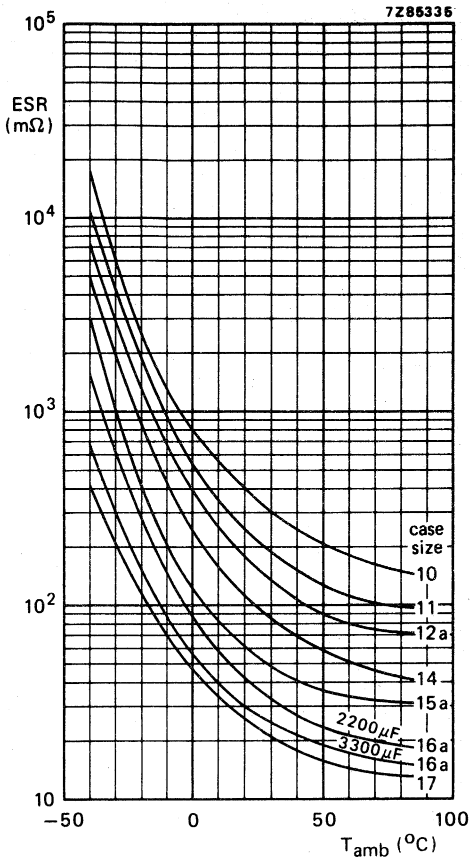


Fig. 4 Typical ESR as a function of temperature at 100 Hz, U_R = 250 V.

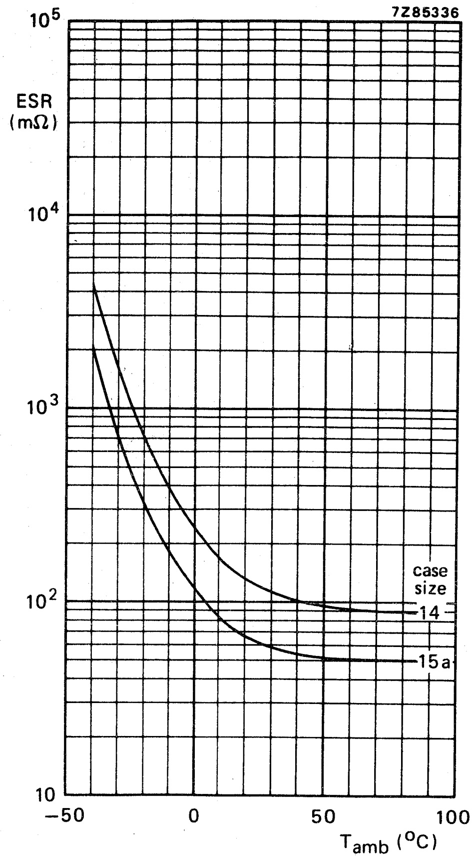


Fig. 5 Typical ESR as a function of temperature at 100 Hz, U_R = 350 V.

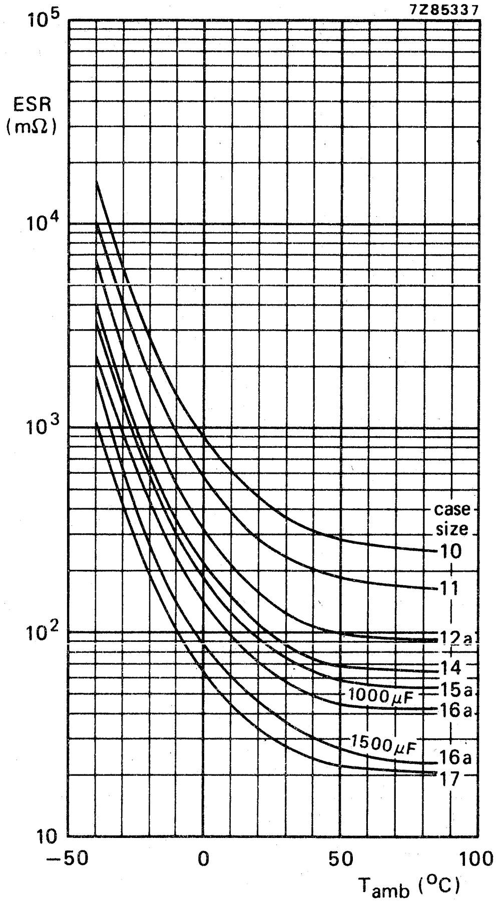


Fig. 6 Typical ESR as a function of temperature at 100 Hz, U_R = 385 V.

Impedance

Impedance at 20 kHz and T_{amb} = 20 °C, measured by means of a four-terminal circuit (Thomson circuit) — see Table 2

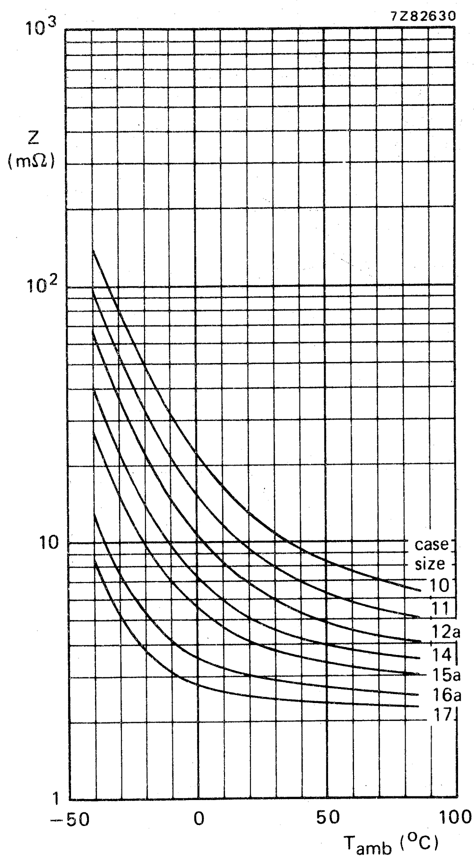


Fig. 7 Typical impedance as a function of temperature at 20 kHz, U_R = 10 V.

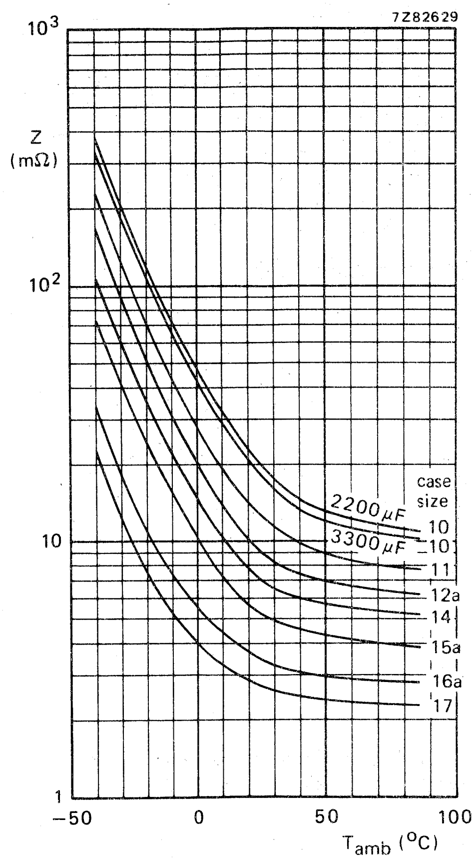


Fig. 8 Typical impedance as a function of temperature at 20 kHz, U_R = 63 V.

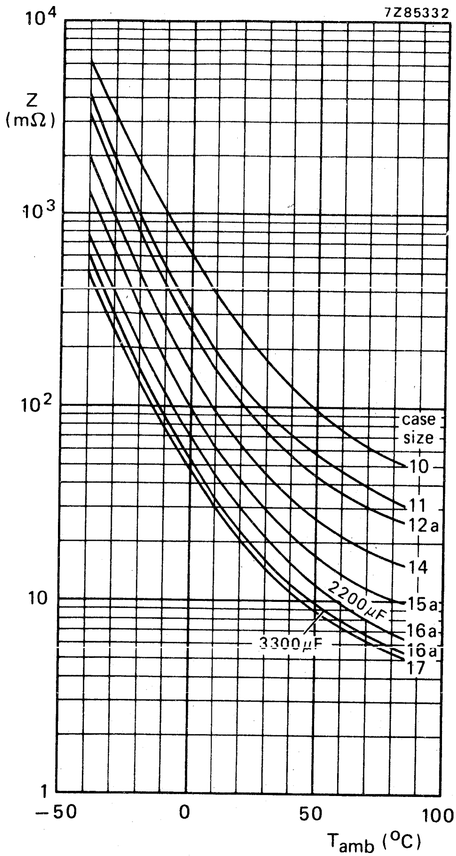


Fig. 9 Typical impedance as a function of temperature at 20 kHz, U_R = 250 V.

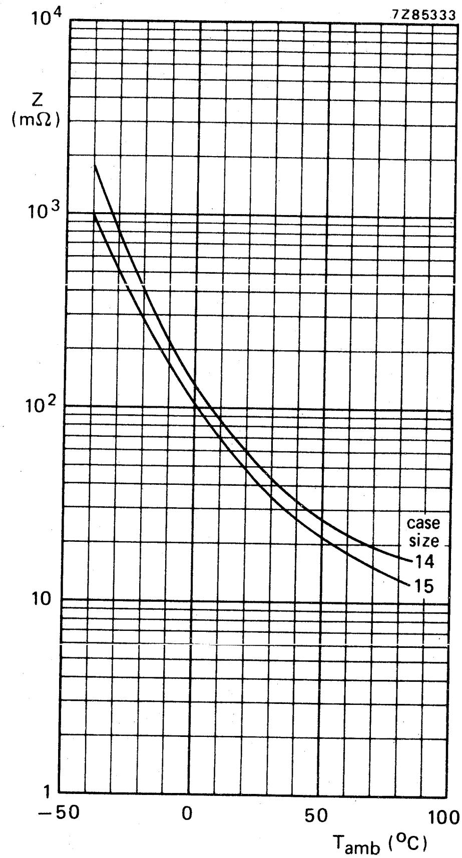


Fig. 10 Typical impedance as a function of temperature at 20 kHz, U_R = 350 V.

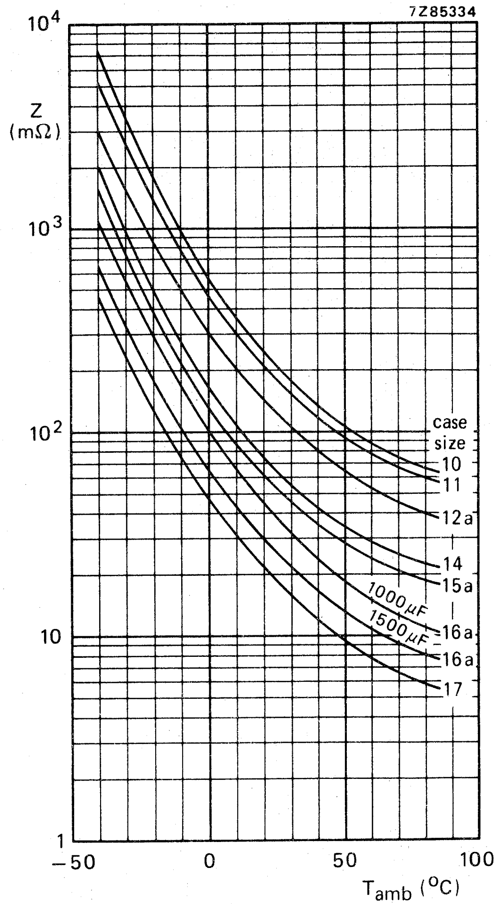


Fig. 11 Typical impedance as a function of temperature at 20 kHz, U_R = 385 V.

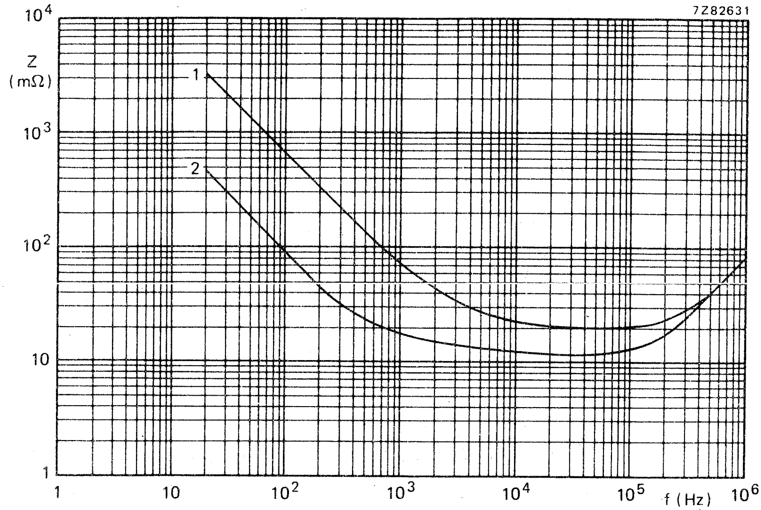


Fig. 12 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 10:**
curve 1 = 2200 μF, 63 V; curve 2 = 15 000 μF, 10 V.

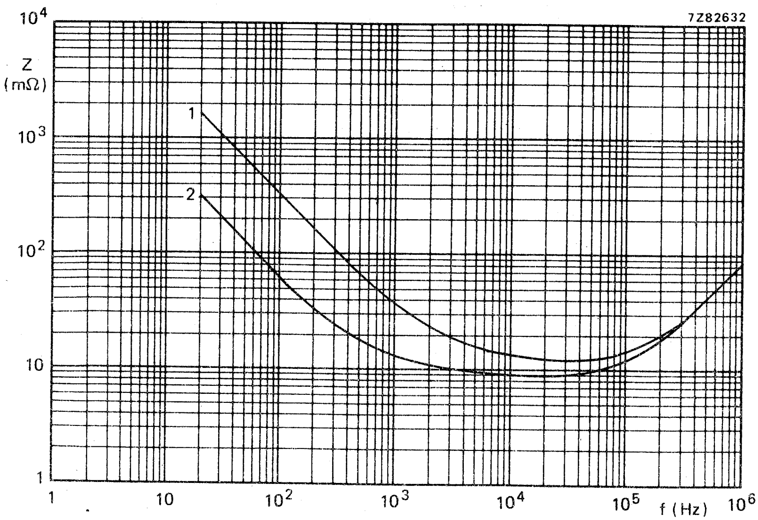


Fig. 13 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 11:**
curve 1 = 4700 μF, 63 V; curve 2 = 22 000 μF, 10 V.

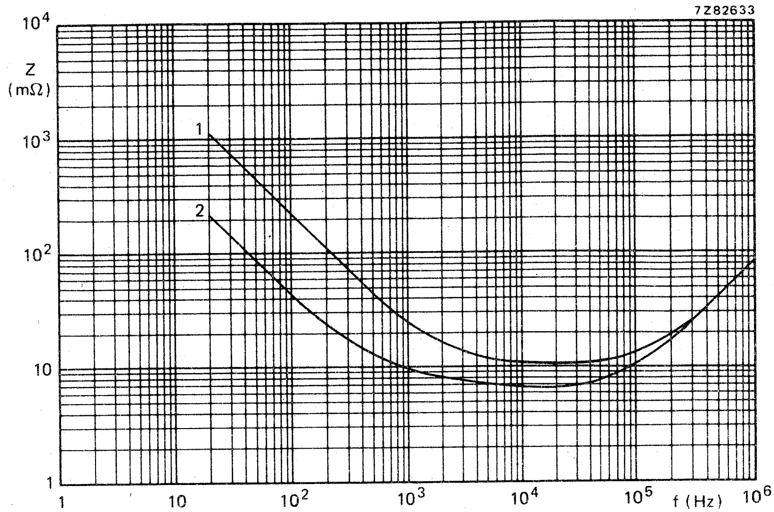


Fig. 14 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 12a:**
curve 1 = 6800 μF, 63 V; curve 2 = 33 000 μF, 10 V.

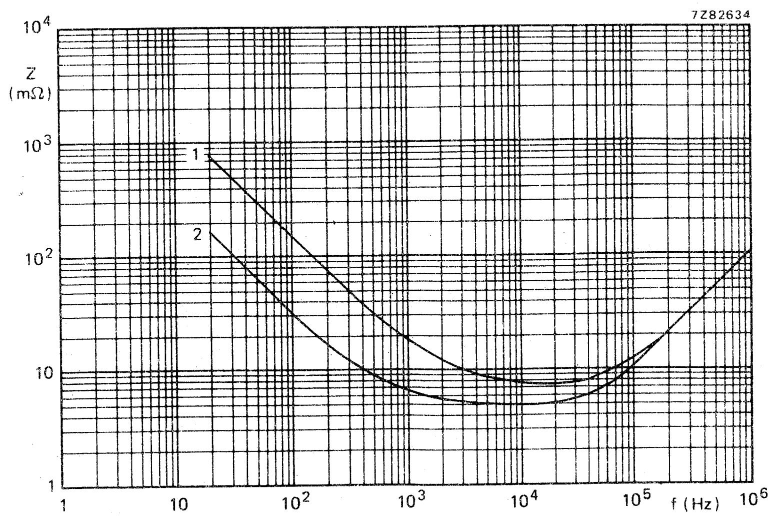


Fig. 15 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 14:**
curve 1 = 10 000 μF, 63 V; curve 2 = 47 000 μF, 10 V.

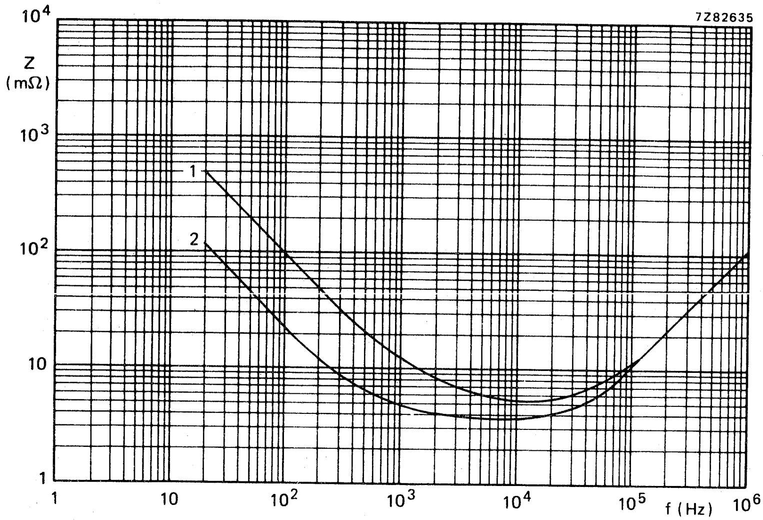


Fig. 16 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 15a:**
curve 1 = 15 000 μF, 63 V; curve 2 = 68 000 μF, 10 V.

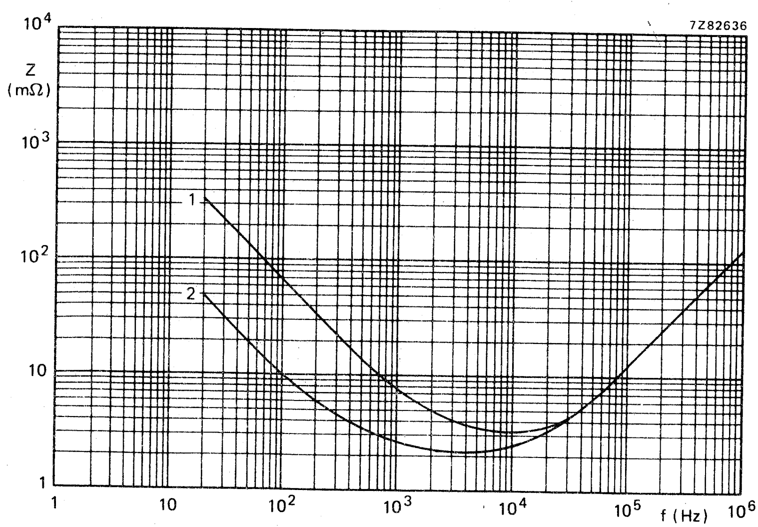


Fig. 17 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 16a:**
curve 1 = 22 000 μF, 63 V; curve 2 = 150 000 μF, 10 V.

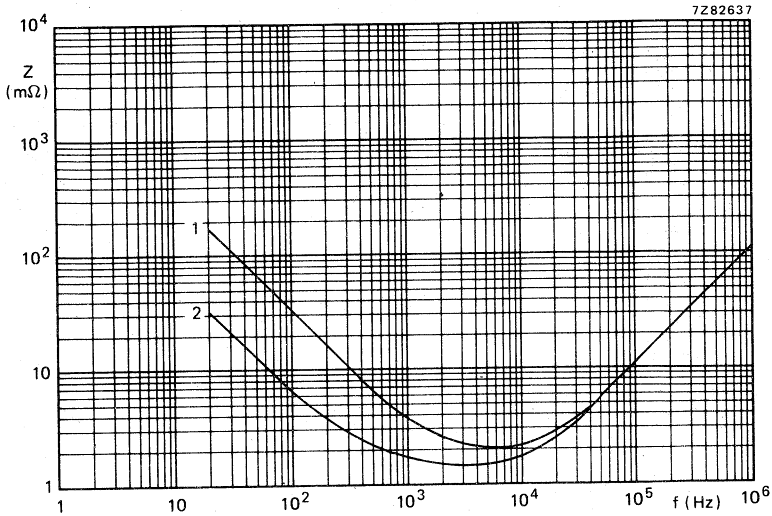


Fig. 18 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 17:**
curve 1 = 47 000 μF, 63 V; curve 2 = 220 000 μF, 10 V.

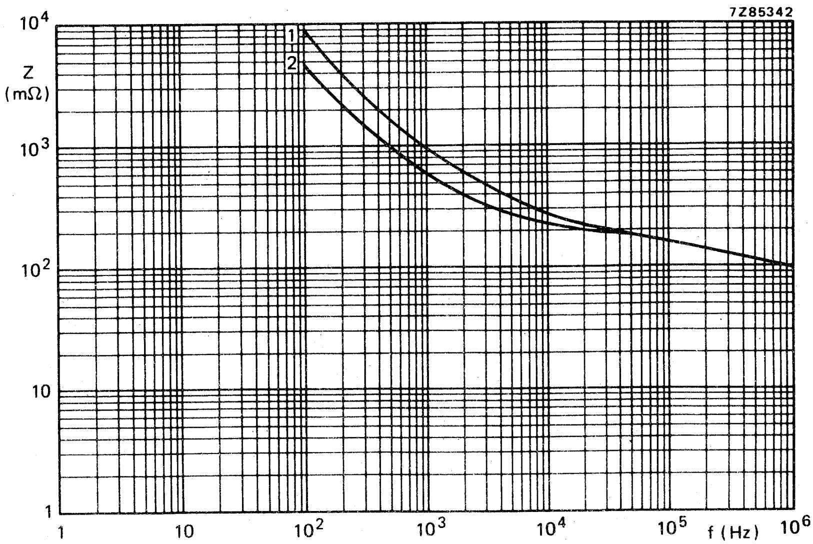


Fig. 19 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 10:**
curve 1 = 150 μF, 385 V; curve 2 = 330 μF, 250 V.

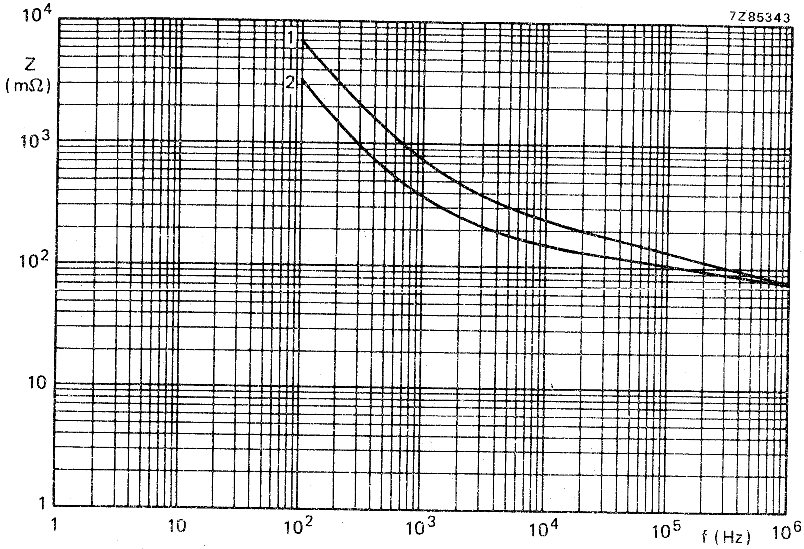


Fig. 20 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 11:**
curve 1 = 220 μF, 385 V; curve 2 = 470 μF, 250 V.

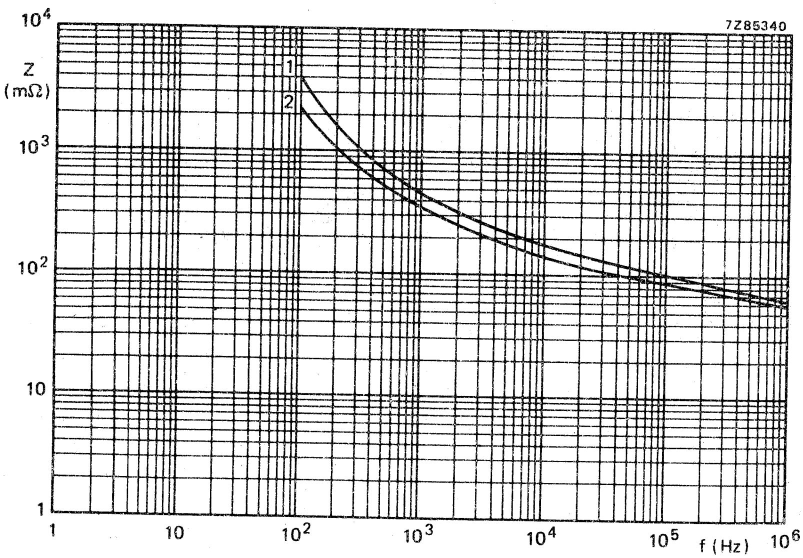


Fig. 21 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 12a:**
curve 1 = 330 μF, 385 V; curve 2 = 680 μF, 250 V.

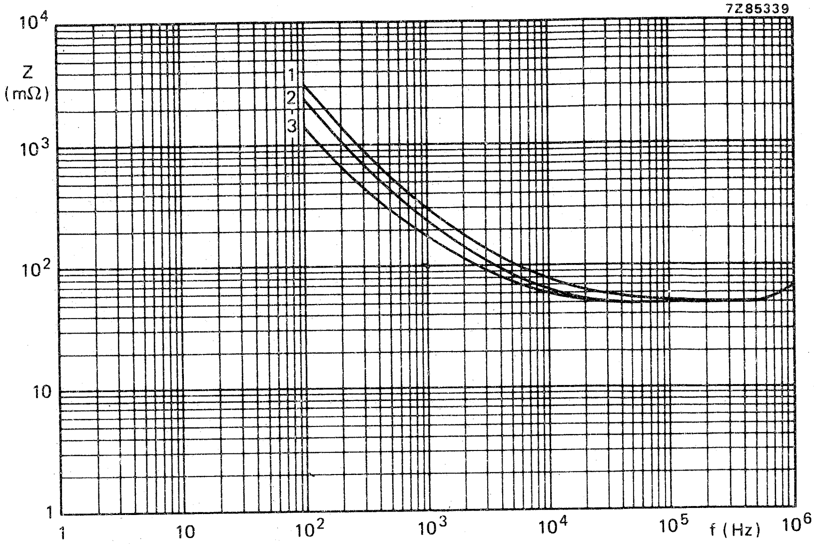


Fig. 22 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 14:**
curve 1 = 470 μF, 385 V;
curve 2 = 680 μF, 350 V;
curve 3 = 1000 μF, 250 V.

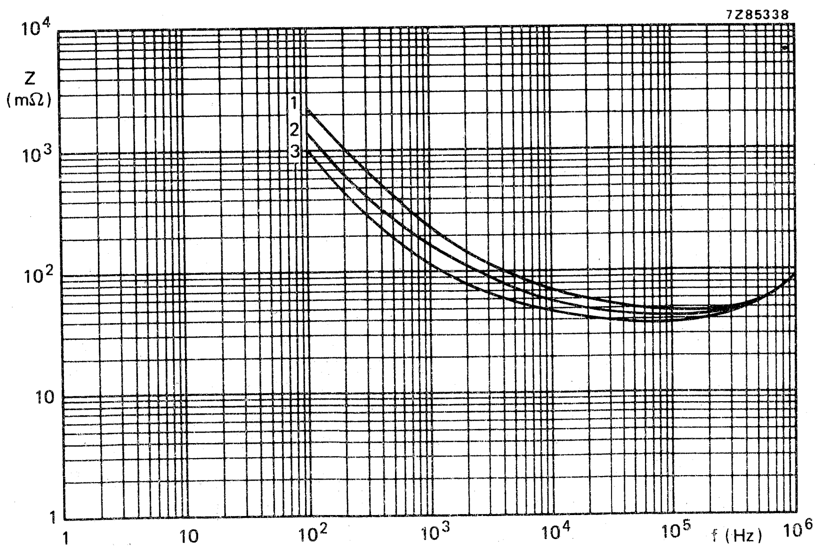


Fig. 23 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 15a:**
curve 1 = 680 μF, 385 V;
curve 2 = 1000 μF, 350 V;
curve 3 = 1500 μF, 250 V.

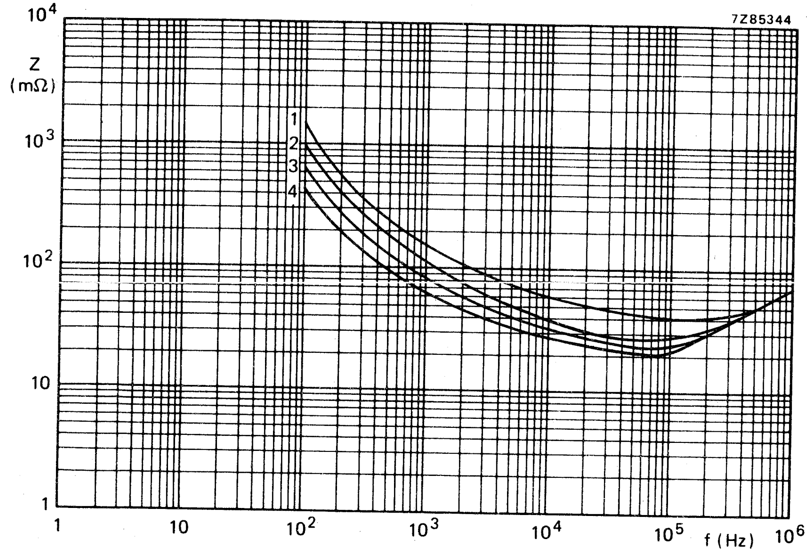


Fig. 24 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 16a:**
curve 1 = 1000 μF, 385 V;
curve 2 = 1500 μF, 385 V;
curve 3 = 2200 μF, 250 V;
curve 4 = 3300 μF, 250 V.

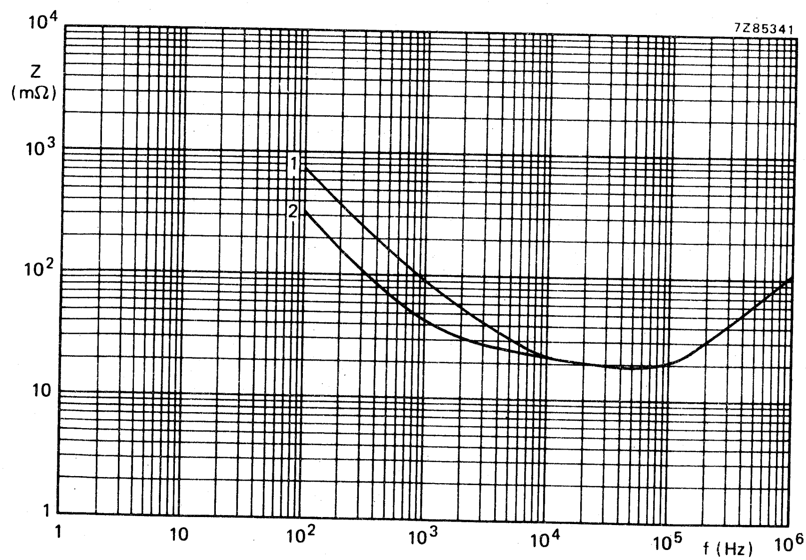


Fig. 25 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 17:**
curve 1 = 2200 μF, 385 V;
curve 2 = 4700 μF, 250 V.

Equivalent series inductance (ESL)

case size	typ. inductance
10, 11 and 12a	13 nH
14 and 15a	16 nH
16a	19 nH
17	20 nH

OPERATIONAL DATA

Category temperature range (for rated voltage) –40 to + 85 °C

Life expectance

Typical life time
- at T_{amb} = 85 °C > 10 000 h
- at T_{amb} = 40 °C > 200 000 h **(25 years)**

Failure rate

Failure rate at rated voltage, T_{amb} = 40 °C
confidence level 60%
- catastrophic $< 10^{-7}$
- catastrophic + degradation $< 3 \times 10^{-7}$

PACKING

The capacitors are packed in boxes.
Case sizes 10, 11, 12a, 14 and 15a: 50 capacitors per box;
case sizes 16a and 17: 25 capacitors per box.

TESTS AND REQUIREMENTS

See Data handbook, Introduction, section 9, under aluminium electrolytic capacitors.

Note: Capacitors 2222 114 and 2222 115 are large types with screw terminals, long-life grade.

MOUNTING ACCESSORIES

Clamps

To facilitate vertical mounting, a series of rigid clamps made of cadmium-plated steel are available. They can easily be slipped over the capacitor and then clamped with a nut and bolt. The clamps have either two or three mounting lugs. Four types of clamp are available, one for each case diameter. They are delivered without nuts or bolts.

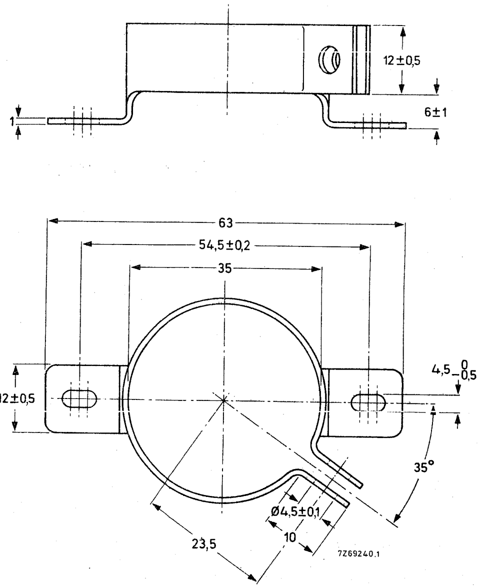


Fig. 26 Clamp for case diameter of 35 mm.
Catalogue number: 4322 043 04272.

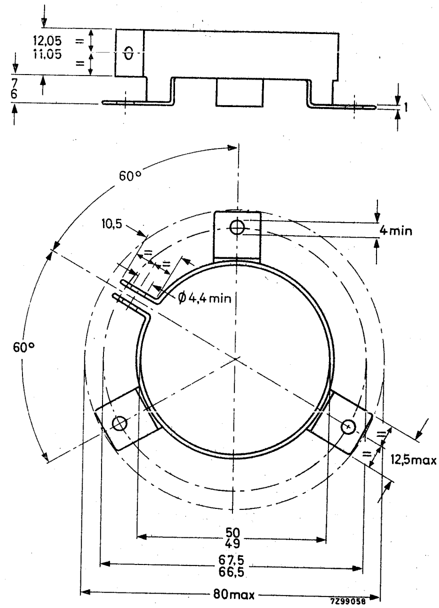


Fig. 27 Clamp for case diameter of 50 mm.
Catalogue number: 4322 043 04281.

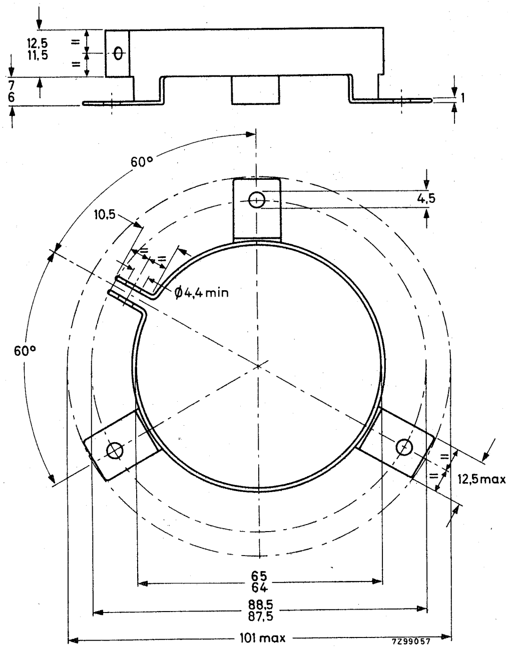


Fig. 28 Clamp for case diameter of 65 mm.
Catalogue number: 4322 043 04291.

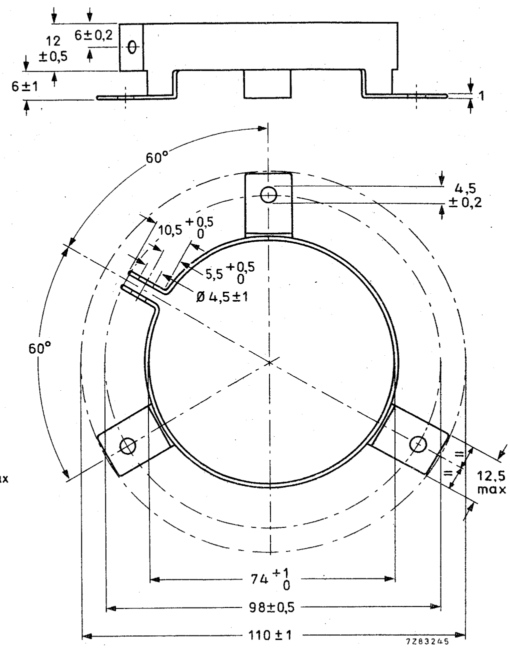


Fig. 29 Clamp for case diameter of 75 mm.
Catalogue number: 4322 043 12990.

Bolt/nut

When mounting with the bolt, which is an integral part of the case, standard metal M8 and M12 nuts and washers can be used. If insulated mounting is required, a synthetic nut and rubber washers are available.

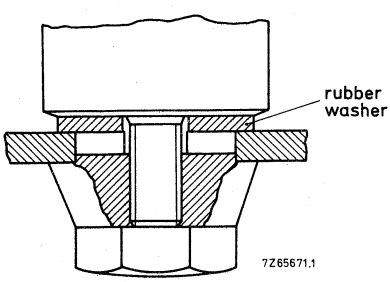


Fig. 30 Insulated mounting.

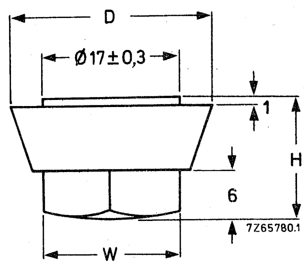
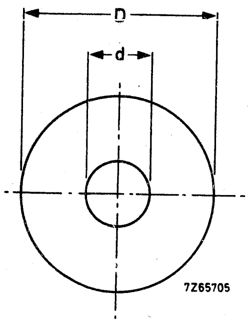


Fig. 31 Synthetic cap nut; see Table 6 for dimensions D, H and W.

Table 5

thread	D	H	W*	min. threaded depth	catalogue number
M8	25	15	17	11,5	4322 043 05561
M12	30	20	19	15,5	4322 043 05571



dimensions in mm

D	d	catalogue number
34	8,4	4322 043 05591
49	13	4322 043 05531
64	13	4322 043 05521
74	13	4322 043 13000

Fig. 32 Rubber washer; thickness 2 mm.

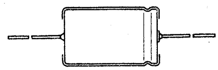
* W measured across flats.

SOLID ALUMINIUM CAPACITORS

U_R = 6,3 to 40 V *

SOLID ALUMINIUM CAPACITORS

- **Small type**
- **Axial leads; metal case**
- **Long life**
- **High reliability**
- **Industrial and military applications**



QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	2,2 to 330 μF
Tolerance on nominal capacitance	−20 to +20%
Rated voltage range, U_R (R5 series)	6,3 to 40 V
Category temperature range	−55 to +125 °C
Endurance test at 125 °C	5000 h
Basic specification	IEC 384-4, long-life grade
Climatic category, IEC 68	55/125/56
Approvals	CECC 30 302-001 U.K. Post Office FOA/FTL (Sweden)

Selection chart for C_{nom}-U_R and relevant case sizes.

C_{nom} μF	U_R (V) 6,3	10	16	25	40
2,2					1
3,3					1
4,7				1	2
6,8					2
10			1	2	3
15		1	2		
22	1			3	4
33		2	3	4	5
47	2	3	4	5	6
68	3		5	6	
100		4	6		
150	4	5			
220	5	6			
330	6				

nominal dimensions (mm)	
1	Ø 6,5 x 17
2	Ø 6,5 x 23
3	Ø 8 x 23
4	Ø 10 x 23
5	Ø 10 x 31
6	Ø 12,5 x 31

* For 50 V version, see the relevant data sheet

APPLICATION

These capacitors utilize advanced technology to achieve long life, high stability, excellent reliability, high ripple current rating and low temperature dependence. The capacitors are not subject to a limitation on charge or discharge currents and they will function in circuits where voltage reversal may occur.

DESCRIPTION

The capacitor has etched aluminium foil electrodes separated by a layer of semiconductive material. The electrolyte is pyrolytically formed manganese dioxide. The capacitor is housed in an aluminium case with axial leads and is sealed by a ceramic disc. The cathode lead is welded to the case, which is insulated with a blue transparent plastic sleeve.

MECHANICAL DATA

Dimensions in mm

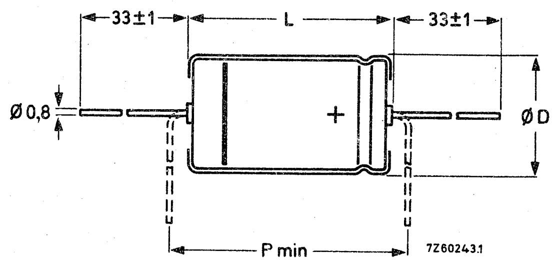


Fig. 1 For dimensions D, L and P, see Table 1.

Table 1

case size	D_{nom}	L_{nom}	D_{max}	L_{max}	P_{min}	mass approx. g
1	6,5	17	6,6	17,5	20	1,2
2	6,5	23	6,6	24	27,5	1,6
3	8	23	8,3	24	27,5	2,4
4	10	23	10,4	24	27,5	3,3
5	10	31	10,4	32	35	4,5
6	12,5	31	12,9	32	35	6,3

Marking

Stamped on the case are: catalogue number, capacitance, rated and derated voltages at corresponding maximum temperatures, date code, a band to identify the negative terminal and "+" signs for the positive terminal.

Mounting

No special provisions are required for soldering to the tinned leads.
(2 mm of the anode lead nearest the body are not solderable.)

ELECTRICAL DATA

Table 2

Unless otherwise specified all electrical values in Table 2 apply at an ambient temperature of 20 to 25 °C, a frequency of 100 Hz, an atmospheric pressure of 86 to 106 kPa and a relative humidity of 45 to 75%.

U_R V	nom. cap. μF	max. r.m.s. ripple current at T_{amb} = 85 °C* mA	max. leakage current at U_R after 5 min (μA)*	max. tan δ*	typ. ESR* Ω	max. impedance at 100 kHz* Ω	case size	catalogue number
6,3	22	45	12,5	0,18	6,51	2,5	1	2222 121 13229
	47	75	25	0,18	3,05	1,25	2	121 13479
	68	105	40	0,18	2,34	0,75	3	121 13689
	150	170	70	0,18	0,95	0,5	4	121 13151
	220	240	125	0,18	0,80	0,4	5	121 13221
	330	335	150	0,18	0,53	0,4	6	121 13331
10	15	40	15	0,16	7,43	2,5	1	121 14159
	33	70	30	0,16	3,86	1,25	2	121 14339
	47	90	47	0,16	2,71	0,75	3	121 14479
	100	145	80	0,16	1,59	0,5	4	121 14101
	150	220	150	0,16	1,17	0,4	5	121 14151
	220	290	200	0,16	0,58	0,4	6	121 14221
16	10	35	16	0,14	9,55	2,5	1	121 15109
	15	50	24	0,14	5,31	1,25	2	121 15159
	33	100	53	0,14	2,89	0,75	3	121 15339
	47	110	75	0,14	1,69	0,5	4	121 15479
	68	150	109	0,14	1,64	0,4	5	121 15689
	100	205	160	0,14	0,95	0,4	6	121 15101
25	4,7	25	12	0,14	16,93	5	1	121 16478
	10	40	25	0,14	11,14	2,5	2	121 16109
	22	70	55	0,14	5,06	1,5	3	121 16229
	33	90	83	0,14	3,86	1	4	121 16339
	47	130	118	0,14	4,06	0,8	5	121 16479
	68	170	170	0,14	1,87	0,5	6	121 16689
40	2,2	20	9	0,12	28,94	5	1	121 17228
	3,3	25	13	0,12	19,29	5	1	121 17338
	4,7	35	19	0,12	16,93	2,5	2	121 17478
	6,8	40	27	0,12	11,70	2,5	2	121 17688
	10	55	40	0,12	9,55	1,5	3	121 17109
	22	90	88	0,12	6,51	1	4	121 17229
	33	125	132	0,12	4,34	0,8	5	121 17339
	47	165	188	0,12	2,37	0,5	6	121 17479

* See also corresponding paragraph.

Capacitance

Nominal capacitance values at 100 Hz and T_{amb} = 20 °C	see Table 2
Tolerance on nominal capacitance at 100 Hz	−20 to +20%

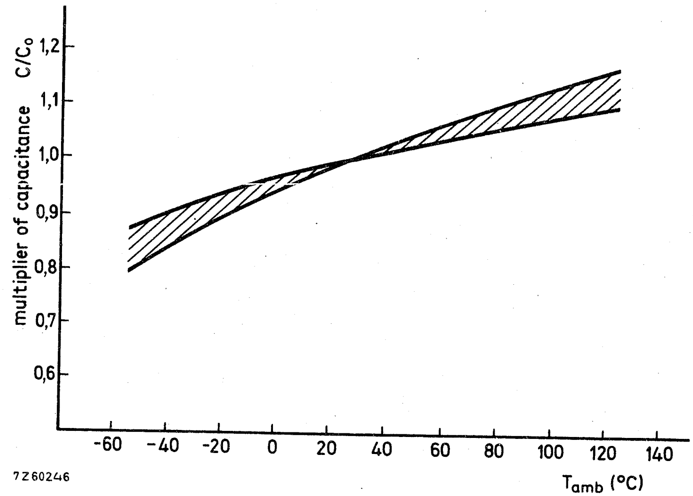


Fig. 2 Typical capacitance as a function of ambient temperature.
C_0 = capacitance at 25 °C, 100 Hz.

Voltage

Rated voltage	= max. permissible voltage at ⩽ 125 °C	see Table 2, U_R
Ripple voltage*	= max. permissible a.c. voltage providing the following three conditions are met:	
	a) max. (d.c. + peak a.c.) voltage	⩽ U_R
	b) max. peak a.c. voltage with d.c. voltage applied	⩽ 1,15 x applied d.c. voltage
	c) max. peak a.c. voltage, 50 Hz, without d.c. voltage applied	0,8 x U_R
Surge voltage	= max. permissible voltage for short periods (see also "Tests and requirements")	1,15 x U_R
Reverse voltage	= max. d.c. voltage continuously (2000 h) applied in the reverse polarity at the maximum category temperature	
	at ⩽ 85 °C	0,30 x U_R
	at > 85 °C up to 125 °C	0,15 x U_R

* Ripple voltages are not applicable if the maximum permissible ripple current is exceeded. In that case the ripple current is decisive.

Ripple current *

Maximum permissible r.m.s. ripple current at 100 Hz and $T_{amb} = 85\ ^oC$ see Table 2

The maximum permissible ripple current ($I_{r\,max}$) is a function of temperature and frequency:

$$I_{r\,max} = I_{r0}\sqrt{kr}$$

where I_{r0} = max. ripple current at 100 Hz up to 85 °C, see Table 2
k = temperature derating factor = P_{max}/P_0
r = frequency dependent derating factor = R_{s0}/R_s

while P_{max} = max. permissible power dissipation, temperature dependent
P_0 = max. permissible power dissipation up to 85 °C = $(I_{r0})^2 R_{s0}$
R_{s0} = series resistance at 100 Hz = $\frac{\tan\delta}{628C}$, C and tan δ to be read from Table 2
R_s = series resistance, frequency dependent (temperature dependence neglected).

The formula is derived as follows:

$$(I_{r\,max})^2 = P_{max}/R_s = k(I_{r0})^2 R_{s0}/R_s;$$

thus $I_{r\,max} = I_{r0}\sqrt{kr}$ (see Table 2 and Fig. 3).

* Ripple currents are not applicable if the maximum permissible ripple voltage is exceeded. In that case the ripple voltage is decisive.

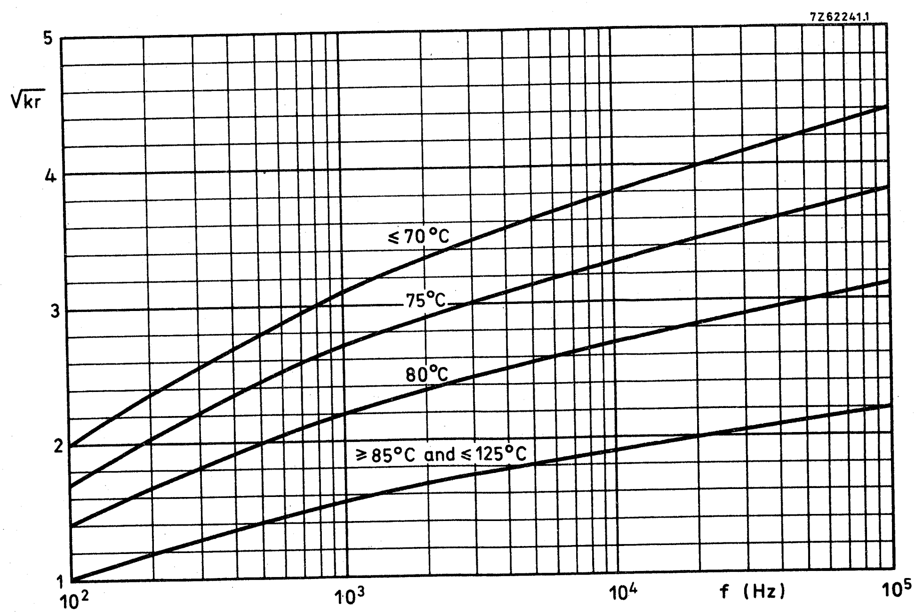


Fig. 3 Factor $\sqrt{kr}$ as a function of frequency for calculation of maximum ripple current.

Leakage current

Maximum leakage current 5 min after application of the rated voltage	see Table 2 (0,1 CU)
Leakage current during continuous operation at U_R,	
at 25 °C	
at 85 °C	approx. 0,4 of value stated in Table 2
at 125 °C	approx. 4 of value stated in Table 2
	approx. 7 of value stated in Table 2

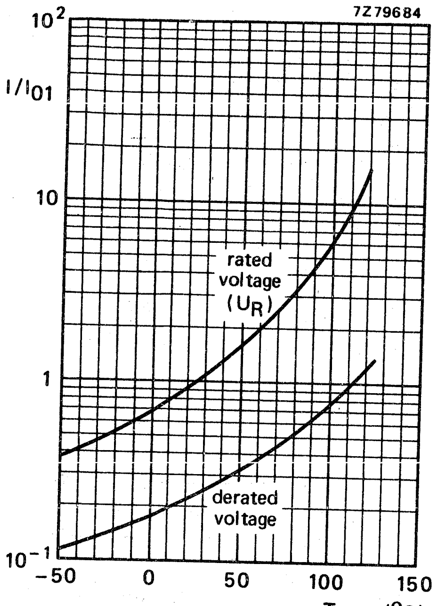


Fig. 4 Multiplier I/I_{01} as a function of ambient temperature; I_{01} = leakage current during continuous operation at T_{amb} = 25 °C at U_R.

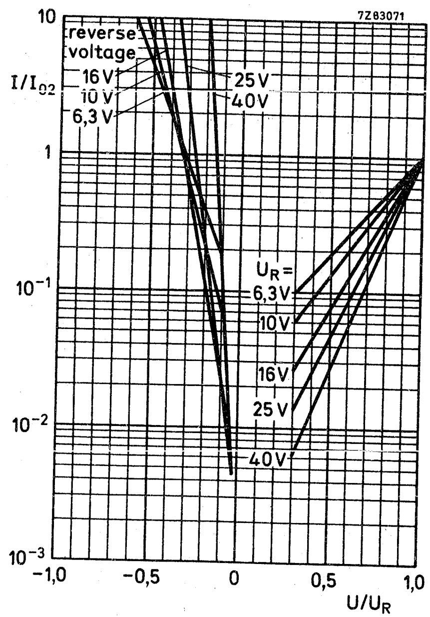


Fig. 5 Multiplier I/I_{02} as a function of U/U_R; I_{02} = leakage current at U_R at a discrete constant temperature.

Tan δ (dissipation factor)

Tan δ at 100 Hz, measured by means of a four-terminal circuit (Thomson circuit) (max. values) — see Table 2

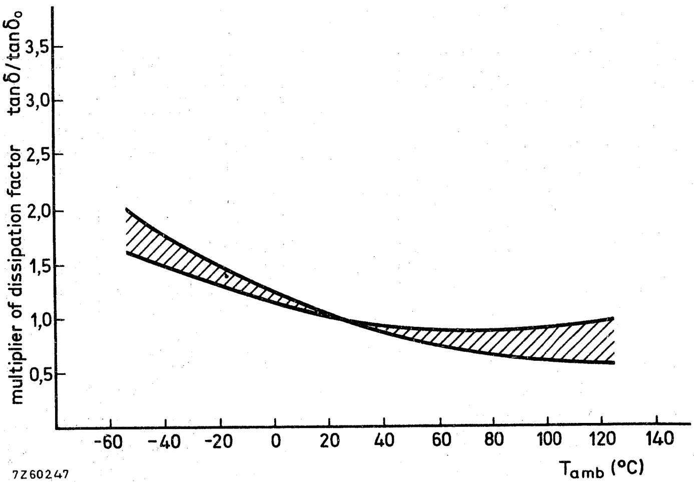


Fig. 6 Typical dissipation factor as a function of ambient temperature; tan δ_0 = dissipation factor at 25 °C, 100 Hz.

Impedance

Impedance at 100 kHz, measured by means of a four-terminal circuit (Thomson circuit) (max. values)	see Table 2
Typical impedance as a function of ambient temperature at 100 kHz	see Figs 7 to 12

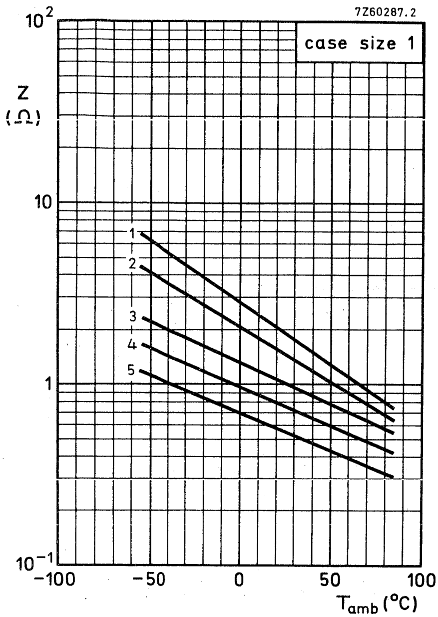


Fig. 7.

Curve 1 = 2,2 μF, 40 V
2 = 4,7 μF, 25 V
3 = 10 μF, 10 V
4 = 15 μF, 10 V
5 = 22 μF, 6,3 V

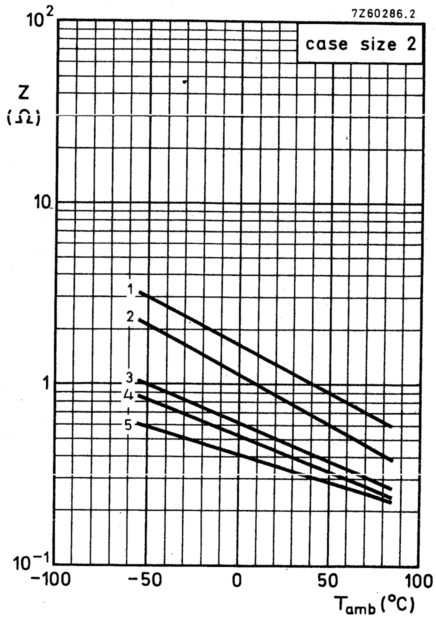


Fig. 8.

Curve 1 = 4,7 μF, 40 V
2 = 10 μF, 25 V
3 = 15 μF, 16 V
4 = 33 μF, 10 V
5 = 47 μF, 6,3 V

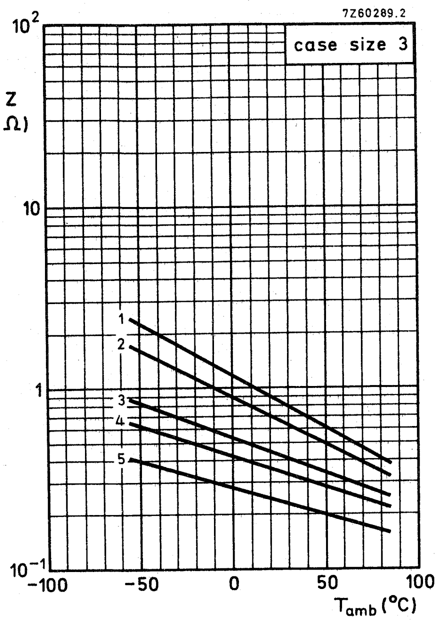


Fig. 9.

Curve 1 = 10 μF, 40 V
2 = 22 μF, 25 V
3 = 33 μF, 16 V
4 = 47 μF, 10 V
5 = 68 μF, 6,3 V

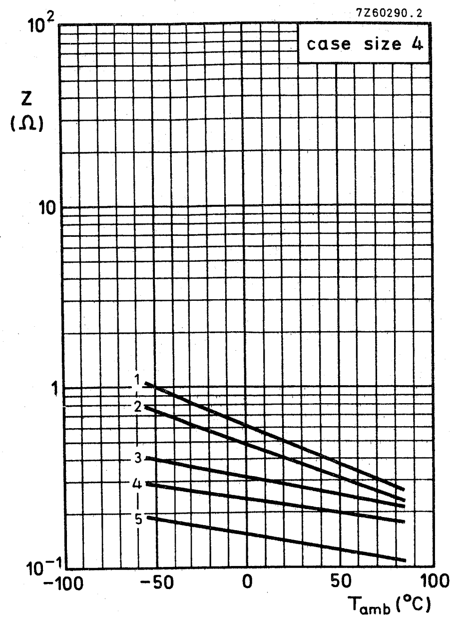


Fig. 10.

Curve 1 = 22 μF, 40 V
2 = 33 μF, 25 V
3 = 47 μF, 16 V
4 = 100 μF, 10 V
5 = 150 μF, 6,3 V

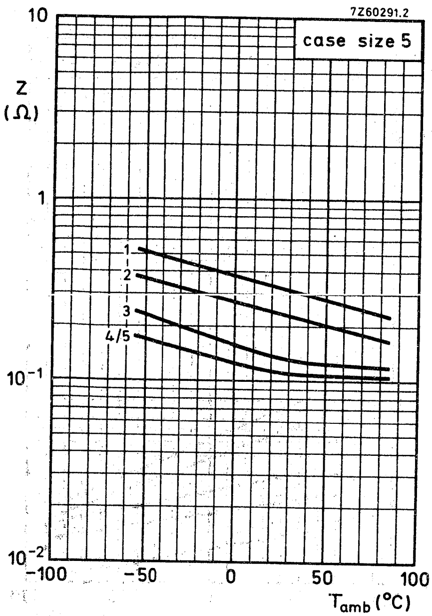


Fig. 11.

Curve 1 = 33 μF, 40 V
2 = 47 μF, 25 V
3 = 68 μF, 16 V
4 = 150 μF, 10 V
5 = 220 μF, 6,3 V

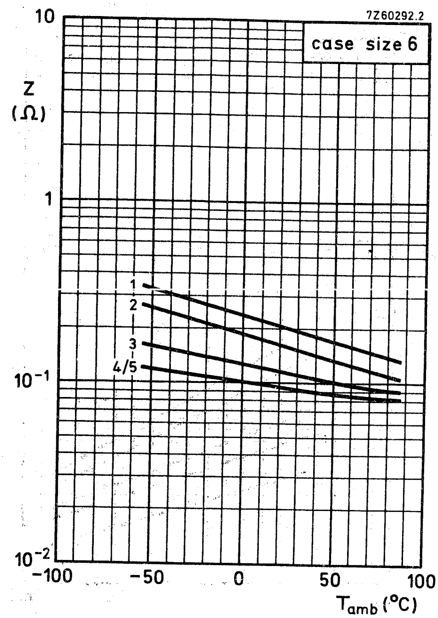


Fig. 12.

Curve 1 = 47 μF, 40 V
2 = 68 μF, 25 V
3 = 100 μF, 16 V
4 = 220 μF, 10 V
5 = 330 μF, 6,3 V

Typical impedance as a function of frequency at 25 °C see Figs 13 and 14.

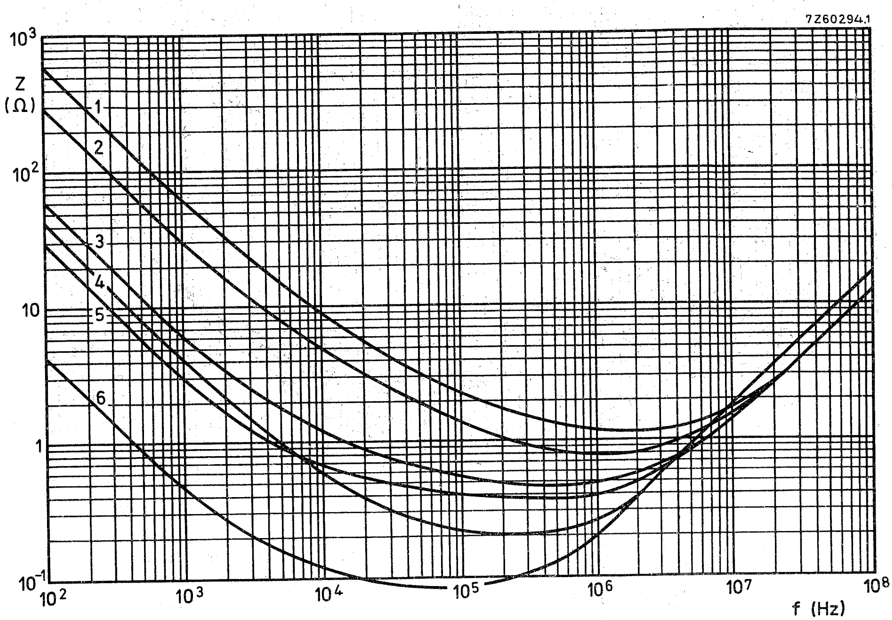


Fig. 13.

Curve 1 = 2,2 μF, 40 V
2 = 4,7 μF, 40 V
3 = 22 μF, 6,3 V
4 = 47 μF, 40 V
5 = 47 μF, 6,3 V
6 = 330 μF, 6,3 V

curve 1 + 3 = case size 1
curve 2 + 5 = case size 2
curve 4 + 6 = case size 6

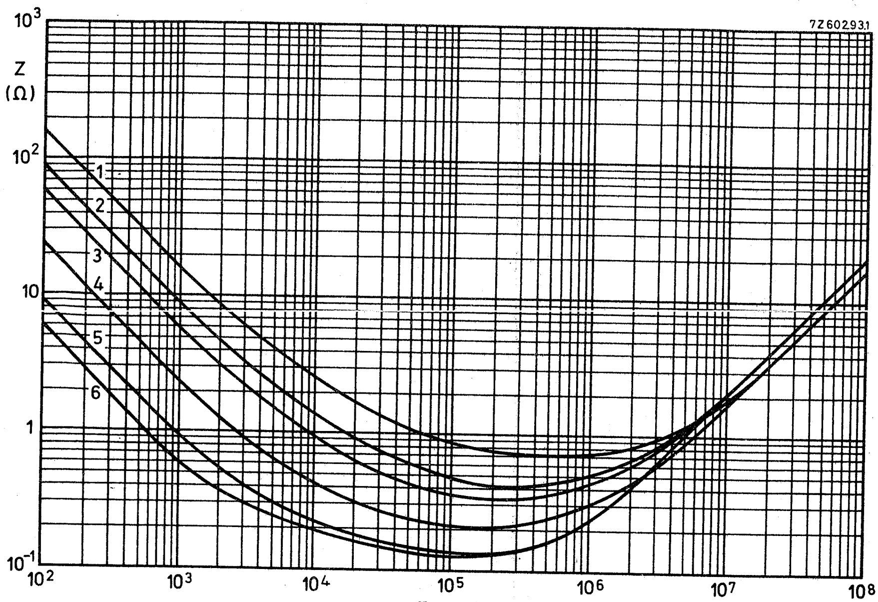


Fig. 14.

Curve 1 = 10 μF, 40 V
2 = 22 μF, 40 V
3 = 33 μF, 40 V
4 = 68 μF, 6,3 V
5 = 150 μF, 6,3 V
6 = 220 μF, 6,3 V

curve 1 + 4 = case size 3
curve 2 + 5 = case size 4
curve 3 + 6 = case size 5

Equivalent series resistance (ESR = tan $\delta/\omega C$)

ESR at 100 Hz and T_{amb} = 20 °C — see Table 2

Self inductance — 20 to 30 nH (typical values)

OPERATIONAL DATA

Category temperature range — −55 to +125 °C

Life expectancy

at 125 °C and U_R	> 20 000 hours
at 150 °C and U_R	> 5000 hours
at 175 °C and U_R	> 2000 hours

PACKING

100 pieces per box.

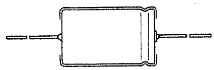
TESTS AND REQUIREMENTS

See Introduction, section 9, under solid aluminium capacitors.

U_R = 50 V *

SOLID ALUMINIUM CAPACITORS

- Small type
- Long life
- Industrial applications



QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	2,2 to 33 μF
Tolerance on nominal capacitance	−20 to +20%
Rated voltage, U_R	50 V
Category temperature range	−55 to +125 °C
Endurance test at 125 °C	5000 h
Climatic category, IEC 68	
at 50 V	55/085/56
at 40 V	55/125/56

U_R (V)	C_{nom} (μF)	case size	nominal dimensions (mm)
50	2,2	1	Ø 6,5 x 17
	4,7	2	Ø 6,5 x 23
	6,8	3	Ø 8 x 23
	15	4	Ø 10 x 23
	22	5	Ø 10 x 31
	33	6	Ø 12,5 x 31

APPLICATION

These capacitors utilize advanced technology to achieve long life, high stability, high ripple current rating and low temperature dependence. The capacitors are not subject to a limitation on charge or discharge currents and they will function in circuits where voltage reversal may occur.

* For 6,3 to 40 V versions, see the relevant data sheet.

DESCRIPTION

The capacitor has etched aluminium foil electrodes separated by a layer of semiconductive material. The electrolyte is pyrolytically formed manganese dioxide. The capacitor is housed in an aluminium case with axial leads and is sealed by a ceramic disc. The cathode lead is welded to the case, which is insulated with a blue transparent plastic sleeve.

MECHANICAL DATA

Dimensions in mm

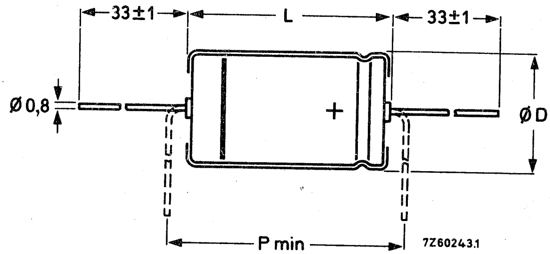


Fig. 1 See Table 1 for dimensions D, L and P.

Table 1

case size	D_{nom}	L_{nom}	D_{max}	L_{max}	P_{min}	mass approx. g
1	6,5	17	6,6	17,5	20	1,2
2	6,5	23	6,6	24	27,5	1,6
3	8	23	8,3	24	27,5	2,4
4	10	23	10,4	24	27,5	3,3
5	10	31	10,4	32	35	4,5
6	12,5	31	12,9	32	35	6,3

Marking

Stamped on the case are: catalogue number, capacitance, rated and derated voltages at corresponding maximum temperatures, date code, a band to identify the negative terminal and "+" signs for the positive terminal.

Mounting

No special provisions are required for soldering to the tinned leads.
(2 mm of the anode lead nearest the body are not solderable.)

ELECTRICAL DATA

Table 2

Unless otherwise specified all electrical values in Table 2 apply at an ambient temperature of 20 to 25 °C, a frequency of 100 Hz, an atmospheric pressure of 86 to 106 kPa and a relative humidity of 45 to 75%.

U_R V	nom. cap. μF	max. r.m.s. ripple current at T_{amb} = 85 °C mA*	max. leakage current at U_R after 5 min μA*	max. tan δ	typ. ESR Ω*	max. impedance at 100 kHz Ω*	case size	catalogue number
50	2,2	14	11	0,25	60	20	1	2222 121 18228
	4,7	25	24	0,25	35	10	2	121 18478
	6,8	30	34	0,25	29	6	3	121 18688
	15	60	75	0,25	13	4	4	121 18159
	22	80	110	0,25	11	3,2	5	121 18229
	33	110	165	0,25	6	2	6	121 18339

Capacitance

Nominal capacitance values at 100 Hz and T_{amb} = 20 °C — see Table 2

Tolerance on nominal capacitance at 100 Hz — −20 to + 20%

* See also corresponding paragraph.

Voltage

		≤ 85 °C	> 85 °C up to 125 °C
Rated voltage (U_R)	= max. permissible voltage at ≤ 85 °C	50 V*	
Derated voltage	= max. permissible voltage at > 85 °C up to +125 °C	40 V	
Ripple voltage **	= max. permissible a.c. voltage providing the following three conditions are met:	≤ 85 °C	> 85 °C up to 125 °C
	a) max. (d.c. + peak a.c.) voltage	50 V	≤ 40 V
	b) max. peak a.c. voltage with d.c. voltage applied	≤ 1,15 applied d.c. voltage	
	c) max. peak a.c. voltage without d.c. voltage applied	0,15 x U_R	0,15 x derated voltage
Surge voltage	= max. permissible voltage up to 500 h	63 V	45 V
Reverse voltage	= max. d.c. voltage applied in the reverse polarity at the maximum category temperature for short periods (see also "Tests and requirements")	0,15 x U_R	0,15 x derated voltage

* Up to 500 h at 85 °C, 63 V is permissible.

** Ripple voltages are not applicable if the maximum permissible ripple current is exceeded. In that case the ripple current is decisive.

Ripple current

Maximum permissible r.m.s. ripple current at 100 Hz and T_{amb} = 85 °C: see Table 2.
The maximum permissible ripple current ($I_{r\,max}$) is a function of temperature and frequency:

$$I_{r\,max} = I_{r0}\sqrt{kr}$$

where I_{r0} = max. ripple current at 100 Hz up to 85 °C, see Table 2
k = temperature derating factor = P_{max}/P_0
r = frequency dependent derating factor = R_{s0}/R_s
while P_{max} = max. permissible power dissipation, temperature dependent
P_0 = max. permissible power dissipation up to 85 °C = $(I_{r0})^2 R_{s0}$
R_{s0} = series resistance at 100 Hz = $\frac{\tan\delta}{628C}$, C and tan δ to be read from Table 2
R_s = series resistance, frequency dependent (temperature dependence neglected).

The formula is derived as follows:

$$(I_{r\,max})^2 = P_{max}/R_s = k(I_{r0})^2 R_{s0}/R_s$$

thus $I_{r\,max} = I_{r0}\sqrt{kr}$ (see Table 2 and graph below).

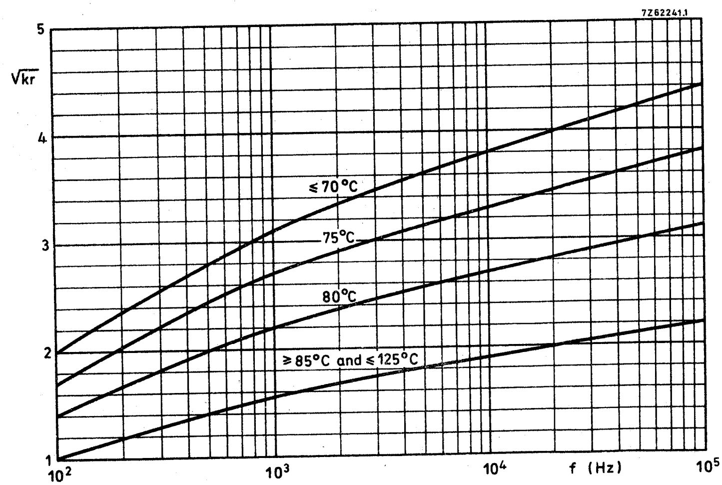


Fig. 2 Factor $\sqrt{kr}$ as a function of frequency for calculation of maximum ripple current.

* Ripple currents are not applicable if the maximum permissible ripple voltage is exceeded. In that case the ripple voltage is decisive.

Leakage current

Maximum leakage current 5 min after application of the rated voltage	see Table 2 (0,1 CU)
Leakage current during continuous operation at U_R, at 25 °C	approx. 0,4 x value stated in Table 2
at 85 °C as well as at derated voltage and 125 °C	approx. 4 x value stated in Table 2

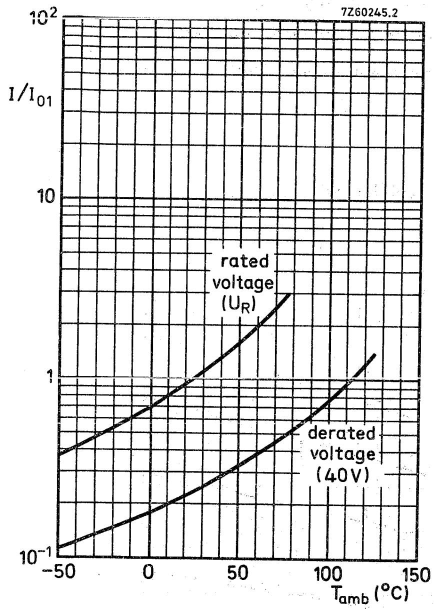


Fig. 3 Multiplier I/I_{01} as a function of temperature; I_{01} = leakage current during continuous operation at T_{amb} = 25 °C at U_R.

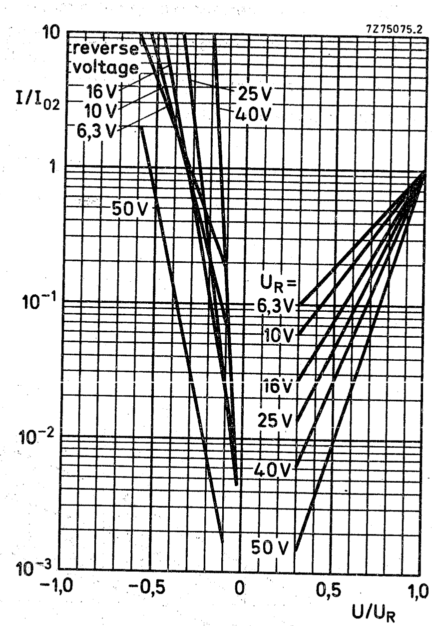


Fig. 4 Multiplier I/I_{02} as a function of U/U_R; I_{02} = leakage current at U_R at a discrete constant temperature.

Tan δ (dissipation factor)

Tan δ at 100 Hz, measured by means of a four-terminal circuit (Thomson circuit) — see Table 2

Impedance

Impedance at 100 kHz, measured by means of a four-terminal circuit (Thomson circuit) — see Table 2

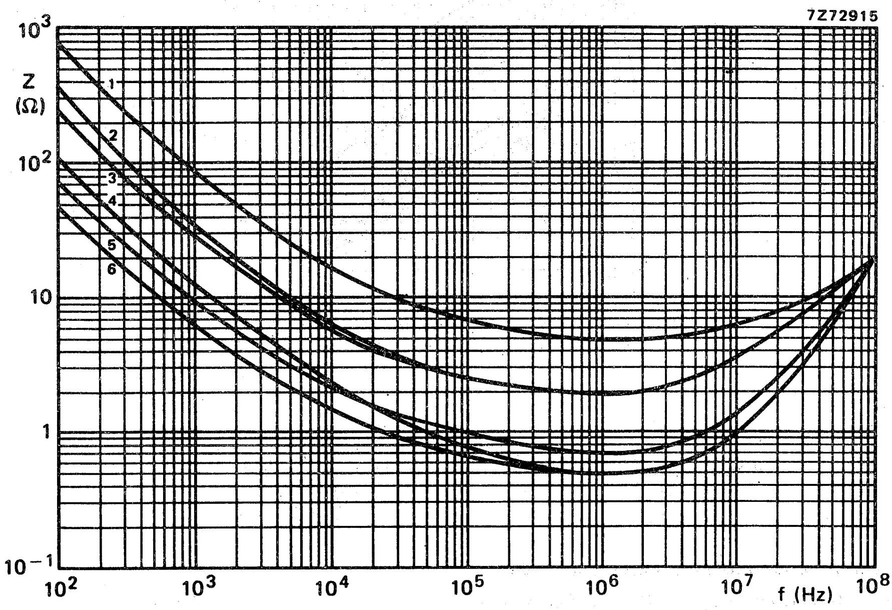


Fig. 5 Typical impedance as a function of frequency at 25 °C.
Curve 1 = 2,2 μF, 50 V;
2 = 4,7 μF, 50 V;
3 = 6,8 μF, 50 V;
Curve 4 = 15 μF, 50 V;
5 = 22 μF, 50 V;
6 = 33 μF, 50 V.

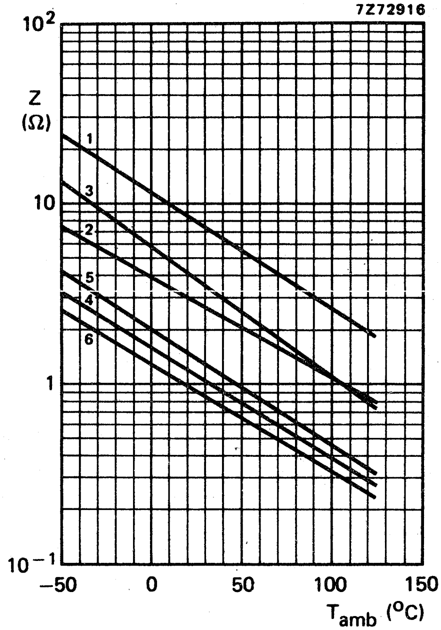


Fig. 6 Typical impedance as a function of temperature at 100 kHz.

Curve 1 = 2,2 μF, 50 V;	Curve 4 = 15 μF, 50 V;
2 = 4,7 μF, 50 V;	5 = 22 μF, 50 V;
3 = 6,8 μF, 50 V;	6 = 33 μF, 50 V.

Equivalent series resistance (ESR = tan δ/ωC)

ESR at 100 Hz and T_{amb} = 20 °C (typical values) — see Table 2

Self inductance — 20 to 30 mH (typical values)

OPERATIONAL DATA

Category temperature range

for rated voltage	–55 to +85 °C
for derated voltage (= 40 V)	–55 to +125 °C

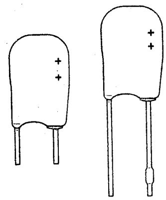
Life expectancy

at 85 °C and U_R or
at 125 °C and derated voltage (= 40 V) — ≥ 10 000 h

PACKING

100 pieces per box.

SOLID ALUMINIUM CAPACITORS



- Miniature type
- Single ended
- Resin dipped
- Long life
- No derating at maximum temperature
- General and industrial applications

QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	0,1 to 68 μF
Tolerance on nominal capacitance	± 20%; ± 10%
Rated voltage range, U_R (R5 series)	6,3 to 40 V
Category temperature range	−55 to + 125 °C
Endurance test	
at 85 °C	5000 h
at 125 °C	2000 h
Basic specification	IEC 384–4, long-life grade
Climatic category, IEC 68	55/125/56
Approval	CECC 30 302-002

Selection chart for C_{nom}–U_R and relevant case sizes.

C_{nom} μF	U_R (V)				
	6,3	10	16	25	40*
0,1					1
0,15					1
0,22					1
0,33					1
0,47					2
0,68				1	2
1				1	3
1,5				1	4
2,2			1	2	4
3,3			1	2	4 **
4,7		1	2	3	
6,8		1	2	4	
10	1	2	3	4 **	
15	2	2	4		
22	2	3			
33	3	4			
47	4				
68	4				

case size	maximum dimensions (mm)
1	12,5 x 8 x 3,5
2	12,5 x 8 x 4,5
3	12,5 x 8 x 5
4	12,5 x 8 x 6

* Up to 85 °C, from 85 to 125 °C this value is 25 V.
** Available to special order.

APPLICATION

Especially for filtering, smoothing, coupling and decoupling purposes in general and industrial applications. These capacitors utilize advanced technology to achieve long life, high reliability, high stability and low temperature dependence.

The capacitors have a very low and stable leakage current, small dimensions and a fixed pitch of 5 mm.

DESCRIPTION

This capacitor is of a construction with a highly etched aluminium plate anode, aluminium oxide as a dielectric and a solid cathode. The capacitor is coated with an orange synthetic resin. The terminal wires are brought out on one side.

The capacitor is available in two styles: style 1 with short wires, style 2 with long wires of which the anode wire has a flattened area at the end.

Note: Capacitors on tape are available in the course of 1982.

MECHANICAL DATA

Dimensions in mm

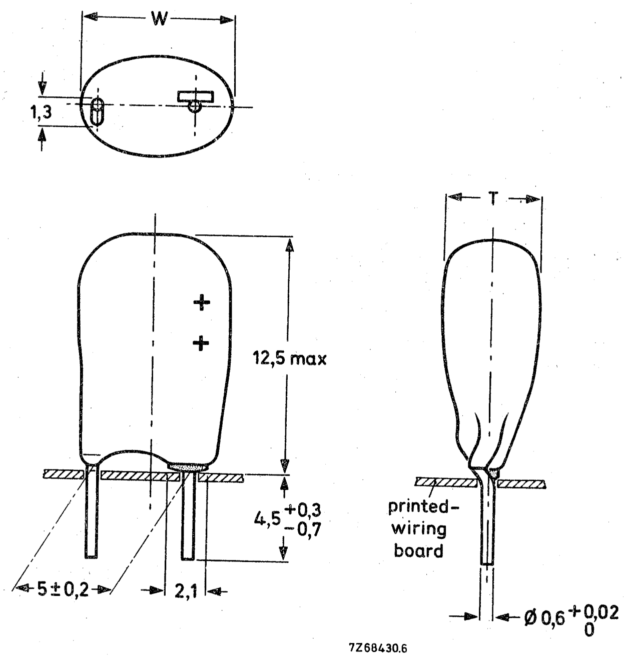


Fig. 1 Style 1; see Table 1 for dimensions T and W.

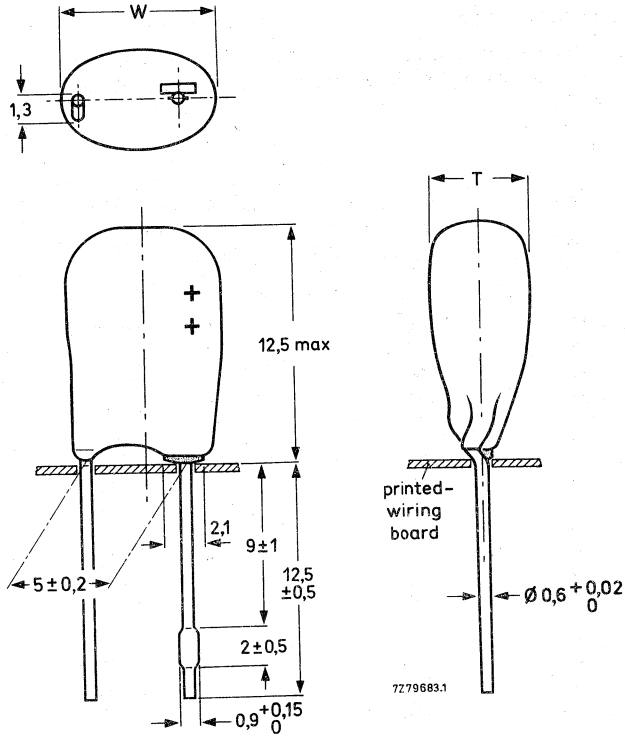


Fig. 2 Style 2; see Table 1 for dimensions T and W.

Table 1

case size	T_{max}	W_{max}
1	3,5	8
2	4,5	8
3	5	8
4	6	8

Note: A kink in the cathode wire avoids solder wetting problems of the lacquer dipped leads. The lacquer is so applied that it cannot pass beyond the centre of the kink, thus ensuring a clean surface of the part of the lead in the printed-wiring board hole. (Also suitable for use in plated-through holes).

Marking

Stamped on the capacitor are: nominal capacitance, rated voltage, "+" signs to identify the anode terminal, tolerance code (M = ± 20%, K = ± 10%), date code (year and month) and name of manufacturer.

Mounting

The diameter of the mounting holes in the printed-wiring board is 0,8 ± 0,1 mm, except that of the hole for the anode lead of style 2 capacitors: 1,3–0,2 mm.

When bending, cutting or straightening the leads, ensure that the capacitor body is relieved of stress.

ELECTRICAL DATA

Unless otherwise specified all electrical values in Table 2 apply at an ambient temperature of 20 to 25 °C, a frequency of 100 Hz, an atmospheric pressure of 93 to 106 kPa and a relative humidity of 45 to 75%.

Table 2

U_R V	nom. cap. μF	max. r.m.s. ripple current at 1 kHz, T_{amb} = 125 °C mA	max. leakage current at U_R after 15 s μA *	max. tan δ	max. impedance at 100 kHz* Ω	case size	catalogue number**
6,3	10	60	3	0,15	5	1	2222 122 .3109
	15	70	5	0,15	3	2	.3159
	22	90	7	0,15	1,3	2	.3229
	33	110	11	0,15	0,9	3	.3339
	47	140	15	0,15	0,7	4	.3479
	68	180	22	0,15	0,5	4	.3689
10	4,7	40	3	0,15	7	1	.4478
	6,8	50	4	0,15	5	1	.4688
	10	60	5	0,15	1,5	2	.4109
	15	75	8	0,15	1	2	.4159
	22	95	11	0,15	0,7	3	.4229
	33	125	17	0,15	0,5	4	.4339
16	2,2	35	2	0,10	10	1	.5228
	3,3	40	3	0,10	7	1	.5338
	4,7	50	4	0,10	2	2	.5478
	6,8	60	6	0,10	1,5	2	.5688
	10	80	8	0,10	1	3	.5109
	15	100	12	0,10	0,7	4	.5159
25	0,68	20	2	0,10	30	1	.6687
	1,0	25	2	0,10	20	1	.6108
	1,5	30	2	0,10	15	1	.6158
	2,2	35	3	0,10	10	2	.6228
	3,3	45	4	0,10	7	2	.6338
	4,7	55	6	0,10	5	3	.6478
	6,8	70	9	0,10	3	4	.6688
	10▲▲	85	13	0,10	2	4	
40▲	0,1	7,5	2	0,10	70	1	.7107
	0,15	10	2	0,10	50	1	.7157
	0,22	12,5	2	0,10	30	1	.7227
	0,33	15	2	0,10	30	1	.7337
	0,47	17,5	2	0,10	20	2	.7477
	0,68	20	2	0,10	15	2	.7687
	1,0	25	2	0,10	10	3	.7108
	1,5	30	3	0,10	7	4	.7158
	2,2	35	5	0,10	5	4	.7228
	3,3▲▲	45	7	0,10		4	

* Versions with lower values of max. leakage current or max. impedance are available to special order.
** Replace dot in catalogue number by 4 for style 1, tol. ±10%; 5 for style 1, tol. ±20%; 7 for style 2, tol. ±20%.
▲ Up to 85 °C; from 85 to 125 °C this value is 25 V. ▲▲ Available to special order.

Capacitance

Nominal capacitance values at 100 Hz and T_{amb} = 25 °C	see Table 2
Tolerance on nominal capacitance at 100 Hz	± 20%; ± 10%

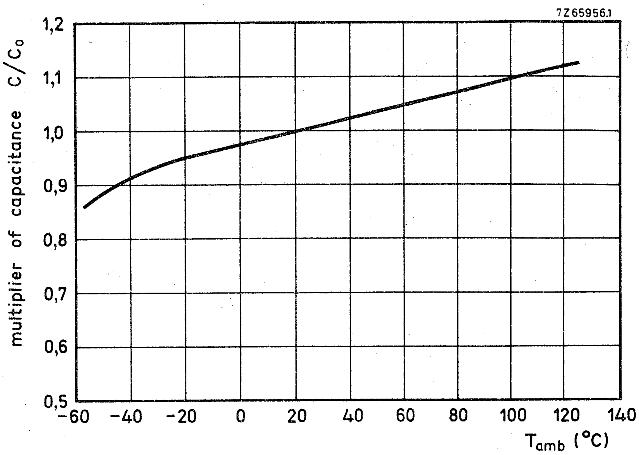


Fig. 3 Typical capacitance as a function of temperature; C_0 = capacitance at 25 °C, 100 Hz.

Voltage

Rated voltage	= max permissible voltage at ≤ 125 °C, for 6,3 to 25 V versions at ≤ 85 °C, for 40 V version	 U_R U_R
Derated voltage, for 40 V version only	= max permissible voltage at > 85 °C up to + 125 °C	 25 V
Surge voltage	= max permissible voltage for short periods (see also Tests and requirements)	 1,15 x U_R
Ripple voltage *	= max permissible a.c. voltage providing the following conditions are met: a) if a.c. + d.c. voltage is applied: • max (d.c. + peak a.c.) voltage • max peak a.c voltage b) if only a.c. voltage is applied: • max peak a.c. voltage (50 Hz)	 ≤ U_R ≤ applied d.c. voltage +0,3 U_R ≤ 0,8 x U_R
Reverse voltage	= max d.c. voltage applied in the reverse polarity at the maximum category temperature for short periods (see also Tests and requirements)	0,30 x U_R

* Ripple voltages are not applicable if the maximum permissible ripple current is exceeded. In that case the ripple current is decisive.

Ripple current *

The maximum permissible r.m.s. ripple current at 1 kHz and 85 °C (I_{ro}) is given in Table 2. The values in this table are based upon the maximum permissible heat dissipation, which is the dominating limiting factor at frequencies above 1 kHz. From 1 kHz onwards the maximum permissible ripple current can be found from the formula: $I_{r\,max} = \alpha .\ I_{ro}$; α is given in Fig. 4. In this graph the curves below 1 kHz are omitted, because at these frequencies the ripple voltage (see under Voltage) is the dominating limiting factor. For frequencies below 1 kHz $I_{r\,max}$ can be calculated from the formula:
$I_{r\,max} = \frac{1}{2}\pi\sqrt{2}.10^{-3}\ (U_R + 0{,}3\ U_R).f.C$ mA,
in which: U_R is rated voltage in V, f is frequency in Hz, C is minimum capacitance (0,8 C_{nom}) in μF.

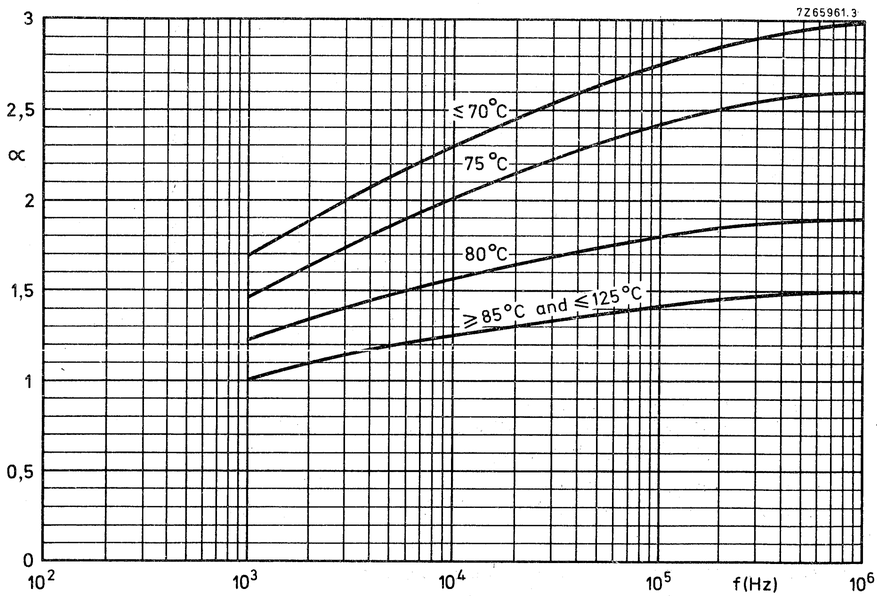


Fig. 4 Multiplying factor α as a function of frequency.

Charge and discharge current

The capacitors may be charged from a source without internal resistance and they may be discharged by short-circuiting. If the capacitors are charged and discharged continuously at a rate of several times per minute, the charge and discharge currents have to be considered as ripple currents flowing through the capacitor. The r.m.s. value of these currents should be determined and the value thus found must not exceed the applicable limit. (See also Tests and requirements.)

* Ripple currents are not applicable if the maximum permissible ripple voltage is exceeded. In that case the ripple voltage is decisive.

Leakage current

Maximum leakage current 15 s after application of the rated voltage, at T_{amb} = 25 °C	see Table 2 (0,05 CU or 2 μA whichever is greater)
Leakage current during continuous operation at U_R	
at 25 °C	approx. 0,02 x value stated in Table 2
at 85 °C	approx. 0,1 x value stated in Table 2

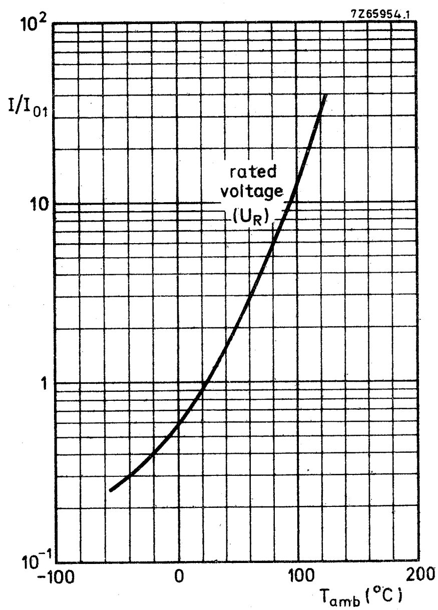


Fig. 5 Multiplier I/I_{01} as a function of temperature; I_{01} = leakage current during continuous operation at U_R, T_{amb} = 25 °C.

Tan δ (dissipation factor)

Maximum tan δ at 100 Hz and T_{amb} = 25 °C, measured by means of a four-terminal circuit (Thomson circuit)	see Table 2

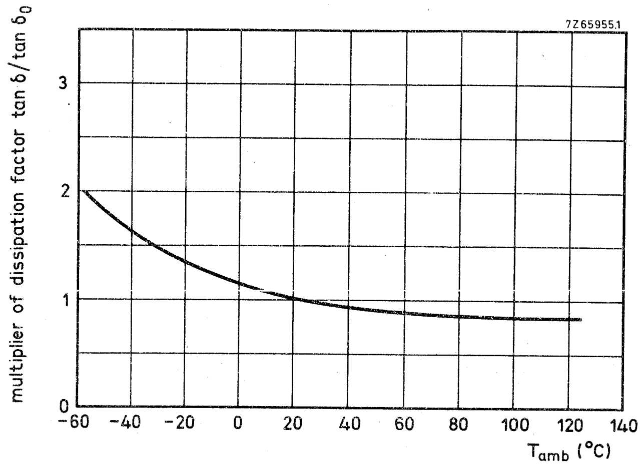


Fig. 6 Multiplier of dissipation factor as a function of temperature; tan δ_0 = dissipation factor at 25 °C, 100 Hz.

Impedance

Maximum impedance at 100 kHz and T_{amb} = 25 °C, measured by means of a four-terminal circuit (Thomson circuit) — see Table 2

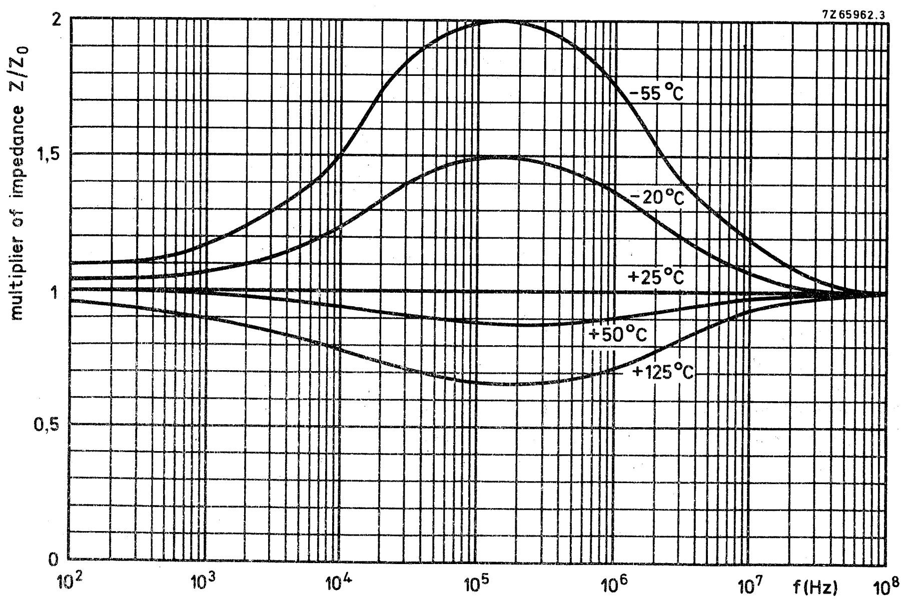


Fig. 7 Multiplier of impedance Z/Z_0 as a function of frequency at different temperatures; Z_0 = impedance initial value at 25 °C.

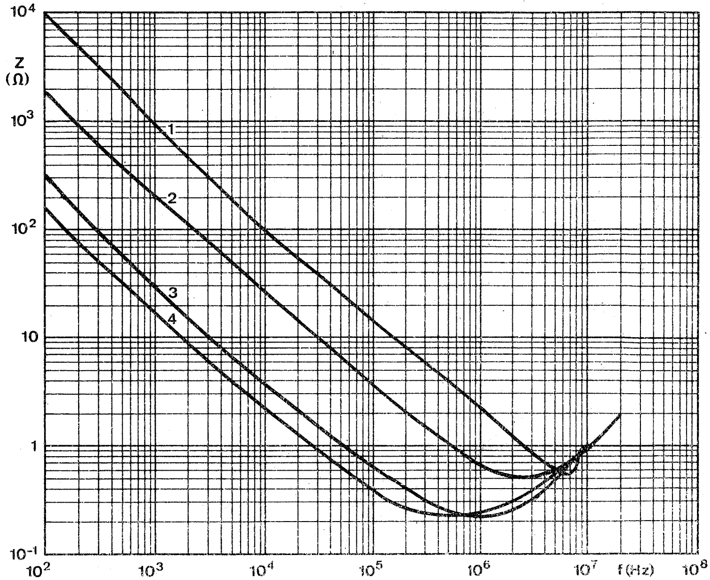


Fig. 8 Typical impedance as a function of frequency at 25 °C, case size 1. Curve 1 = 0,15 μF, 40 V; curve 2 = 0,68 μF, 25 V; curve 3 = 4,7 μF, 10 V; curve 4 = 10 μF, 6,3 V.

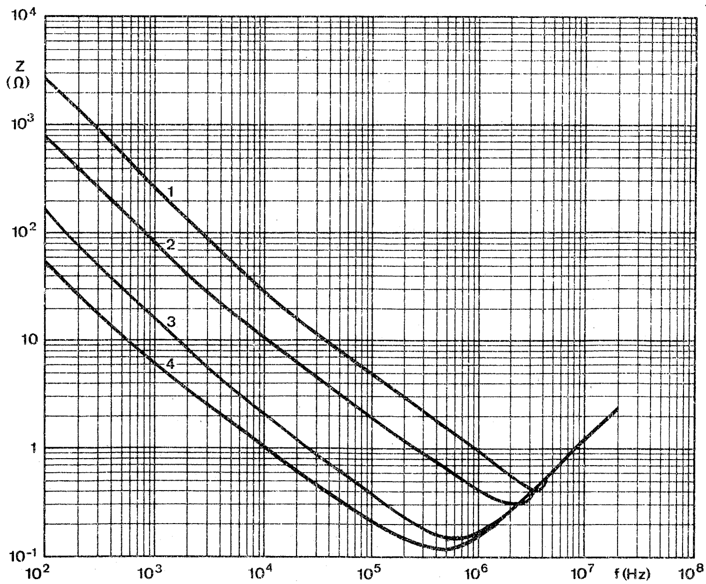


Fig. 9 Typical impedance as a function of frequency at 25 °C; case size 2. Curve 1 = 0,47 μF, 40 V; curve 2 = 2,2 μF, 25 V; curve 3 = 10 μF, 10 V; curve 4 = 22 μF, 6,3 V.

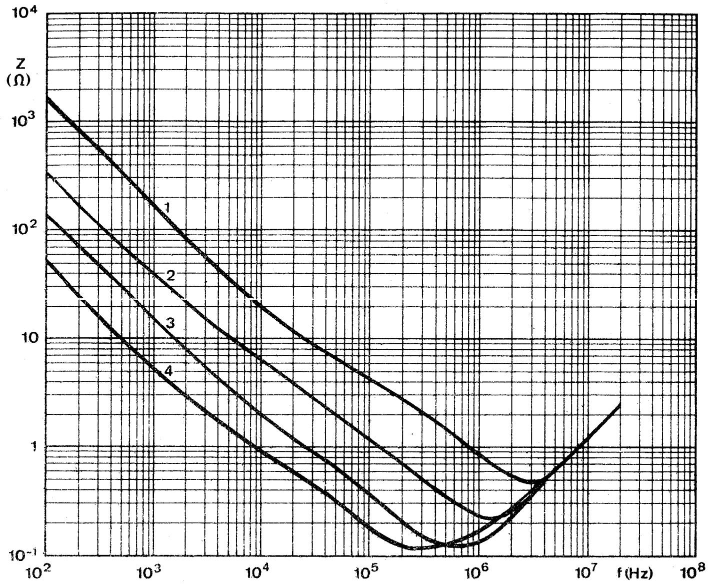


Fig. 10 Typical impedance as a function of frequency at 25 °C; **case size 3.** Curve 1 = 1 μF, 40 V; curve 2 = 4,7 μF, 25 V; curve 3 = 10 μF, 16 V; curve 4 = 33 μF, 6,3 V.

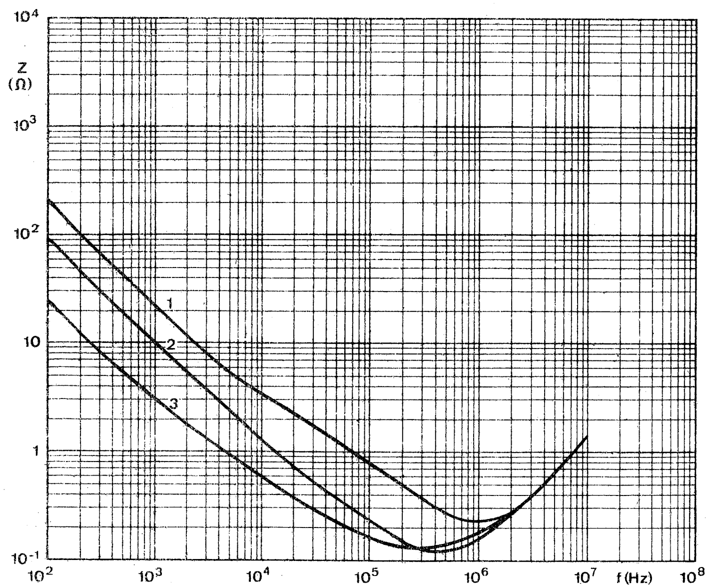


Fig. 11 Typical impedance as a function of frequency at 25 °C; **case size 4.** Curve 1 = 6,8 μF, 25 V; curve 2 = 15 μF, 16 V; curve 3 = 68 μF, 6,3 V.

Equivalent series resistance (ESR) at 100 Hz

$$ESR = \frac{\tan \delta}{\omega C}$$

Tan δ and C at 100 Hz see Table 2

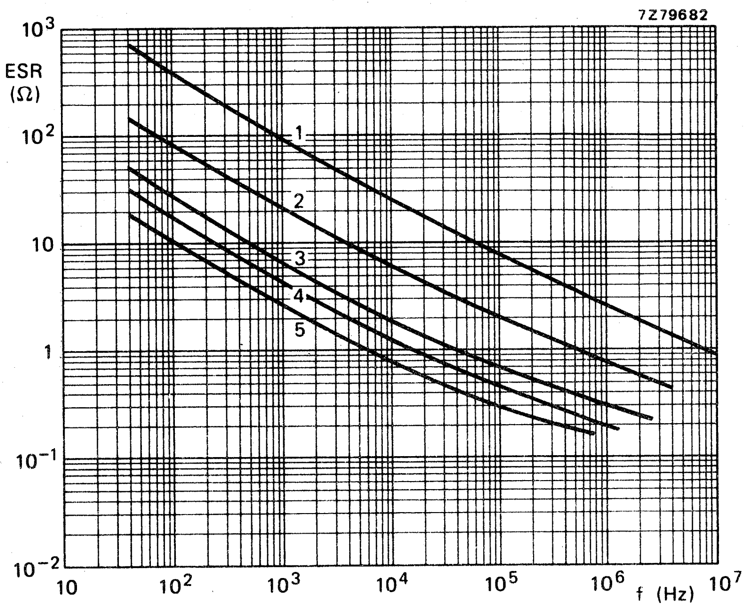


Fig. 12 Typical ESR as a function of frequency; **case size 1**. Curve 1 = 0,33 μF, 40 V; curve 2 = 1 μF, 25 V; curve 3 = 3,3 μF, 16 V; curve 4 = 4,7 μF, 10 V; curve 5 = 10 μF, 6,3 V.

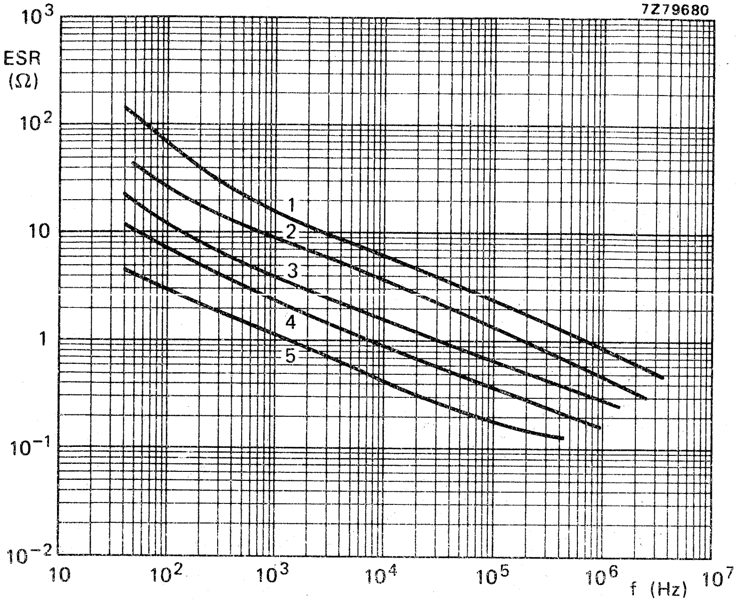


Fig. 13 Typical ESR as a function of frequency; **case size 2.** Curve 1 = 0,47 μF, 40 V; curve 2 = 2,2 μF, 25 V; curve 3 = 4,7 μF, 16 V; curve 4 = 10 μF, 10 V; curve 5 = 22 μF, 6,3 V.

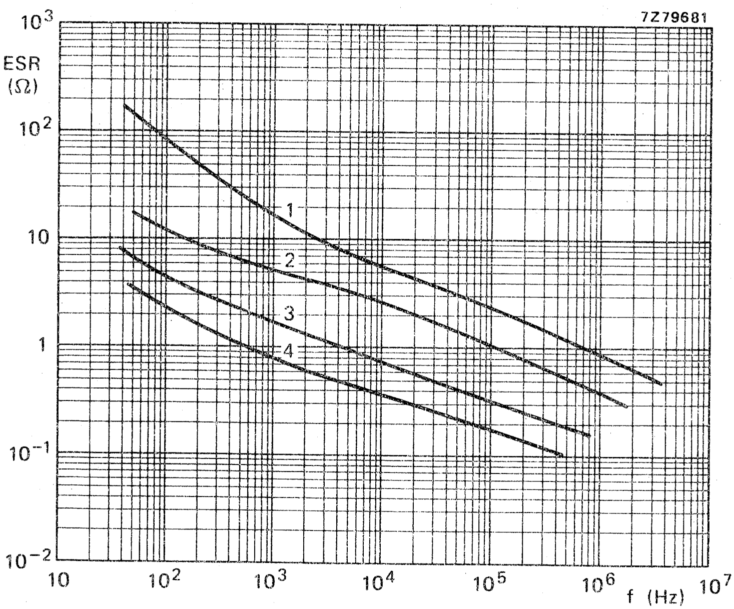


Fig. 14 Typical ESR as a function of frequency; **case size 3.** Curve 1 = 1 μF, 40 V; curve 2 = 4,7 μF, 25 V; curve 3 = 10 μF, 16 V; curve 4 = 33 μF, 6,3 V.

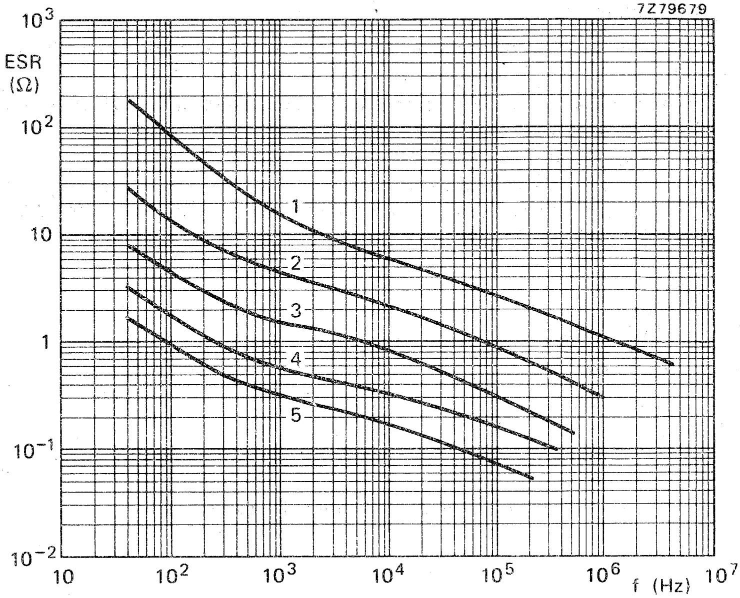


Fig. 15 Typical ESR as a function of frequency; **case size 4**. Curve 1 = 1,5 μF, 40 V; curve 2 = 6,8 μF, 25 V; curve 3 = 15 μF, 16 V; curve 4 = 33 μF, 10 V; curve 5 = 68 μF, 6,3 V.

OPERATIONAL DATA

Category temperature range

for rated voltage, U_R = 6,3 to 25 V	−55 to +125 °C
for rated voltage, U_R = 40 V	−55 to +85 °C
for derated voltage, U_R = 40 V	−55 to +125 °C

Life expectancy

at 85 °C	> 20 000 hours
at 125 °C	> 10 000 hours

PACKING

1000 pieces per box: 200 pieces per plastic bag, 5 bags per box.

TESTS AND REQUIREMENTS

See Introduction, section 9, under solid aluminium capacitors, with the addition of the following solvent resistance tests.

Conditions: immersion time of samples 5 min., at ambient temperature, at boiling temperature, in vapour of boiling solvent, and ultrasonic (40 kHz).

Solvents:
- deionized water (50 ± 5 ^{o}C);
- Calgonite solution (20 g/l, 70 ± 5 ^{o}C);
- mixture of 4,5% butylcellosolve, 4,5% mono-ethanolamine, and 91% water (70 ± 5 ^{o}C);
- I.I.I. trichloro-ethane;
- Arklone K*;
- Freon TMC**;
- Freon TE**;
- Freon TMS**.

→ Requirement: visual appearance not affected.

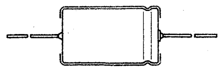
NOTE: After no-load tests leakage current measurements are done after 1 min.

* Trade mark of I.C.I.

** Trade mark of Dupont de Nemours.

SOLID ALUMINIUM CAPACITORS

- Enhanced capacitance
- Small type
- Axial leads; metal case
- Long life
- High reliability
- Industrial and military applications



QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	2,2 to 680 µF (1000 µF available to special order)
Tolerance on nominal capacitance	± 10% and ± 20%
Rated voltage range, U_R (R5 series)	6,3 to 40 V
Category temperature range	−55 to + 125 °C
Endurance test at 125 °C	2000 h
Basic specification	IEC 384-4, long-life grade
Climatic category, IEC 68	55/125/56

Selection chart for C_{nom}-U_R and relevant case sizes.

C_{nom} µF	U_R (V)				
	6,3	10	16	25	40
2,2					1
3,3					1
4,7					1
6,8					1
10			1	1	2
15			1		2
22			1	2	3
33		1	2	3	4
47	1	2	3	3	4
68		2	3	4	5
100	2	3	4	5	6
150	3	4	5	6	
220		4	6		
330	4	5			
470	5	6			
680	6				
1000*	6				

nominal dimensions (mm)	
1	Ø 6,5 x 17
2	Ø 6,5 x 22
3	Ø 8 x 22
4	Ø 10 x 22
5	Ø 10 x 31
6	Ø 12,5 x 31

* Available to special order.

APPLICATION

These capacitors with high CU-product per unit volume, utilize advanced technology to achieve long life, high stability, excellent reliability, high ripple current rating and low temperature dependence. The capacitors are not subject to a limitation on charge or discharge currents and they will function in circuits where voltage reversal may occur.

DESCRIPTION

The capacitor has etched aluminium foil electrodes separated by a layer of semiconductive material. The electrolyte is pyrolitically formed manganese dioxide. The capacitor is housed in an aluminium case with axial leads and is sealed by a ceramic disc. The cathode lead is welded to the case, which is insulated with a blue transparent plastic sleeve.

Note: Special versions are available, which withstand severe shock tests (10 000g, 0,1 ms) and vibration tests (50g or 7,5 mm, 10 to 2000 Hz).

MECHANICAL DATA

Dimensions in mm

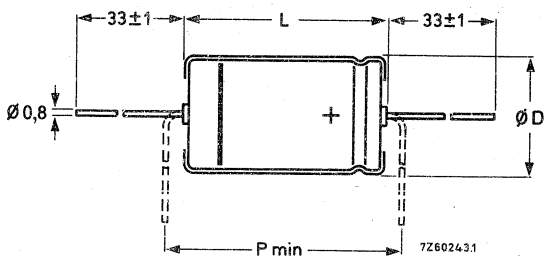


Fig. 1 For dimensions D, L and P, see Table 1.

Table 1

case size	D_{nom}	L_{nom}	D_{max}	L_{max}	P_{min}	mass approx. g
1	6,5	17	6,7	17,5	20	1,2
2	6,5	22	6,7	23	25	1,6
3	8	22	8,3	23	25	2,4
4	10	22	10,3	23	25	3,3
5	10	31	10,3	32	35	4,5
6	12,5	31	12,9	32	35	6,3

Marking

Stamped on the case are: catalogue number, capacitance, rated voltage, date code, a band to identify the negative terminal and "+" signs for the positive terminal.

Mounting

No special provisions are required for soldering to the tinned leads.
(2 mm of the anode lead nearest the body are not solderable.)

ELECTRICAL DATA

Table 2

Unless otherwise specified all electrical values in Table 2 apply at an ambient temperature of 20 to 25 °C, a frequency of 100 Hz, an atmospheric pressure of 86 to 106 kPa and a relative humidity of 45 to 75%.

U_R V	nom. cap. μF	max. r.m.s. ripple current at T_{amb} = 125 °C mA	max. leakage current at U_R after 1 min (μA)	max. tan δ	max. impedance at 100 kHz Ω	case size	catalogue number*
6,3	47	75	25	0,18	2,5	1	2222 123 .3479
	100	125	65	0,18	1,2	2	101
	150	170	70	0,18	0,8	3	151
	330	330	150	0,18	0,5	4	331
	470	400	300	0,18	0,4	5	471
	680	500	450	0,25	0,4	6	681
	1000**	600	650	0,25	0,4	6	102
10	33	70	30	0,16	2,5	1	.4339
	47	90	45	0,16	1,2	2	479
	68	110	70	0,16	1,2	2	689
	100	145	80	0,16	0,8	3	101
	150	220	150	0,16	0,5	4	151
	220	290	200	0,16	0,5	4	221
	330	350	330	0,16	0,4	5	331
	470	450	450	0,16	0,4	6	471
16	10	35	16	0,14	2,5	1	.5109
	15	50	24	0,14	2,5	1	159
	22	60	35	0,14	2,5	1	229
	33	100	55	0,14	1,2	2	339
	47	110	75	0,14	0,8	3	479
	68	150	110	0,14	0,8	3	689
	100	205	160	0,14	0,5	4	101
	150	250	240	0,14	0,4	5	151
	220	330	350	0,14	0,4	6	221
25	10	40	25	0,14	5	1	.6109
	22	70	55	0,14	2,5	2	229
	33	90	85	0,14	1,5	3	339
	47	130	120	0,14	1,5	3	479
	68	170	170	0,14	0,8	4	689
	100	200	250	0,14	0,8	5	101
	150	270	400	0,14	0,5	6	151

* Replace dot in catalogue number by:
1 for tolerance ± 20%;
2 for tolerance ± 10%;
3 for versions which withstand severe shocks and vibrations; tolerance ± 20%.

** Available to special order.

Table 2 (continued)

U_R V	nom. cap. μF	max. r.m.s. ripple current at T_{amb} = 125 °C mA	max. leakage current at U_R after 1 min (μA)	max. tan δ	max. impedance at 100 kHz Ω	case size	catalogue number*
40	2,2	20	9	0,12	5	1	2222 123 .7228
	3,3	25	13	0,12	5	1	338
	4,7	35	19	0,12	5	1	478
	6,8	40	27	0,12	5	1	688
	10	55	40	0,12	2,5	2	109
	15	65	60	0,12	2,5	2	159
	22	90	90	0,12	1,5	3	229
	33	125	130	0,12	0,8	4	339
	47	155	190	0,12	0,8	4	479
	68	200	270	0,12	0,8	5	689
	100	240	400	0,12	0,5	6	101

* Replace dot in catalogue number by:
1 for tolerance ± 20%;
2 for tolerance ± 10%;
3 for versions which withstand severe shocks and vibrations; tolerance ± 20%.

Capacitance

Nominal capacitance values at 100 Hz and T_{amb} = 20 °C — see Table 2

Tolerance on nominal capacitance at 100 Hz — ± 10% and ± 20%

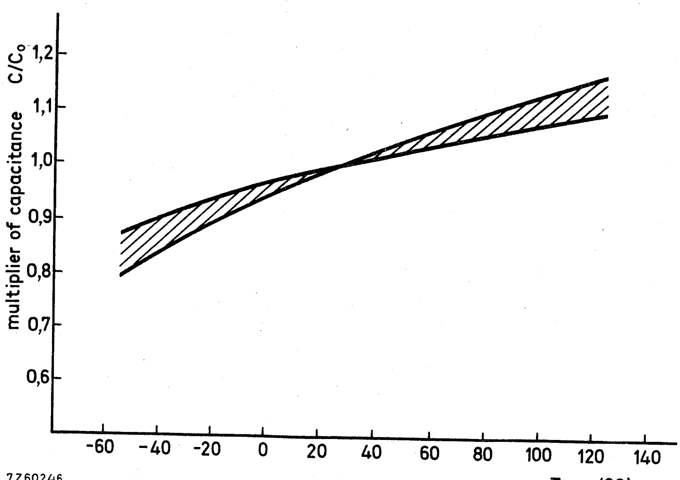


Fig. 2 Typical capacitance as a function of ambient temperature.
C_0 = capacitance at 25 °C, 100 Hz.

Voltage

Rated voltage	= max. permissible voltage	U_R
Ripple voltage*	= max. permissible a.c. voltage provising the following two conditions are met:	
	a) max. (d.c. + peak a.c.) voltage	$\leq U_R$
	b) max. peak a.c. voltage, 50 Hz without d.c. voltage applied	$0{,}8 \times U_R$
Surge voltage	= max. permissible voltage for short periods (see also "Tests and requirements")	$1{,}15 \times U_R$
Reverse voltage	= max. d.c. voltage continuously (2000 h) applied in the reverse polarity at the maximum category temperature	
	at $\leq$ 85 °C	$0{,}30 \times U_R$
	at > 85 °C up to 125 °C	$0{,}15 \times U_R$

Ripple current**

Maximum permissible r.m.s. ripple current at 100 Hz and T_{amb} = 125 °C — see Table 2

The maximum permissible ripple current ($I_{r\,max}$) is a function of temperature and frequency:

$$I_{r\,max} = I_{r0}\sqrt{kr}$$

where I_{r0} = max. ripple current at 100 Hz up to 125 °C, see Table 2
k = temperature derating factor = P_{max}/P_0
r = frequency dependent derating factor = R_{s0}/R_s

while P_{max} = max. permissible power dissipation, temperature dependent
P_0 = max. permissible power dissipation up to 125 °C = $(I_{r0})^2 R_{s0}$
R_{s0} = series resistance at 100 Hz = $\frac{\tan\delta}{628C}$, C and tan δ to be read from Table 2
R_s = series resistance, frequency dependent (temperature dependence neglected).

The formula is derived as follows:

$$(I_{r\,max})^2 = P_{max}/R_s = k(I_{r0})^2 R_{s0}/R_s;$$
$$\text{thus } I_{r\,max} = I_{r0}\sqrt{kr} \text{ (see Table 2 and Fig. 3)}$$

Leakage current

Maximum leakage current 1 min after application of the rated voltage	see Table 2
Typical leakage current 1 min after application of the rated voltage	0,15 of the value stated in Table 2
Leakage current during continuous operation at U_R,	
at 25 °C	approx. 0,1 x of value stated in Table 2
at 125 °C	approx. 5 x of value stated in Table 2

* Ripple voltages are not applicable if the maximum permissible ripple current is exceeded. In that case the ripple current is decisive.

** Ripple currents are not applicable is the maximum permissible ripple voltage is exceeded. In that case the ripple voltage is decisive.

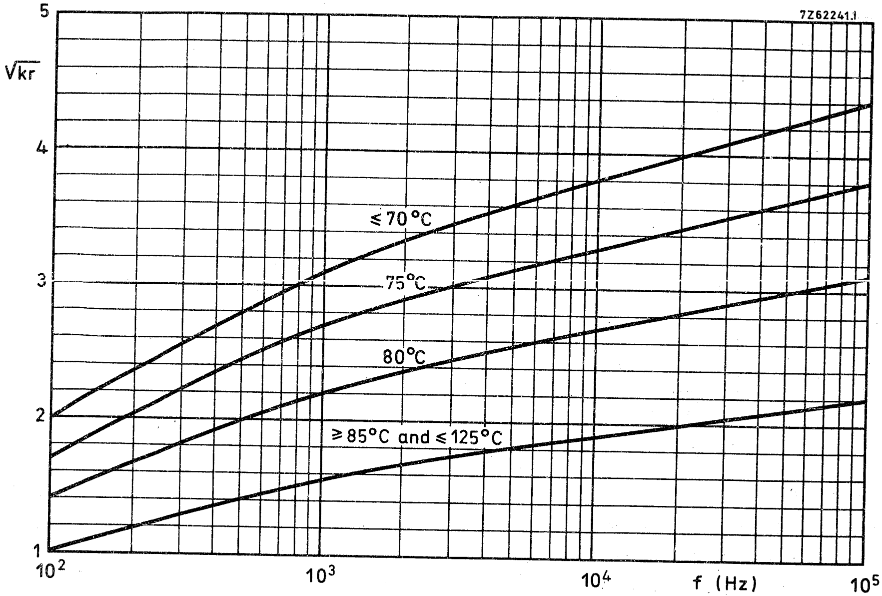


Fig. 3 Factor $\sqrt{kr}$ as a function of frequency for calculation of maximum ripple current.

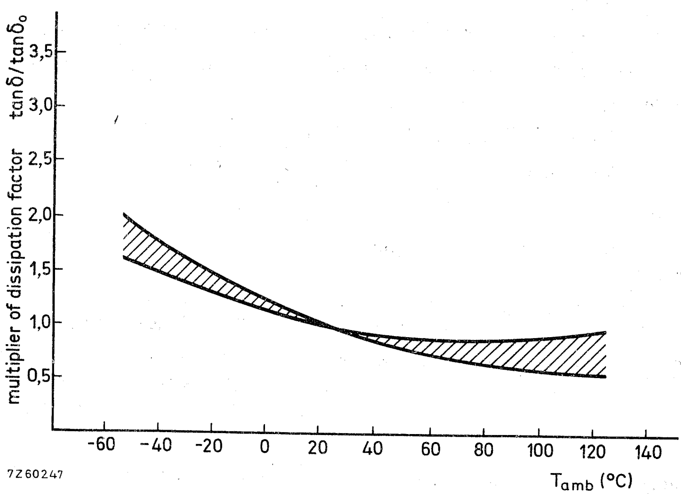


Fig. 4 Typical dissipation factor as a function of ambient temperature; $\tan \delta_0$ = dissipation factor at 25 °C, 100 Hz.

Tan δ (dissipation factor)

Tan δ at 100 Hz, measured by means of a four-terminal circuit (Thomson circuit) (max. values) — see Table 2

Impedance

Impedance at 100 kHz, measured by means of a four-terminal circuit (Thomson circuit) (max. values) — see Table 2

Typical impedance at 100 kHz — 0,5 of the stated limits in Table 2

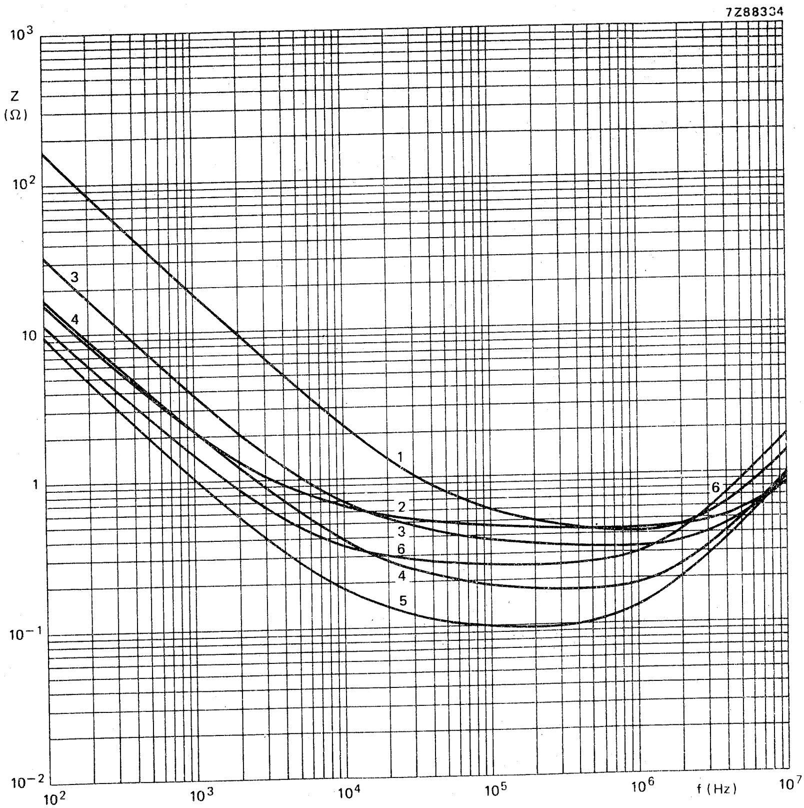


Fig. 5 Typical impedance as a function of frequency at 25 °C.

curve 1 = case size 1, 10 μF, 16 V;
curve 2 = case size 2, 100 μF, 6,3 V;
curve 3 = case size 3, 47 μF, 16 V;
curve 4 = case size 4, 100 μF, 16 V;
curve 5 = case size 5, 150 μF, 16 V;
curve 6 = case size 6, 150 μF, 25 V.

Equivalent series resistance (ESR)

$$ESR = \frac{\tan \delta}{\omega C}$$

Tan δ and C at 100 Hz — see Table 2

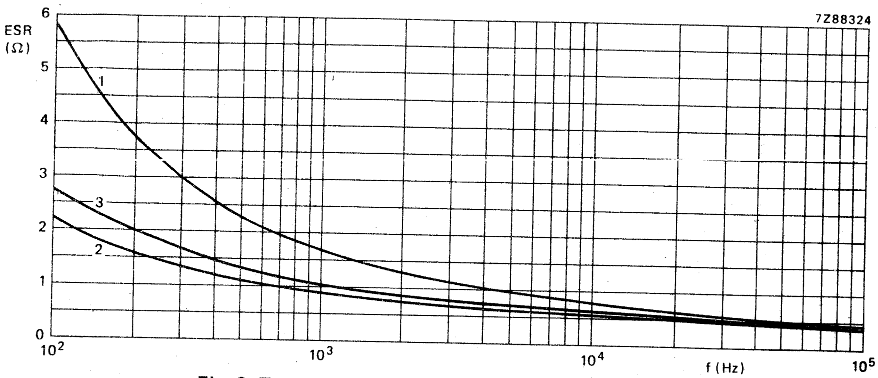


Fig. 6 Typical ESR as a function of frequency at 25 °C.
curve 1 = case size 1, 10 μF, 16 V; curve 2 = case size 2, 100 μF, 6,3 V; curve 3 = case size 3, 47 μF, 16 V.

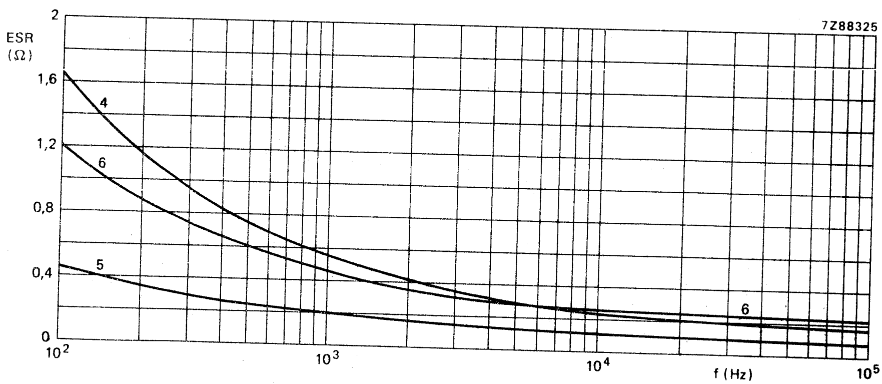


Fig. 7 Typical ESR as a function of frequency at 25 °C.
curve 4 = case size 4, 100 μF, 16 V; curve 5 = case size 5, 150 μF, 16 V; curve 6 = case size 6, 150 μF, 25 V.

OPERATIONAL DATA

Category temperature range	−55 to + 125 °C
Life expectancy at 125 °C and U_R	> 20 000 hours

PACKING

100 pieces per box.

TEST AND REQUIREMENTS

See Handbook C14, Introduction, section 9, under solid aluminium capacitors.

SOLID TANTALUM CAPACITORS

SOLID TANTALUM CAPACITORS
hermetic seal tubular case, axial leads
style CSR13 according to MIL-C-39003/01; established reliability

QUICK REFERENCE DATA

Nominal capacitance range (E12 series)	0,1 to 330 μF
Tolerance on nominal capacitance	±20% and ±10% (±5% on request)
Rated voltage range, U_R	6 to 75 V (100 V on request)
Category temperature range	
at U_R	−55 to +85 °C
at 0,67 U_R	−55 to +125 °C
Basic specification	MIL-C-39003/01, style CSR13
Climatic category, IEC68	
at U_R	55/085/56
at 0,67 U_R	55/125/56

Selection chart for C-U_R and relevant case sizes

C_{nom} μF	U_R (V) 10	15	20	35	50	75
0,1					A	A
0,12					A	A
0,15					A	A
0,18					A	A
0,22					A	A
0,27					A	A
0,33					A	A
0,39					A	A
0,47					A	A
0,56					A	A
0,68					A	A
0,82					A	B
1					A	B
1,2			A		B	B
1,5			A		B	B
1,8			A		B	B
2,2			A		B	B
2,7		A			B	B
3,3		A			B	B
3,9	A				B	B
4,7	A				B	C

C_{nom} μF	U_R (V) 6	10	15	20	35	50	75
5,6	A				B	C	C
6,8	A				B	C	C
8,2				B		C	C
10				B		C	C
12				B		C	D
15				B		C	D
18			B			C	
22			B		C	D	
27		B		C	D		
33		B		C	D		
39		B		C	D		
47	B			C	D		
56	B		C	D			
68			C	D			
82		C		D			
100		C		D			
120		C	D				
150	C		D				
180	C	D					
220		D					
270	D						
330	D						

APPLICATION

These capacitors are designed for circuit functions such as:

- bypassing;
- coupling and decoupling;
- filtering;
- blocking;
- timing.

They are intended for use in polarized or d.c. biased circuits where the a.c. component is small compared to the d.c. rated voltage.

DESCRIPTION

The capacitors consist of a highly purified sintered tantalum anode body utilizing an electrolytically formed oxide dielectric, and a solid electrolyte, enclosed in a hermetically sealed insulated metal case with axial leads. Standard construction includes tin-lead plated leads.

MECHANICAL DATA

Dimensions in mm (including insulation)

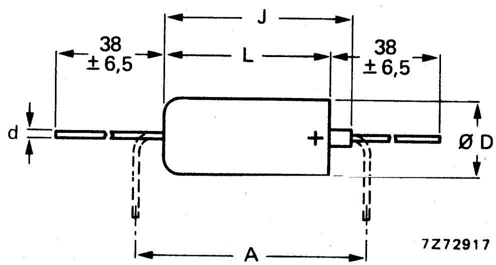


Fig.1.

Table 1

case size	A	D		L		J_{max}	d		approx. mass g
A	12,7	3,43	+0,41 −0,38	7,26	±0,79	10,72	0,51	±0,05	0,7
B	17,8	4,70		12,04		15,49	0,51		1,6
C	25,4	7,34		17,42		20,88	0,64		4,9
D	27,9	8,92		19,96		23,42	0,64		8,8

Marking

The capacitors are marked as follows:

1st line, all case sizes : military specification number;
2nd line, case sizes A and B : specification sheet number and trade mark;
2nd line, case sizes C and D : specification sheet number, dash number and J (for JAN) *;
3rd line, case sizes A and B : dash number and J (for JAN) *;
3rd line, case sizes C and D : polarity, date code (year and week) and lot code;
4th line, case sizes A and B : polarity, date code (year and week) and lot code;
4th line, case sizes C and D : polarity and nominal capacitance;
5th line, case size B : source code number of manufacturer;
5th line, case sizes C and D : tolerance on nominal capacitance and rated voltage;
6th line, case size B : nominal capacitance, tolerance on nominal capacitance and rated voltage;
6th line, case sizes C and D : source code number of manufacturer.

Marking examples of capacitors with different case sizes:

case size A	case size B	case size C and D
39003	M 39003	M 39003/
01–N	01–N	01–2261 J
2001 J	2246 J	+ 7626 C
+ 7626 A	+ 7626 B	+ 100 μF
	26769	10% 10 V
	56 K 6 V **	26769

* Not for failure rate level L.
** K = ±10%, M = ±20%, J = ±5%.

ELECTRICAL DATA

Table 2

Unless otherwise specified all electrical values apply at an ambient temperature of 20 to 25 °C, a frequency of 100 Hz, an atmospheric pressure of 860 to 1060 mbar and a relative humidity of 45 to 75%. Notes are at the end of the table.

MIL type designation (note 1)	U_R	nom. cap.	cap. tol.	max. leakage current at U_R after 5 min (μA) at			tan δ (%) at		case size	cat. no. 2222 141 ..... for failure rate level (% per 1000 h) (note 2)				
	V	μF	%	+25 °C	+85 °C	+125 °C	−55 °C +25 °C	+85 °C +125 °C		2,0 L	1,0 M	0,1 P	0,01 R	0,001 S
CSR13B565K	6	5,6	10	0,3	6	7,5	4	4	A	20011	22411	24811	27211	29611
CSR13B685K	6	6,8	10	0,3	6	7,5	6	6	A	20021	22421	24821	27221	29621
CSR13B685M	6	6,8	20	0,3	6	7,5	6	6	A	20031	22431	24831	27231	29631
CSR13B476K	6	47	10	1,5	24	30	6	6	B	20042	22442	24842	27242	29642
CSR13B476M	6	47	20	1,5	24	30	6	6	B	20052	22452	24852	27252	29652
CSR13B566K	6	56	10	1,5	24	30	6	6	B	20062	22462	24862	27262	29662
CSR13B157K	6	150	10	4,5	90	113	8	8	C	20073	22473	24873	27273	29673
CSR13B157M	6	150	20	4,5	90	113	8	8	C	20083	22483	24883	27283	29683
CSR13B187K	6	180	10	5,5	110	138	8	8	C	20093	22493	24893	27293	29693
CSR13B277K	6	270	10	6,5	130	163	8	8	D	20104	22504	24904	27304	29704
CSR13B337K	6	330	10	7,5	150	188	8	8	D	20114	22514	24914	27314	29714
CSR13B337M	6	330	20	7,5	150	188	8	8	D	20124	22524	24924	27324	29724
CSR13C395K	10	3,9	10	0,3	6	7,5	4	4	A	20131	22531	24931	27331	29731
CSR13C475K	10	4,7	10	0,4	7	8,6	4	4	A	20141	22541	24941	27341	29741
CSR13C475M	10	4,7	20	0,4	7	8,8	4	4	A	20151	22551	24951	27351	29751
CSR13C276K	10	27	10	2	40	50	6	6	B	20162	22562	24962	27362	29762
CSR13C336K	10	33	10	2,5	50	63	6	6	B	20172	22572	24972	27372	29772
CSR13C336M	10	33	20	2,5	50	63	6	6	B	20182	22582	24982	27382	29782
CSR13C396K	10	39	10	2,5	50	63	6	6	B	20192	22592	24992	27392	29792
CSR13C826K	10	82	10	4	80	100	6	6	C	20203	22603	25003	27403	29803
CSR13C107K	10	100	10	5	100	125	8	8	C	20213	22613	25013	27413	29813
CSR13C107M	10	100	20	5	100	125	8	8	C	20223	22623	25023	27423	29823
CSR13C127K	10	120	10	6	120	150	8	8	C	20233	22633	25033	27433	29833
CSR13C187K	10	180	10	9	180	226	8	8	D	20244	22644	25044	27444	29844

CSR13C227K	10	220	10	10	200	250	8	8	D	20254	22654	25054	27454	29854
CSR13C227M	10	220	10	20	200	250	8	8	D	20264	22664	25064	27464	29864
CSR13D275K	15	2,7	10	0,3	6	7,5	4	4	A	20271	22671	25071	27471	29871
CSR13D335K	15	3,3	10	0,4	8	10	4	4	A	20281	22681	25081	27481	29881
CSR13D335M	15	3,3	20	0,4	8	10	4	4	A	20291	22691	25091	27491	29891
CSR13D186K	15	18	10	2	35	44	6	6	B	20302	22702	25102	27502	29902
CSR13D226K	15	22	10	2	40	50	6	6	B	20312	22712	25112	27512	29912
CSR13D226M	15	22	20	2	40	50	6	6	B	20322	22722	25122	27522	29922
CSR13D566K	15	56	10	4	80	100	6	6	C	20333	22733	25133	27533	29933
CSR13D686K	15	68	10	5	100	125	6	6	C	20343	22743	25143	27543	29943
CSR13D686M	15	68	20	5	100	125	6	6	C	20353	22753	25153	27553	29953
CSR13D127K	15	120	10	9	180	226	8	8	D	20364	22764	25164	27564	29964
CSR13D157K	15	150	10	10	200	250	8	8	D	20374	22774	25174	27574	29974
CSR13D157M	15	150	20	10	200	250	8	8	D	20384	22784	25184	27584	29984
CSR13E125K	20	1,2	10	0,3	6	7,5	4	4	A	20391	22791	25191	27591	29991
CSR13E155K	20	1,5	10	0,3	6	7,5	4	4	A	20401	22801	25201	27601	30001
CSR13E155M	20	1,5	20	0,3	6	7,5	4	4	A	20411	22811	25211	27611	30011
CSR13E185K	20	1,8	10	0,3	6	7,5	4	4	A	20421	22821	25221	27621	30021
CSR13E225K	20	2,2	10	0,4	8	10	4	4	A	20431	22831	25231	27631	30031
CSR13E225M	20	2,2	20	0,4	8	10	4	4	A	20441	22841	25241	27641	30041
CSR13E825K	20	8,2	10	1	20	25	6	6	B	20452	22852	25252	27652	30052
CSR13E106K	20	10	10	1,5	30	38	6	6	B	20462	22862	25262	27662	30062
CSR13E106M	20	10	20	1,5	30	38	6	6	B	20472	22872	25272	27672	30072
CSR13E126K	20	12	10	1,8	35	44	6	6	B	20482	22882	25282	27682	30082
CSR13E156K	20	15	10	2	40	50	6	6	B	20492	22892	25292	27692	30092
CSR13E156M	20	15	20	2	40	50	6	6	B	20502	22902	25302	27702	30102
CSR13E276K	20	27	10	2,5	50	63	6	6	C	20513	22913	25313	27713	30113
CSR13E336K	20	33	10	3,5	70	88	6	6	C	20523	22923	25323	27723	30123
CSR13E336M	20	33	20	3,5	70	88	6	6	C	20533	22933	25333	27733	30133
CSR13E396K	20	39	10	4	80	100	6	6	C	20543	22943	25343	27743	30143
CSR13E476K	20	47	10	4,5	90	113	6	6	C	20553	22953	25353	27753	30153
CSR13E476M	20	47	20	4,5	90	113	6	6	C	20563	22963	25363	27763	30163
CSR13E566K	20	56	10	5,5	110	138	6	6	D	20574	22974	25374	27774	30174
CSR13E686K	20	68	10	7	140	175	6	6	D	20584	22984	25384	27784	30184
CSR13E686M	20	68	20	7	140	175	6	6	D	20594	22994	25394	27794	30194
CSR13E826K	20	82	10	8	160	200	6	6	D	20604	23004	25404	27804	30204

Table 2 (continued)

MIL type designation (note 1)	U_R	nom. cap.	cap. tol.	max. leakage current at U_R after 5 min (μA) at			tan δ (%) at		case size	cat. no. 2222 141 ..... for failure rate level (% per 1000 h) (note 2)				
	V	μF	%	+25 °C	+85 °C	+125 °C	−55 °C +25 °C	+85 °C +125 °C		2,0 L	1,0 M	0,1 P	0,01 R	0,001 S
CSR13E107K	20	100	10	10	200	250	8	8	D	20614	23014	25414	27814	30214
CSR13E107M	20	100	20	10	200	250	8	8	D	20624	23024	25424	27824	30224
CSR13F565K	35	5,6	10	1,3	25	32	4	4	B	20632	23032	25432	27832	30232
CSR13F685K	35	6,8	10	1,5	30	38	6	6	B	20642	23042	25442	27842	30242
CSR13F685M	35	6,8	20	1,5	30	38	6	6	B	20652	23052	25452	27852	30252
CSR13F226K	35	22	10	4	80	100	6	6	C	20663	23063	25463	27863	30263
CSR13F226M	35	22	20	4	80	100	6	6	C	20673	23073	25473	27873	30273
CSR13F276K	35	27	10	4,5	90	113	6	6	D	20684	23084	25484	27884	30284
CSR13F336K	35	33	10	5,5	110	138	6	6	D	20694	23094	25494	27894	30294
CSR13F336M	35	33	20	5,5	110	138	6	6	D	20704	23104	25504	27904	30304
CSR13F396K	35	39	10	7	140	175	6	6	D	20714	23114	25514	27914	30314
CSR13F476K	35	47	10	8	160	200	6	6	D	20724	23124	25524	27924	30324
CSR13F476M	35	47	20	8	160	200	6	6	D	20734	23134	25534	27934	30334
CSR13G104K	50	0,1	10	0,3	5	6,3	2	4	A	20981	23381	25781	28181	30581
CSR13G104M	50	0,1	20	0,3	5	6,3	2	4	A	20991	23391	25791	28191	30591
CSR13G124K	50	0,12	10	0,3	5	6,3	2	4	A	21001	23401	25801	28201	30601
CSR13G154K	50	0,15	10	0,3	5	6,3	2	4	A	21011	23411	25811	28211	30611
CSR13G154M	50	0,15	20	0,3	5	6,3	2	4	A	21021	23421	25821	28221	30621
CSR13G184K	50	0,18	10	0,3	5	6,3	2	4	A	21031	23431	25831	28231	30631
CSR13G224K	50	0,22	10	0,3	5	6,3	2	4	A	21041	23441	25841	28241	30641
CSR13G224M	50	0,22	20	0,3	5	6,3	2	4	A	21051	23451	25851	28251	30651
CSR13G274K	50	0,27	10	0,3	5	6,3	2	4	A	21061	23461	25861	28261	30661
CSR13G334K	50	0,33	10	0,3	5	6,3	2	4	A	21071	23471	25871	28271	30671
CSR13G334M	50	0,33	20	0,3	5	6,3	2	4	A	21081	23481	25881	28281	30681
CSR13G394K	50	0,39	10	0,3	5	6,3	2	4	A	21091	23491	25891	28291	30691
CSR13G474K	50	0,47	10	0,3	5	6,3	2	4	A	21101	23501	25901	28301	30701
CSR13G474M	50	0,47	20	0,3	5	6,3	2	4	A	21111	23511	25911	28311	30711
CSR13G564K	50	0,56	10	0,3	5	6,3	2	4	A	21121	23521	25921	28321	30721

CSR13G684K	50	0,68	10	0,3	5	6,3	2	4	A	21131	23531	25931	28331	30731
CSR13G684M	50	0,68	20	0,3	5	6,3	2	4	A	21141	23541	25941	28341	30741
CSR13G824K	50	0,82	10	0,3	5	6,3	2	4	A	21151	23551	25951	28351	30751
CSR13G105K	50	1	10	0,4	8	10	2	4	A	21161	23561	25961	28361	30761
CSR13G105M	50	1	20	0,4	8	10	2	4	A	21171	23571	25971	28371	30771
CSR13G125K	50	1,2	10	0,4	9	11	4	4	B	21182	23582	25982	28382	30782
CSR13G155K	50	1,5	10	0,6	12	15	4	4	B	21192	23592	25992	28392	30792
CSR13G155M	50	1,5	20	0,6	12	15	4	4	B	21202	23602	26002	28402	30802
CSR13G185K	50	1,8	10	0,7	14	18	4	4	B	21212	23612	26012	28412	30812
CSR13G225K	50	2,2	10	0,8	17	22	4	4	B	21222	23622	26022	28422	30822
CSR13G225M	50	2,2	20	0,8	17	22	4	4	B	21232	23632	26032	28432	30832
CSR13G275K	50	2,7	10	1	20	25	4	4	B	21242	23642	26042	28442	30842
CSR13G335K	50	3,3	10	1,2	25	32	4	4	B	21252	23652	26052	28452	30852
CSR13G335M	50	3,3	20	1,2	25	32	4	4	B	21262	23662	26062	28462	30862
CSR13G395K	50	3,9	10	1,5	30	38	4	4	B	21272	23672	26072	28472	30872
CSR13G475K	50	4,7	10	1,7	35	44	4	4	B	21282	23682	26082	28482	30882
CSR13G475M	50	4,7	20	1,7	35	44	4	4	B	21292	23692	26092	28492	30892
CSR13G565K	50	5,6	10	2,2	45	56	4	4	C	21303	23703	26103	28503	30903
CSR13G685K	50	6,8	10	2,2	45	56	6	6	C	21313	23713	26113	28513	30913
CSR13G685M	50	6,8	20	2,2	45	56	6	6	C	21323	23723	26123	28523	30923
CSR13G825K	50	8,2	10	2,5	50	63	6	6	C	21333	23733	26133	28533	30933
CSR13G106K	50	10	10	2,5	50	63	6	6	C	21343	23743	26143	28543	30943
CSR13G106M	50	10	20	2,5	50	63	6	6	C	21353	23753	26153	28553	30953
CSR13G126K	50	12	10	3	60	75	6	6	C	21363	23763	26163	28563	30963
CSR13G156K	50	15	10	4	80	100	6	6	C	21373	23773	26173	28573	30973
CSR13G156M	50	15	20	4	80	100	6	6	C	21383	23783	26183	28583	30983
CSR13G186K	50	18	10	4,5	90	113	6	6	C	21393	23793	26193	28593	30993
CSR13G226K	50	22	10	5,5	110	138	6	6	D	21404	23804	26204	28604	31004
CSR13G226M	50	22	20	5,5	110	138	6	6	D	21414	23814	26214	28614	31014
CSR13H104K	75	0,1	10	0,3	5	6,3	2	4	A	21421	23821	26221	28621	31021
CSR13H104M	75	0,1	20	0,3	5	6,3	2	4	A	21431	23831	26231	28631	31031
CSR13H124K	75	0,12	10	0,3	5	6,3	2	4	A	21441	23841	26241	28641	31041
CSR13H154K	75	0,15	10	0,3	5	6,3	2	4	A	21451	23851	26251	28651	31051
CSR13H154M	75	0,15	20	0,3	5	6,3	2	4	A	21461	23861	26261	28661	31061
CSR13H184K	75	0,18	10	0,3	5	6,3	2	4	A	21471	23871	26271	28671	31071
CSR13H224K	75	0,22	10	0,3	5	6,3	2	4	A	21481	23881	26281	28681	31081
CSR13H224M	75	0,22	20	0,3	5	6,3	2	4	A	21491	23891	26291	28691	31091

Table 2 (continued)

MIL type designation (note 1)	U_R	nom. cap.	cap. tol.	max. leakage current at U_R after 5 min (μA) at			tan δ (%) at		case size	cat. no. 2222 141 ..... for failure rate level (% per 1000 h) (note 2)				
	V	μF	%	+25 °C	+85 °C	+125 °C	−55 °C +25 °C	+85 °C +125 °C		2,0 L	1,0 M	0,1 P	0,01 R	0,001 S
CSR13H274K	75	0,27	10	0,3	5	6,3	2	4	A	21501	23901	26301	28701	31101
CSR13H334K	75	0,33	10	0,3	5	6,3	2	4	A	21511	23911	26311	28711	31111
CSR13H334M	75	0,33	20	0,3	5	6,3	2	4	A	21521	23921	26321	28721	31121
CSR13H394K	75	0,39	10	0,3	5	6,3	2	4	A	21531	23931	26331	28731	31131
CSR13H474K	75	0,47	10	0,3	5	6,3	2	4	A	21541	23941	26341	28741	31141
CSR13H474M	75	0,47	20	0,3	5	6,3	2	4	A	21551	23951	26351	28751	31151
CSR13H564K	75	0,56	10	0,3	5	6,3	2	4	A	21561	23961	26361	28761	31161
CSR13H684K	75	0,68	10	0,3	5	6,3	2	4	A	21571	23971	26371	28771	31171
CSR13H684M	75	0,68	20	0,3	5	6,3	2	4	A	21581	23981	26381	28781	31181
CSR13H824K	75	0,82	10	0,3	5	6,3	2	4	B	21592	23992	26392	28792	31192
CSR13H105K	75	1	10	0,3	5	6,3	2	4	B	21602	24002	26402	28802	31202
CSR13H105M	75	1	20	0,3	5	6,3	4	4	B	21612	24012	26412	28812	31212
CSR13H125K	75	1,2	10	0,3	5	6,3	4	4	B	21622	24022	26422	28822	31222
CSR13H155K	75	1,5	10	0,5	10	13	4	4	B	21632	24032	26432	28832	31232
CSR13H155M	75	1,5	20	0,5	10	13	4	4	B	21642	24042	26442	28842	31242
CSR13H185K	75	1,8	10	0,5	10	13	4	4	B	21652	24052	26452	28852	31252
CSR13H225K	75	2,2	10	0,7	10	19	4	4	B	21662	24062	26462	28862	31262
CSR13H225M	75	2,2	20	0,7	15	19	4	4	B	21672	24072	26472	28872	31272
CSR13H275K	75	2,7	10	0,7	15	19	4	4	B	21682	24082	26482	28882	31282
CSR13H335K	75	3,3	10	1	20	25	4	4	B	21692	24092	26492	28892	31292
CSR13H335M	75	3,3	20	1	20	25	4	4	B	21702	24102	26502	28902	31302
CSR13H395K	75	3,9	10	1	20	25	4	4	B	21712	24112	26512	28912	31312
CSR13H475K	75	4,7	10	3	60	75	4	4	C	21723	24123	26523	28923	31323
CSR13H475M	75	4,7	20	3	60	75	4	4	C	21733	24133	26533	28933	31333
CSR13H565K	75	5,6	10	3	60	75	4	4	C	21743	24143	26543	28943	31343
CSR13H685K	75	6,8	10	5	100	125	6	6	C	21753	24153	26553	28953	31353
CSR13H685M	75	6,8	20	5	100	125	6	6	C	21763	24163	26563	28963	31363
CSR13H825K	75	8,2	10	5	100	125	6	6	C	21773	24173	26573	28973	31373
CSR13H106K	75	10	10	5	100	125	6	6	C	21783	24183	26583	28983	31383

CSR13H106M	75	10	20	5	100	125	6	6	C	21793	24193	26593	28993	31393
CSR13H126K	75	12	10	5	100	125	6	6	D	21804	24204	26604	29004	31404
CSR13H156K	75	15	10	7	140	175	6	6	D	21814	24214	26614	29014	31414
CSR13H156M	75	15	20	7	140	175	6	6	D	21824	24224	26624	29024	31424

Note 1: Complete MIL type designation will include an additional symbol to indicate failure rate level; see also MIL coding system.
Note 2: Failure rate level L (2%) has been made obsolete by MIL-C-39003/1E. It is available for purchase but cannot carry a JAN marking.
Note 3: The following capacitor versions are available on request:
U_R = 75 V: 0,0047 to 0,82 μF (E12 series), case size A;
U_R = 100 V: 0,0047 to 0,56 μF (E12 series), case size A and 0,68 to 2,7 μF (E12 series), case size B.
On request the above-mentioned capacitance values, and all capacitance values in Table 2, are available with a tolerance of ±5%.

Military coding system

CSR13. . . . .

style: established reliability sintered tantalum anode solid electrolyte capacitor. Insulated case only.

rated voltage U_R
B = 6 V E = 20 V G = 50 V
C = 10 V F = 35 V H = 75 V
D = 15 V

nominal capacitance in pF; first two digits are significant figure, third figure is number of zeros to follow.

capacitance tolerance
K = ±10% M = ±20% J = ±5%

failure rate level in % per 1000 h
L = 2% P = 0,1% S = 0,001%
M = 1% R = 0,01%

Ordering coding system

2222 141 . . . . .

dash number of failure rate level according to MIL-C-39003/1E

case size
1 = case size A
2 = case size B
3 = case size C
4 = case size D

Capacitance

The nominal capacitance values at 100 Hz are given in Table 2. The tolerance on nominal capacitance at 100 Hz is ±20% and ±10% (±5% on request).

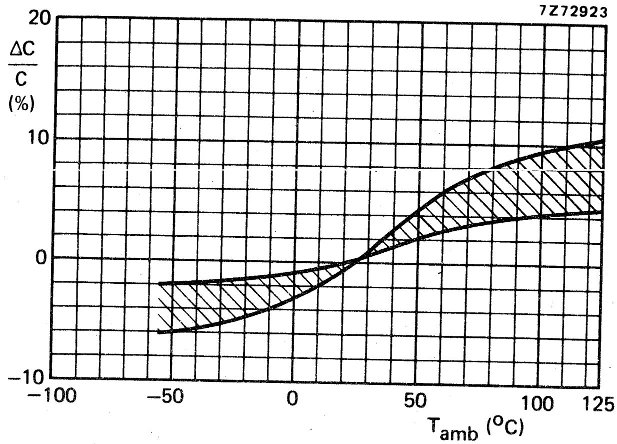


Fig.2 Typical capacitance as a function of ambient temperature.

The change in capacitance from the initial value measured at 25 °C shall not exceed the following percentages:

10% at −55 °C;
8% at +85 °C;
12% at +125 °C.

Voltage

Rated voltage

The rated voltage, U_R in Table 2, is the maximum permissible voltage at −55 to +85 °C. The capacitors may be operated up to 125 °C by derating the rated voltage in accordance with Fig.3.

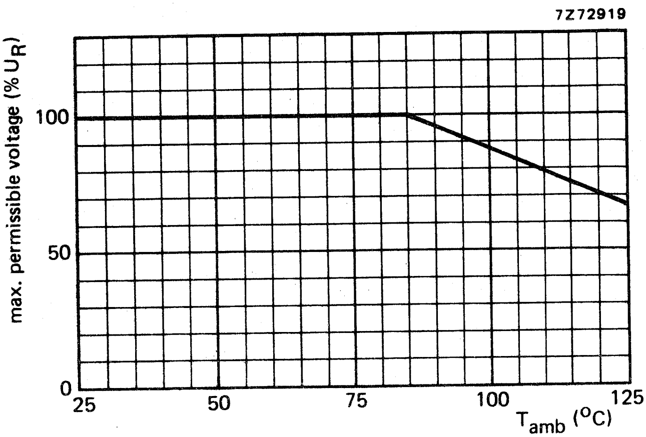


Fig.3 Maximum permissible voltage as a function of ambient temperature.

Surge voltage

The surge voltage (see Table 3) is the maximum short duration voltage which may be applied to the capacitor; i.e. turn-on transients, peak a.c. voltage, or any other voltage pulses which may be superimposed on the rated voltage. In no case may the sum of the a.c. voltage and the applied rated voltage exceed the rated d.c. surge voltage.

Table 3

U_R V	surge voltage (V)	
	at ≤ 85 °C	at 85 to 125 °C
6	8	5
10	13	9
15	20	12
20	26	16
35	46	28
50	65	40
75	97	64
100	130	86

Surge voltage test

The appropriate surge voltage shall be applied to the test capacitors via a 1000 Ω series limiting resistor for 30 s. The test capacitors shall then be discharged via the 1000 Ω resistor for 5½ min. This charge-discharge cycle shall be repeated 2000 times.
Following the surge test the following requirements must be met:

- capacitance shall not change more than ±5%;
- dissipation factor shall meet initial requirements;
- d.c. leakage current shall meet initial requirements.

Reverse voltage

The reverse voltage is the maximum d.c. voltage applied in the reverse polarity at the maximum category temperature; its value is 0,5 V.

Ripple voltage

As in all electrical equipment the temperature rise in a capacitor must be controlled. The temperature rise is a result of the I^2R loss in the equivalent series resistance (ESR) of the capacitor when the capacitor is subjected to an a.c. ripple current. To insure safe operating conditions the sum of the applied d.c. voltage and peak a.c. voltage should not exceed the rated voltage of the capacitor.

The maximum permissible a.c. voltage (r.m.s. value) at 60 Hz and 25 °C is shown in Fig.4. For the maximum permissible a.c. voltage at other operating conditions multiply the maximum permissible a.c. voltage found in Fig.4 by the appropriate temperature derating factor from Fig.5 and frequency derating factor from Fig.6.

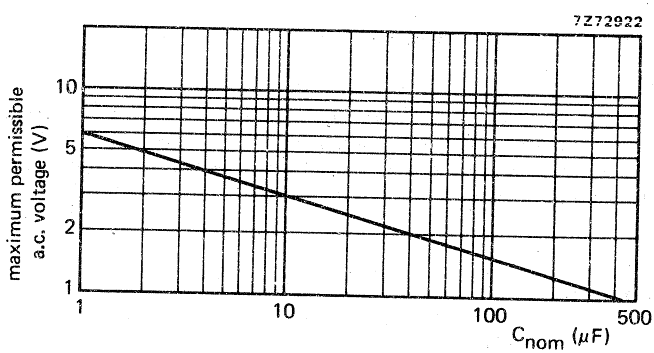


Fig.4 Maximum permissible a.c. voltage at 25 °C and 60 Hz as a function of nominal capacitance.

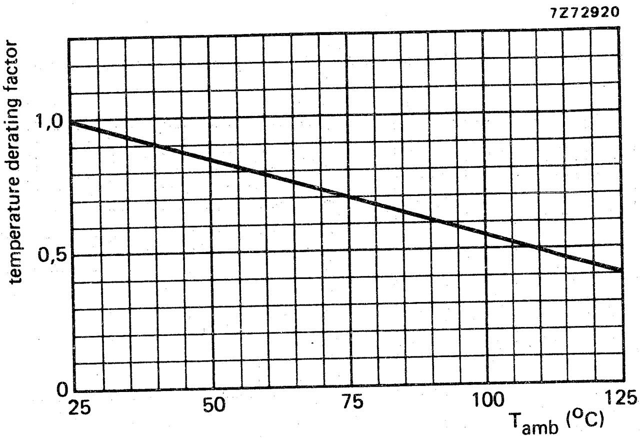


Fig.5 Effect of temperature on maximum permissible a.c. voltage.

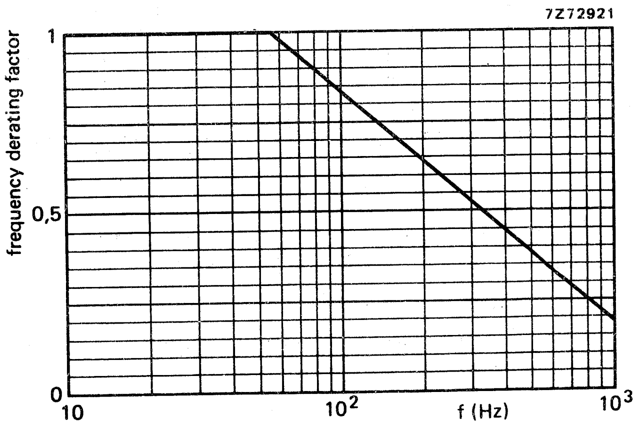


Fig.6 Effect of frequency on maximum permissible a.c. voltage.

Example

At 125 °C the maximum permissible ripple voltage of 400 Hz that can be applied to a capacitor of 10 μF is found in the following way. Fig.4 shows 2,7 V at 25 °C and 60 Hz; from Fig.5 the temperature derating factor at 125 °C is 0,4, from Fig.6 the frequency derating factor at 400 Hz is 0,45.
At the stated conditions the maximum permissible ripple voltage is 2,7 x 0,4 x 0,45 = 0,486 V.

Leakage current

The maximum leakage current 5 min after application of the rated voltage U_R is given in Table 2.

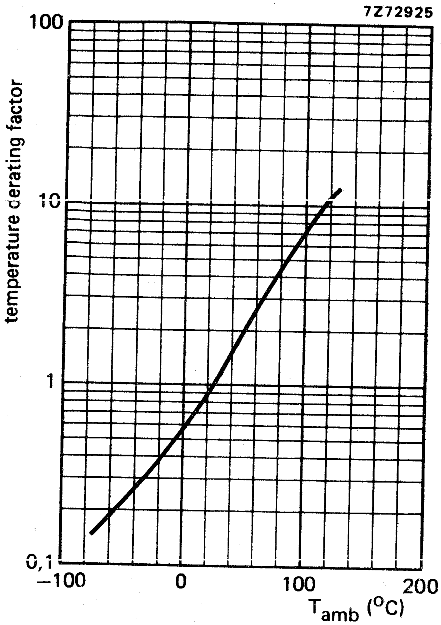


Fig.7 Typical effect of ambient temperature on leakage current.

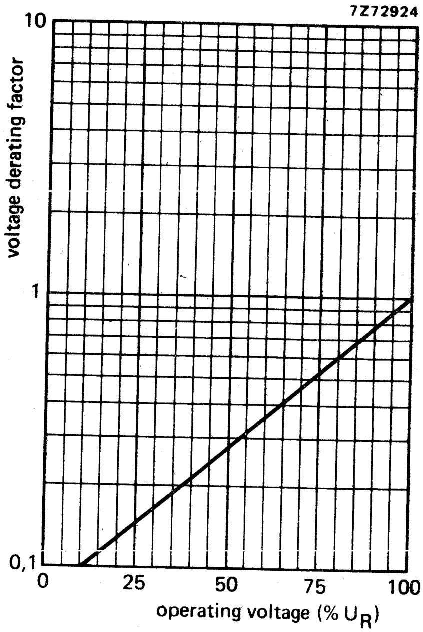


Fig.8 Typical effect of operating voltage on leakage current.

Tan δ (dissipation factor)

Tan δ at 100 Hz at −55 to +85 °C, measured by means of a four-terminal circuit (Thomson circuit), is given in Table 2.

Impedance

The impedance is measured by means of a four-terminal circuit (Thomson circuit).
See graphs on the following pages.

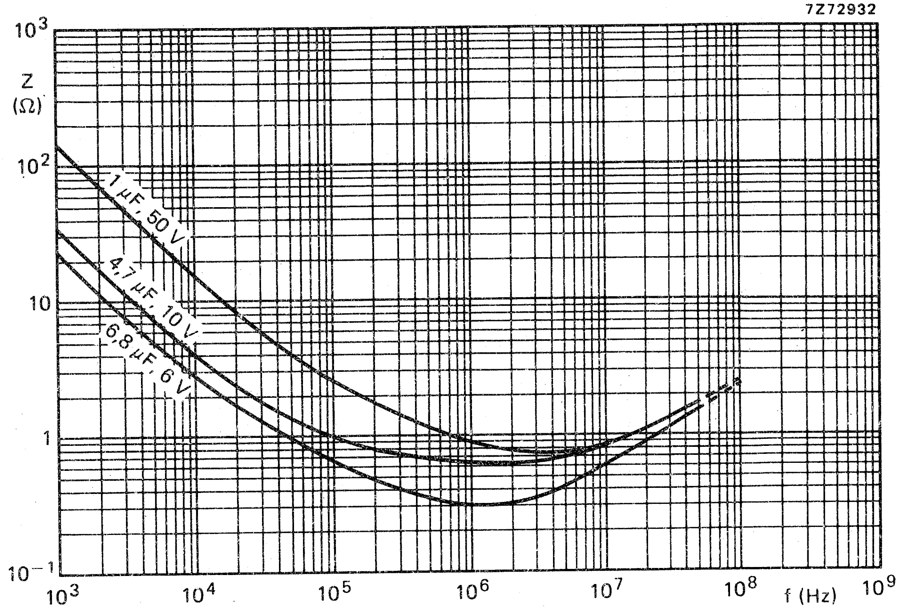


Fig.9 Typical impedance as a function of frequency at 25 °C; case size A.

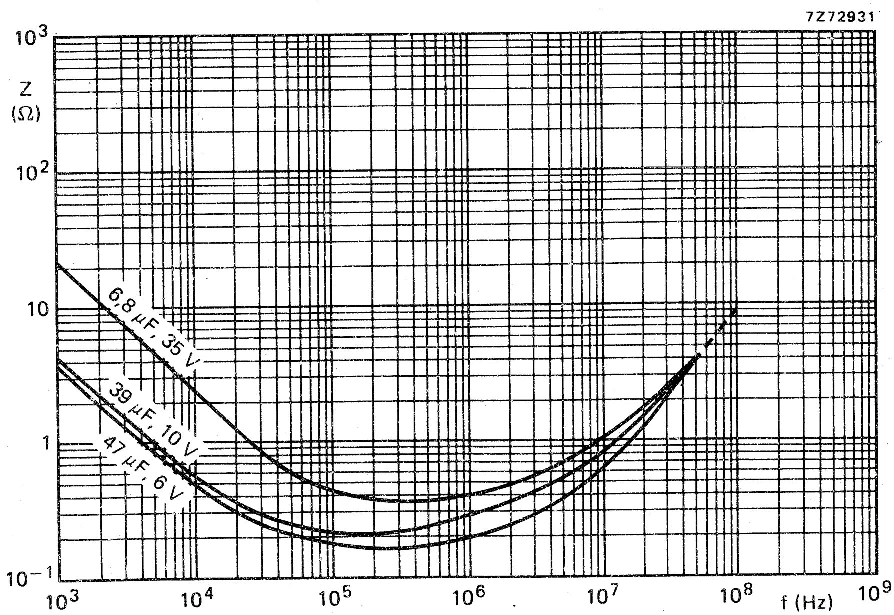


Fig.10 Typical impedance as a function of frequency at 25 °C; case size B.

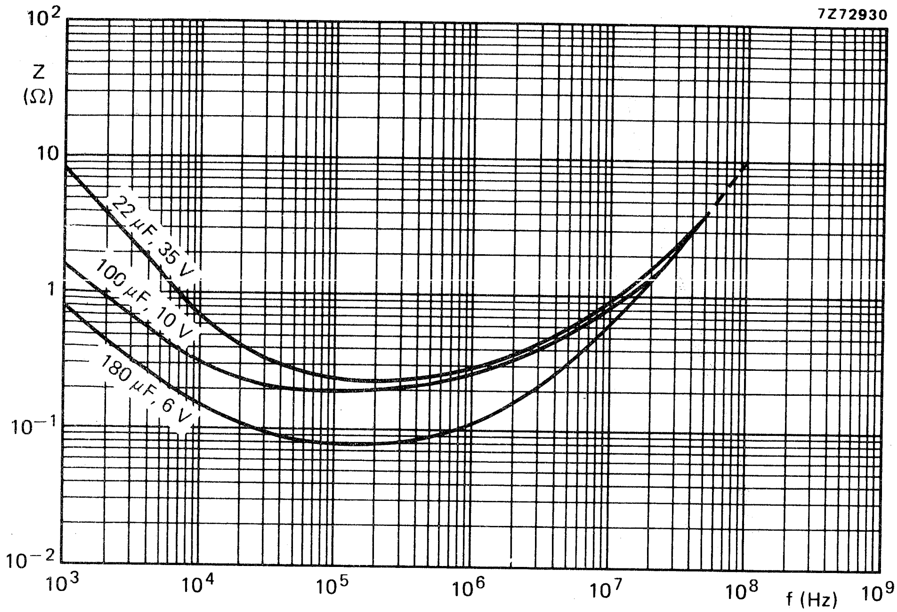


Fig.11 Typical impedance as a function of frequency at 25 °C; case size C.

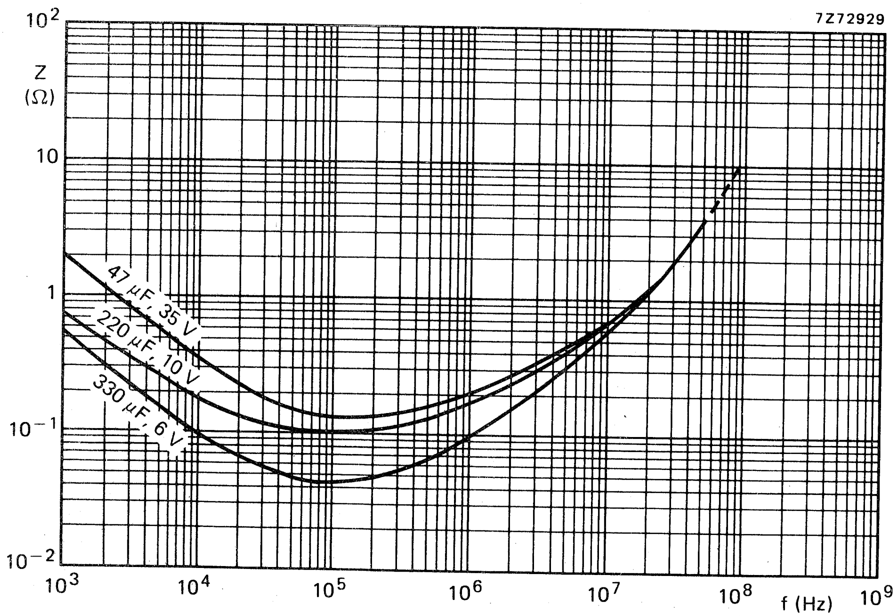


Fig.12 Typical impedance as a function of frequency at 25 °C; case size D.

Equivalent series resistance (ESR = tan $\delta/\omega C$)

Tan δ and C at 100 Hz are given in Table 2.

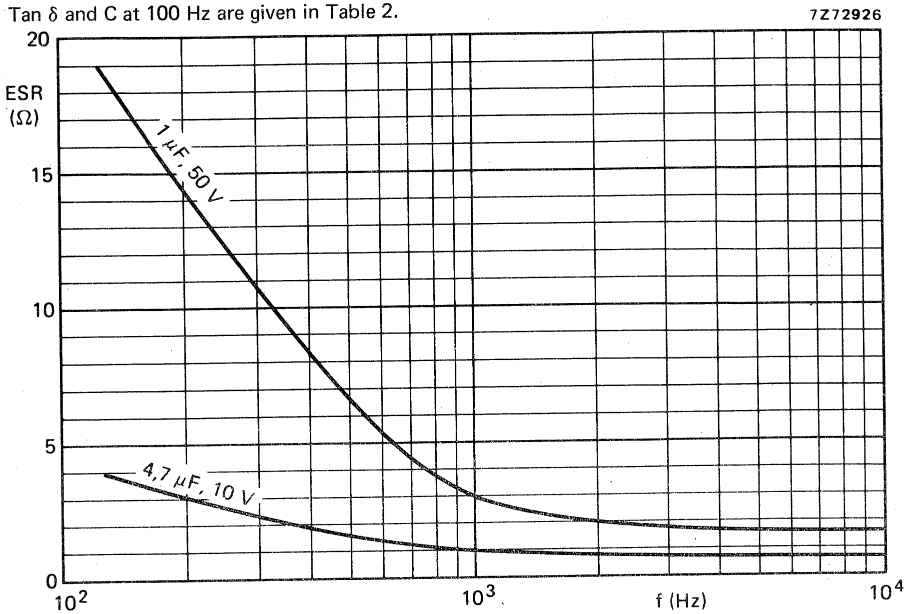


Fig.13 Typical ESR as a function of frequency; case size A.

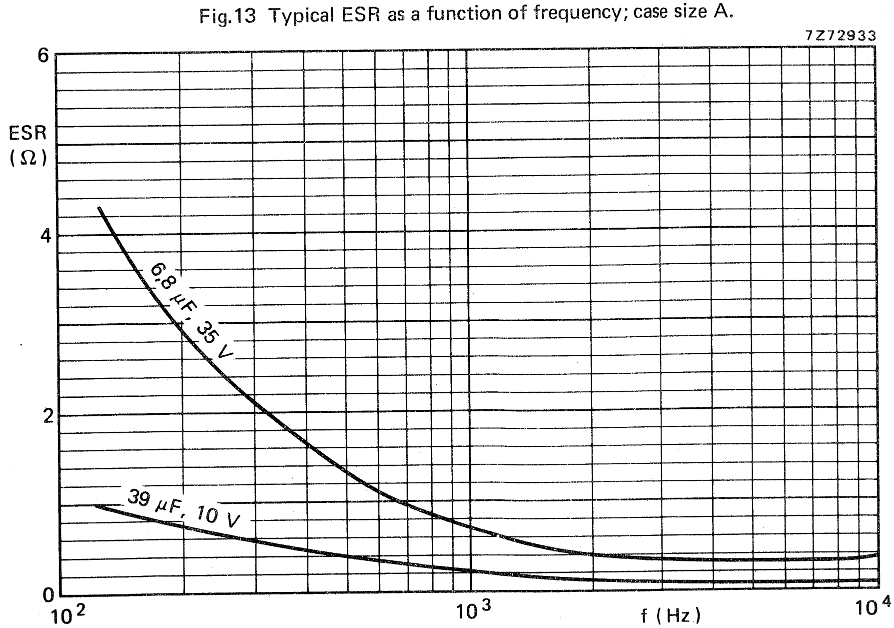


Fig.14 Typical ESR as a function of frequency; case size B.

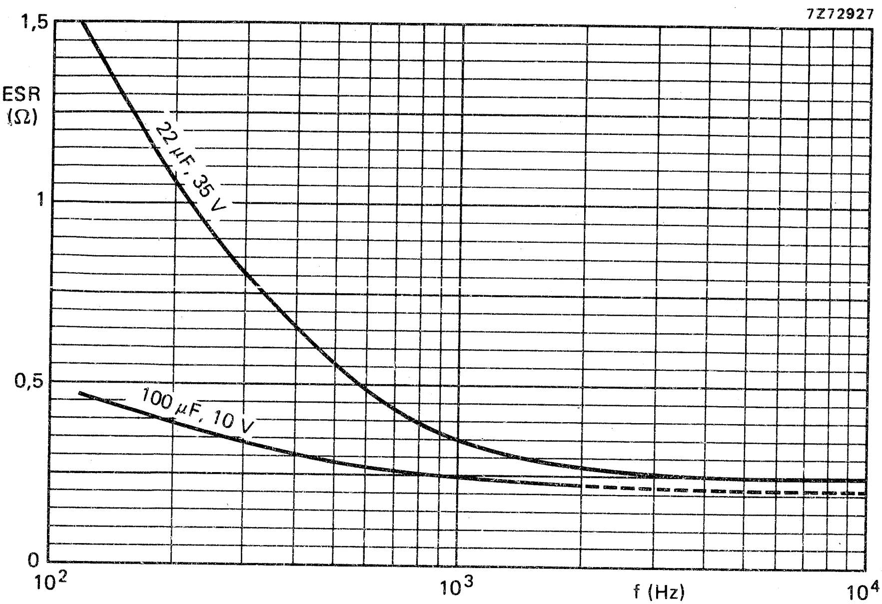


Fig.15 Typical ESR as a function of frequency; case size C.

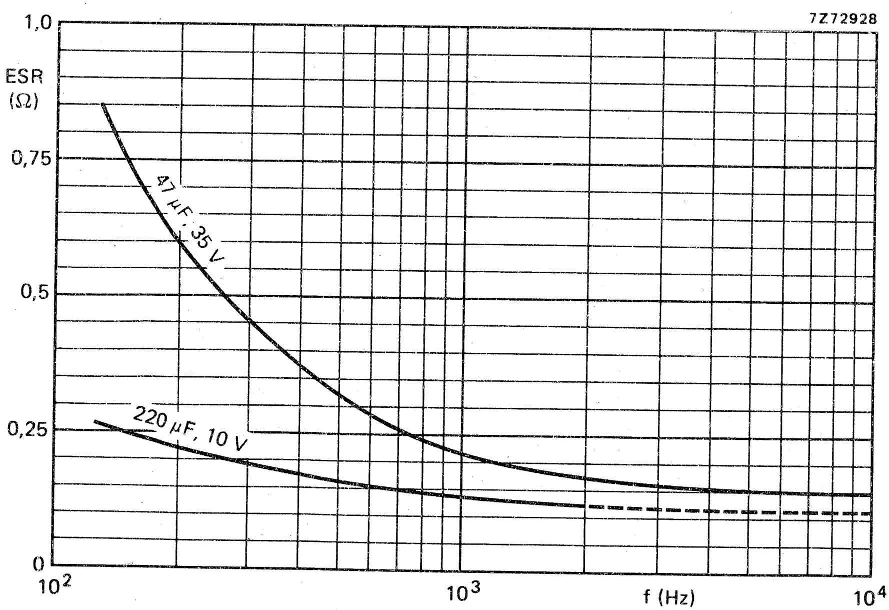


Fig.16 Typical ESR as a function of frequency; case size D.

OPERATIONAL DATA

Category temperature range

Category temperature range

at U_R	–55 to +85 °C
at 0,67 U_R	–55 to +125 °C

Low-impedance applications

A word of caution concerning the use of solid electrolyte tantalum capacitors in low impedance circuits. Solid electrolyte tantalum capacitors do not have the self-healing characteristics of the liquid electrolyte types, nor do the solids have the ability to dampen or disperse current surges in the manner of the liquid electrolyte types. Both of these characteristics of solid electrolyte capacitors result in increased failure rates as the circuit impedance, as seen by the capacitor, is reduced. Experience has shown that a circuit resistance of 3 Ω per volt is desirable to limit possible surge damage to the dielectric.

Reliability

The reliability of the solid tantalum capacitor is dependent upon the operating voltage and temperature. This relationship is clearly defined in the reliability alignment chart (Fig.17). The designer may use this nomogram as an aid in predicting failure rate under conditions of voltage and temperature which are different to those for which the failure rate is known.

Note
The failure rates are normally established at maximum rated conditions (85 °C, rated voltage, maximum circuit impedance 3 Ω). The alignment chart will then give expected failure rate under actual operating conditions. For example, if a particular batch of capacitors has a failure rate of 0,5%/1000 h at 85 °C, rated voltage, and if these capacitors are operated at 70% of rated voltage and 83 °C, the failure rate will improve by about 2 orders of magnitude to 0,005%/1000 h.
The increase in circuit impedance provides additional improvement in failure rate as shown in Table 4.

Table 4

circuit impedance Ω/V	failure rate improvement (multiplying factors)
0,1	1,0
0,2	0,8
0,4	0,6
0,6	0,4
0,8	0,3
1,0	0,2
2,0	0,1
3 or greater	0,07

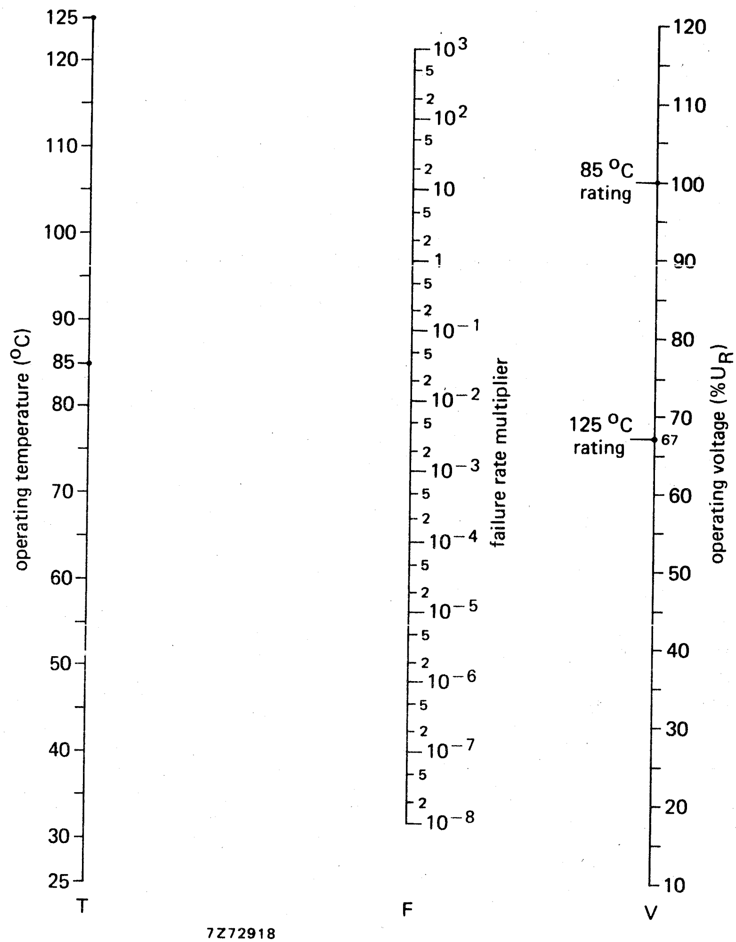


Fig.17 Reliability alignment chart. Connect the temperature and applied voltage of interest with a straight edge. The multiplier of rated failure is given at the intersection of this line with the model scale.

PACKING

Case size A: 1000 pieces per box.
Case size B: 1000 pieces per box.
Case size C: 400 pieces per box.
Case size D: 300 pieces per box.

SOLID TANTALUM CAPACITORS

hermetic seal tubular case, axial leads

QUICK REFERENCE DATA	
Nominal capacitance range (E12 series)	0, 1 to 330 μF
Tolerance on nominal capacitance	±20% and ±10% (±5% on request)
Rated voltage range, U_R	6 to 50 V
Category temperature range at U_R	−55 to +85 °C
at 0,67 U_R	−55 to +125 °C
Endurance test at 85 °C, at U_R	2000 h
at 125 °C, at 0,67 U_R	2000 h
Basic specification	MIL-STD-C-39003
Climatic category, IEC 68, at U_R	55/085/56
at 0,67 U_R	55/125/56

Selection chart for C-U_R and relevant case sizes.

C_{nom} (μF)	U_R (V)					
	6	10	15	20	35	50
0,1					A	A
0,12					A	A
0,15					A	A
0,18					A	A
0,22					A	A
0,27					A	A
0,33					A	A
0,39					A	A
0,47					A	A
0,56					A	A
0,68					A	A
0,82					A	A
1					A	A
1,2				A	B	B
1,5				A	B	B
1,8				A	B	B
2,2				A	B	B
2,7			A		B	B
3,3			A		B	B
3,9		A			B	B
4,7		A			B	B
5,6	A				B	C

C_{nom} (μF)	U_R (V)					
	6	10	15	20	35	50
6,8	A				B	C
8,2				B	C	C
10				B	C	C
12				B	C	C
15				B	C	C
18			B		C	C
22			B		C	D
27		B		C	D	
33		B		C	D	
39		B		C	D	
47	B			C	D	
56	B		C	D		
68			C	D		
82		C		D		
100		C		D		
120		C	D			
150	C		D			
180	C	D				
220		D				
270	D					
330	D					

APPLICATION

These capacitors are designed for use as :

- bypass capacitors;
- coupling capacitors (decoupling);
- filter capacitors;
- blocking capacitors;
- timing capacitors.

They are intended for use in polarized or d.c. biased circuits where the a.c. component is small compared to the d.c. rated voltage.

DESCRIPTION

The capacitors consist of a highly purified sintered tantalum anode body utilizing an electrolytically formed oxide dielectric, and a solid electrolyte, enclosed in a hermetically sealed insulated metal case with axial leads. Standard construction includes tin-lead plated leads.

MECHANICAL DATA

Dimensions in mm (including insulation)

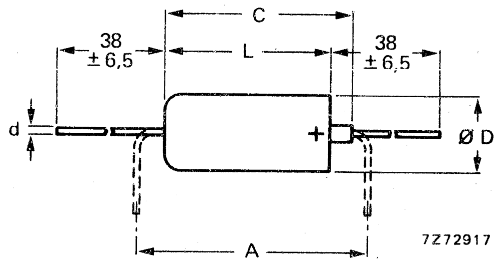


Fig. 1

Table 1

case size	A	D		L		C_{max}	d		approx. mass (g)
A	12,7	3,43	+0,41 −0,38	7,26	± 0,79	10,72	0,51	± 0,05	0,7
B	17,8	4,70		12,04		15,49	0,51		1,6
C	25,4	7,34		17,42		20,88	0,64		4,9
D	27,9	8,92		19,96		23,42	0,64		8,8

Marking

The capacitors are marked as follows :

1st line : polarity and company logo;
2nd line : nominal capacitance and tolerance on nominal capacitance;
3rd line : polarity and rated voltage;
4th line : date code (year and week).

Marking examples of capacitors with different case sizes :

case size A	case size B	case size C and D
+NCI	+NCI	+NCI
1.0K [1])	6.8M [1])	100 ± 10%
+35 V	+25 VDC	+10 VDC
7626	7626	7626

[1]) K = ± 10%; M = ± 20%.

ELECTRICAL DATA

Table 2

Unless otherwise specified all electrical values in Table 2 apply at an ambient temperature of 20 to 25 °C, a frequency of 100 Hz, an atmospheric pressure of 860 to 1060 mbar and a relative humidity of 45 to 75%.

U_R V [1]	nom. cap. (μF) [1]	max. leakage current at U_R after 5 min at T_{amb} = 25 °C (μA) [1]	max. tan δ [1]	case size	catalogue number [2]
6	5,6	0,6	0,06	A	2222 143 .3568
	6,8	0,6	0,06	A	.3688
	47	4	0,06	B	.3479
	56	5	0,06	B	.3569
	150	9	0,08	C	.3151
	180	11	0,08	C	.3181
	270	16	0,08	D	.3271
	330	20	0,08	D	.3331
10	3,9	0,6	0,06	A	2222 143 .4398
	4,7	0,7	0,06	A	.4478
	27	4	0,06	B	.4279
	33	5	0,06	B	.4339
	39	5	0,06	B	.4399
	82	8	0,06	C	.4829
	100	10	0,08	C	.4101
	120	12	0,08	C	.4121
	180	18	0,08	D	.4181
	220	20	0,08	D	.4221
15	2,7	0,6	0,06	A	2222 143 .5278
	3,3	0,8	0,06	A	.5338
	18	4	0,06	B	.5189
	22	5	0,06	B	.5229
	56	7	0,06	C	.5569
	68	9	0,06	C	.5689
	120	13	0,08	D	.5121
	150	15	0,08	D	.5151
20	1,2	0,6	0,04	A	2222 143 .6128
	1,5	0,6	0,04	A	.6158
	1,8	0,6	0,04	A	.6188
	2,2	0,7	0,04	A	.6228
	8,2	2,5	0,06	B	.6828

[1] See also corresponding paragraph.
[2] Replace dot in catalogue number by: 1 for capacitance tolerance ±20%;
8 for capacitance tolerance ±10%.

Table 2 (continued)

U_R (V) 1)	nom. cap. (µF) 1)	max. leakage current at U_R after 5 min at T_{amb} = 25 °C (µA) 1)	max. tan δ 1)	case size	catalogue number 2)
20	10	3,0	0,06	B	2222 143 .6109
	12	3,5	0,06	B	.6129
	15	5	0,06	B	.6159
	27	5	0,06	C	.6279
	33	6	0,06	C	.6339
	39	6	0,06	C	.6399
	47	7	0,06	C	.6479
	56	8,5	0,06	D	.6569
	68	10	0,06	D	.6689
	82	12	0,06	D	.6829
	100	15	0,06	D	.6101
35	0,1	0,6	0,04	A	2222 143 .7107
	0,12	0,6	0,04	A	.7127
	0,15	0,6	0,04	A	.7157
	0,18	0,6	0,04	A	.7187
	0,22	0,6	0,04	A	.7227
	0,27	0,6	0,04	A	.7277
	0,33	0,6	0,04	A	.7337
	0,39	0,6	0,04	A	.7397
	0,47	0,6	0,04	A	.7477
	0,56	0,6	0,04	A	.7567
	0,68	0,6	0,04	A	.7687
	0,82	0,6	0,04	A	.7827
	1,0	0,6	0,04	A	.7108
	1,2	0,6	0,04	B	.7128
	1,5	0,8	0,04	B	.7158
	1,8	1	0,04	B	.7188
	2,2	1,2	0,04	B	.7228
	2,7	1,4	0,04	B	.7278
	3,3	1,7	0,04	B	.7338
	3,9	2	0,04	B	.7398
	4,7	2,5	0,04	B	.7478
	5,6	3	0,06	B	.7568
	6,8	3,5	0,06	B	.7688
	8,2	3,5	0,06	C	.7828
	10	4	0,06	C	.7109
	12	4	0,06	C	.7129

1) See also corresponding paragraph.
2) Replace dot in catalogue number by: 1 for capacitance tolerance ± 20%;
8 for capacitance tolerance ± 10%.

Table 2 (continued)

U_R (V) [1]	nom. cap. (μF) [1]	max. leakage current at U_R after 5 min at T_{amb} = 25 °C (μA) [1]	max. tan δ [1]	case size	catalogue number [2]
35	15	6	0,06	C	2222 143 .7159
	18	6	0,06	C	.7189
	22	7	0,06	C	.7229
	27	7	0,06	D	.7279
	33	8	0,06	D	.7339
	39	10	0,06	D	.7399
	47	10	0,06	D	.7479
50	0,1	0,6	0,04	A	2222 143 .8107
	0,12	0,6	0,04	A	.8127
	0,15	0,6	0,04	A	.8157
	0,18	0,6	0,04	A	.8187
	0,22	0,6	0,04	A	.8227
	0,27	0,6	0,04	A	.8277
	0,33	0,6	0,04	A	.8337
	0,39	0,6	0,04	A	.8397
	0,47	0,6	0,04	A	.8477
	0,56	0,6	0,04	A	.8567
	0,68	0,6	0,04	A	.8687
	0,82	0,7	0,04	A	.8827
	1,0	0,8	0,04	A	.8108
	1,2	0,9	0,04	B	.8128
	1,5	1,2	0,04	B	.8158
	1,8	1,4	0,04	B	.8188
	2,2	1,7	0,04	B	.8228
	2,7	2	0,04	B	.8278
	3,3	2,5	0,04	B	.8338
	3,9	3	0,04	B	.8398
	4,7	3,5	0,04	B	.8478
	5,6	4,5	0,04	C	.8568
	6,8	5	0,06	C	.8688
	8,2	5	0,06	C	.8828
	10	5	0,06	C	.8109
	12	6	0,06	C	.8129
	15	6	0,06	C	.8159
	18	7	0,06	C	.8189
	22	8	0,06	D	.8229

1) See also corresponding paragraph.
2) Replace dot in catalogue number by: 1 for capacitance tolerance ±20%;
8 for capacitance tolerance ± 10%.

Note: The following versions are available on request:

U_R = 35 V;
capacitance range (E 12 series): 0,0047 to 0,082 µF; case size A.

U_R = 75 V;
capacitance range (E 12 series): 0,0047 to 0,68 µF; case size A;
0,82 to 3,9 µF; case size B;
4,7 to 10 µF; case size C;
12 to 15 µF; case size D.

U_R = 100 V;
capacitance range (E 12 series): 0,0047 to 0,56 µF; case size A;
0,68 to 2,7 µF; case size B.

On request the above-mentioned capacitance values, and all capacitance values in Table 2, are available with a tolerance of ±5%.

Capacitance

Nominal capacitance values at 100 Hz	see Table 2
Tolerance on nominal capacitance at 100 Hz	±20% and ± 10%

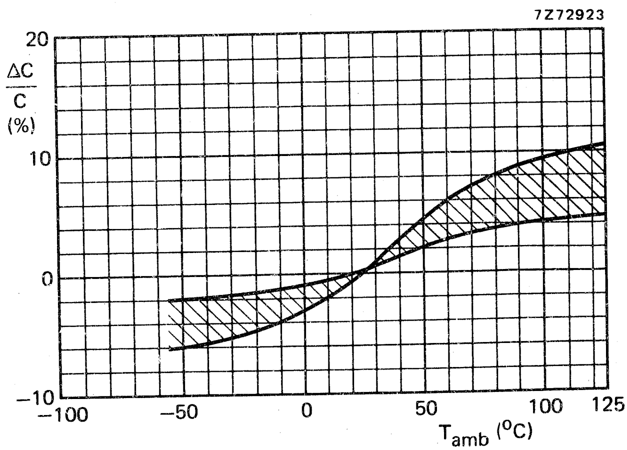


Fig. 2. Typical capacitance as a function of ambient temperature.

The change in capacitance from initial 25 °C measured capacitance shall not exceed the following percentages:
10% at −55 °C;
8% at +85 °C;
12% at + 125 °C.

Voltage

Rated voltage

Rated voltage = maximum permissible voltage at −55 to +85 °C U_R, see Table 2

The capacitors may be further operated up to 125 °C by derating the rated voltage in accordance with the following graph.

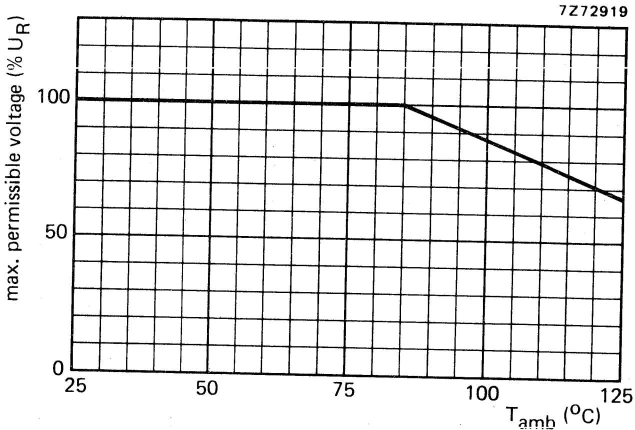


Fig. 3. Maximum permissible voltage as a function of ambient temperature.

Surge voltage

The surge voltage (see Table 3) is the maximum short duration voltage which may be applied to the capacitor; i.e. turn-on transients, peak a.c. voltage, or any other voltage pulses which may be superimposed on the rated voltage. In no case may the sum of the a.c. voltage and the applied rated voltage exceed the rated d.c. surge voltage.

Table 3

U_R (V)	surge voltage (V)	
	at ≤ 85 °C	at 85 to 125 °C
6	8	5
10	13	9
15	20	12
20	26	16
35	46	28
50	65	40
75	97	64
100	130	86

Surge voltage test

The appropriate surge voltage shall be applied to the test capacitors via a 1000 Ω series limiting resistor for 30 s. The test capacitors shall then be discharged via the 1000 Ω resistor for $5\frac{1}{2}$ min. This charge-discharge cycle shall be repeated 2000 times. Following the surge test the following requirements must be met:

- capacitance shall not change more than ± 5%;
- dissipation factor shall meet initial requirements;
- d.c. leakage current shall meet initial requirements.

Reverse voltage

Reverse voltage = maximum d.c. voltage applied in the reverse polarity at the maximum category temperature 0,5 V

Ripple voltage

As in all electrical equipment the temperature rise in a capacitor must be controlled. The temperature rise is a result of the I^2R loss in the Equivalent Series Resistance (ESR) of the capacitor when the capacitor is subjected to an a.c. ripple current. To insure safe operating conditions the sum of the applied d.c. voltage and peak a.c. voltage should not exceed the rated voltage of the capacitor.

The maximum permissible a.c. voltage (r.m.s. value) at 60 Hz and 25 °C is shown in Fig. 4. For the maximum permissible a.c. voltage at other operating conditions multiply the maximum permissible a.c. voltage found in Fig. 4 by the appropriate temperature derating factor from Fig. 5 and frequency derating factor from Fig. 6.

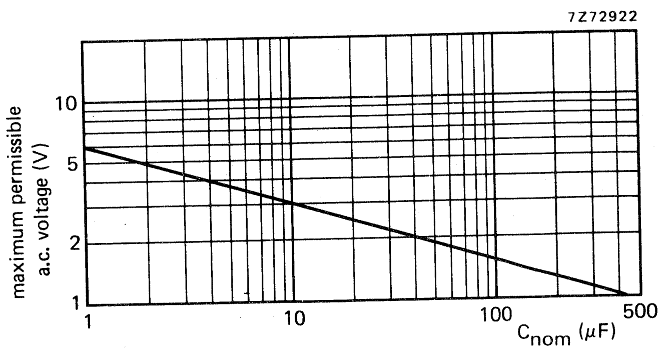


Fig. 4. Maximum permissible a.c. voltage at 25 °C and 60 Hz as a function of nominal capacitance.

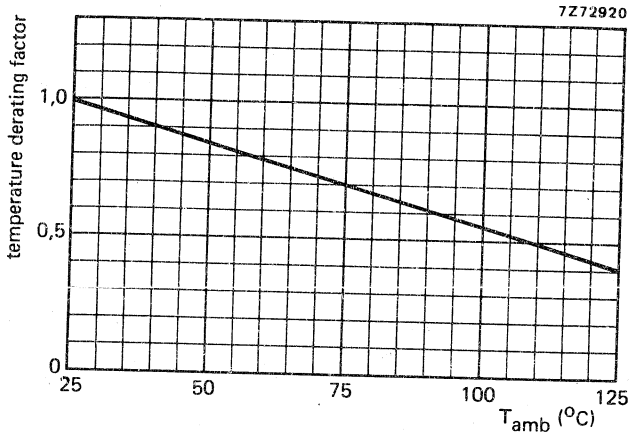


Fig. 5. Effect of temperature on maximum permissible a.c. voltage.

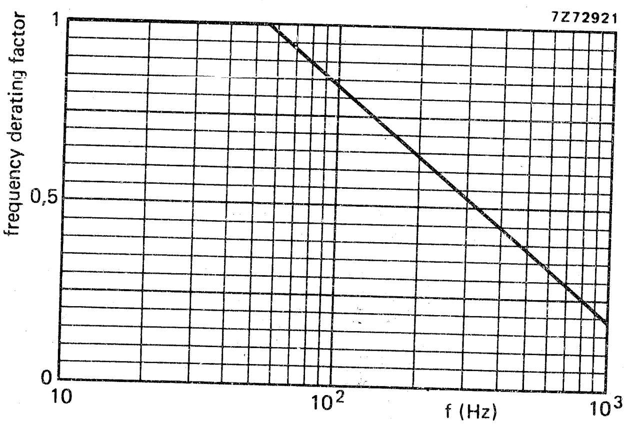


Fig. 6. Effect of frequency on maximum permissible a.c. voltage.

Example: At 125 °C the maximum permissible ripple voltage of 400 Hz that can be applied to a capacitor of 10 μF is found in the following way. Fig. 4 shows 2,7 V at 25 °C and 60 Hz; from Fig. 5 the temperature derating factor at 125 °C is 0,4, from Fig. 6 the frequency derating factor at 400 Hz is 0,45.
At the stated conditions the maximum permissible ripple voltage is
2,7 x 0,4 x 0,45 = 0,486 V.

Leakage current

Maximum leakage current 5 min after application of the rated voltage U_R at 25 °C	see Table 2
at 85 °C	10 x value stated in Table 2
at 125 °C	12 x value stated in Table 2

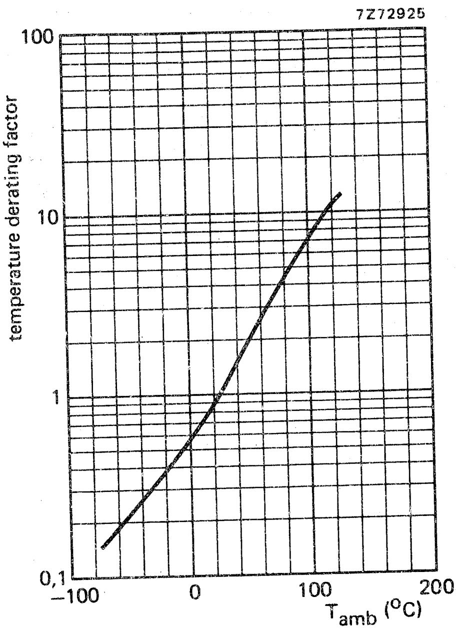


Fig. 7. Typical effect of ambient temperature on leakage current.

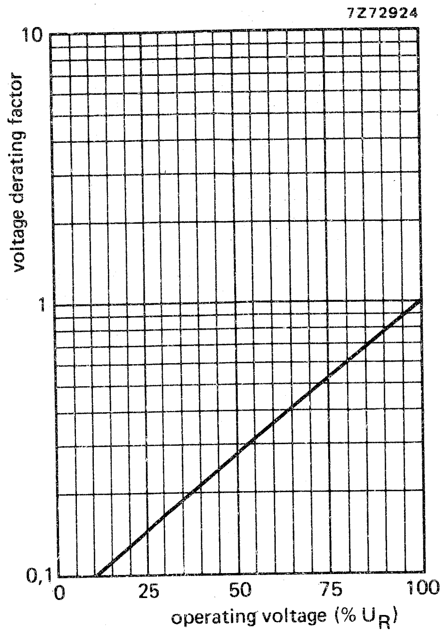


Fig. 8. Typical effect of operating voltage on leakage current.

Tan δ (dissipation factor)

Tan δ at 100 Hz at −55 to +85 °C, measured by means of a four-terminal circuit (Thomson circuit)	see Table 2

Impedance

The impedance is measured by means of a four-terminal circuit (Thomson circuit). See graphs on the following pages.

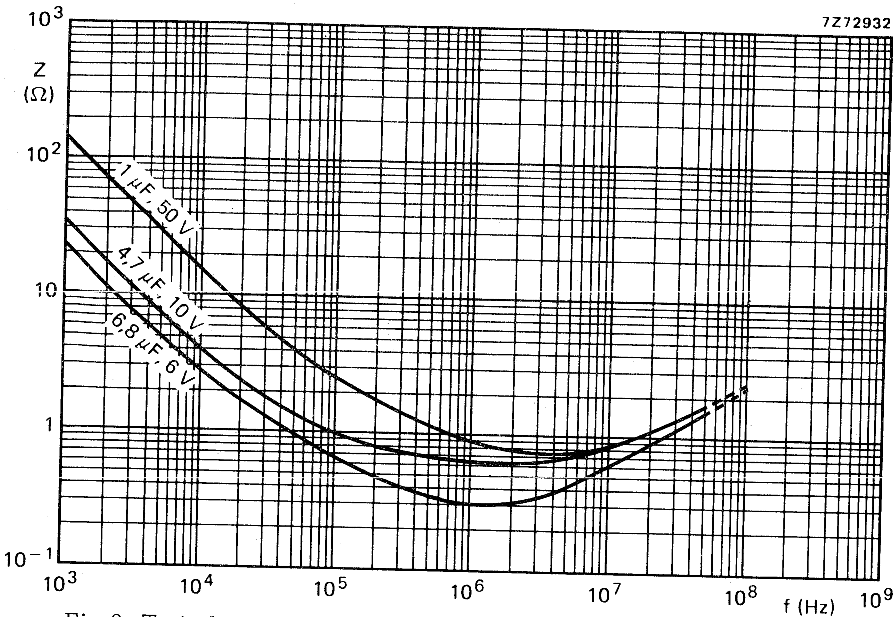


Fig. 9. Typical impedance as a function of frequency at 25 °C; case size A.

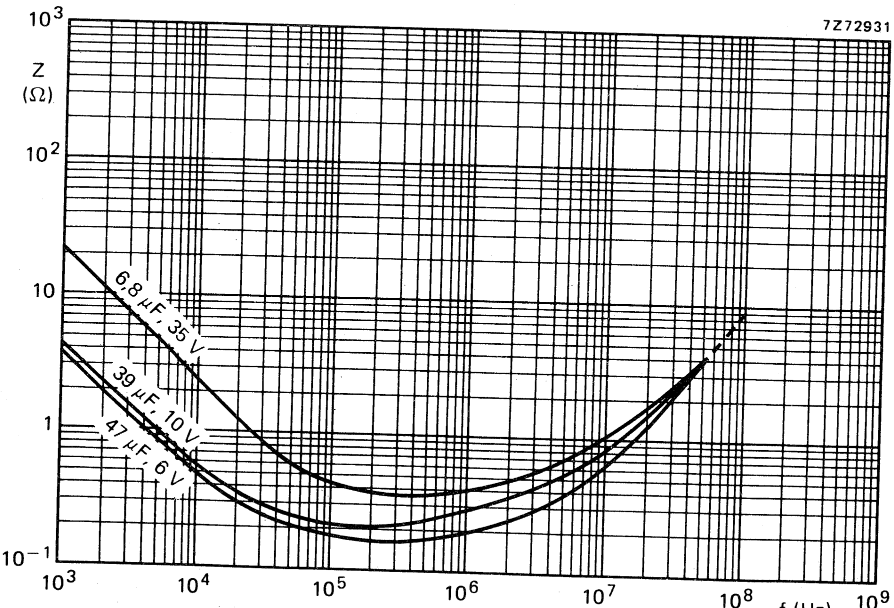


Fig. 10. Typical impedance as a function of frequency at 25 °C; case size B.

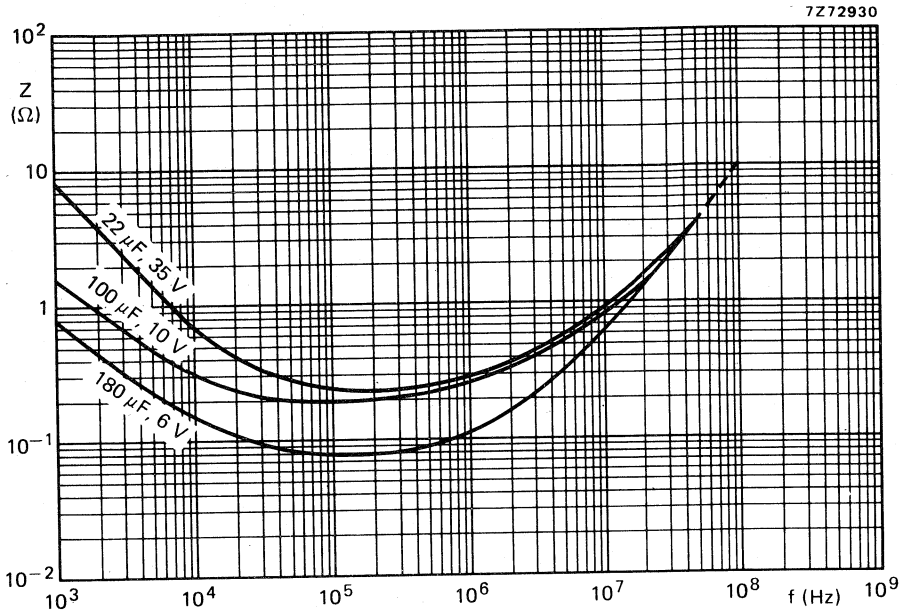


Fig. 11. Typical impedance as a function of frequency at 25 °C; case size C.

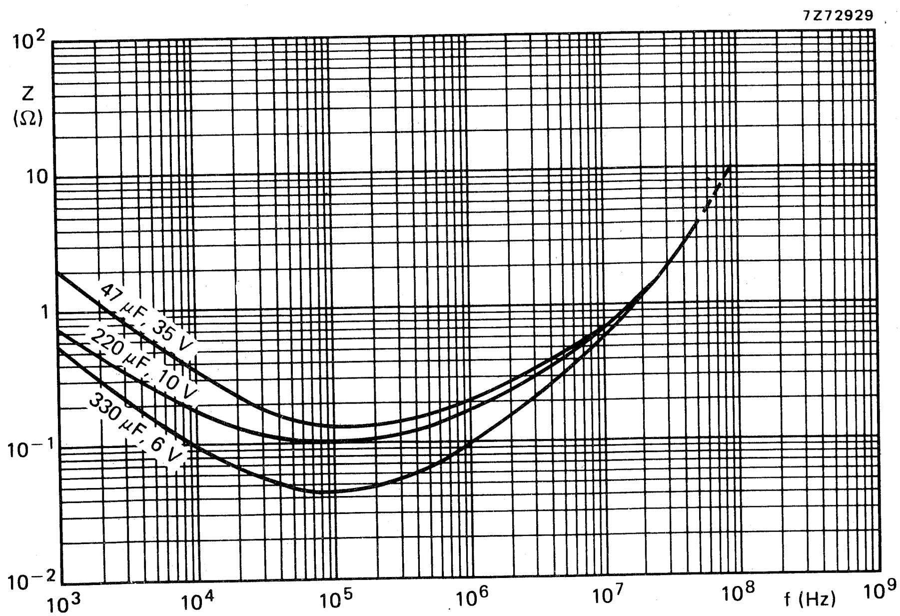


Fig. 12. Typical impedance as a function of frequency at 25 °C; case size D.

Equivalent series resistance (ESR = tan $\delta/\omega C$)

Tan δ and C at 100 Hz

see Table 2

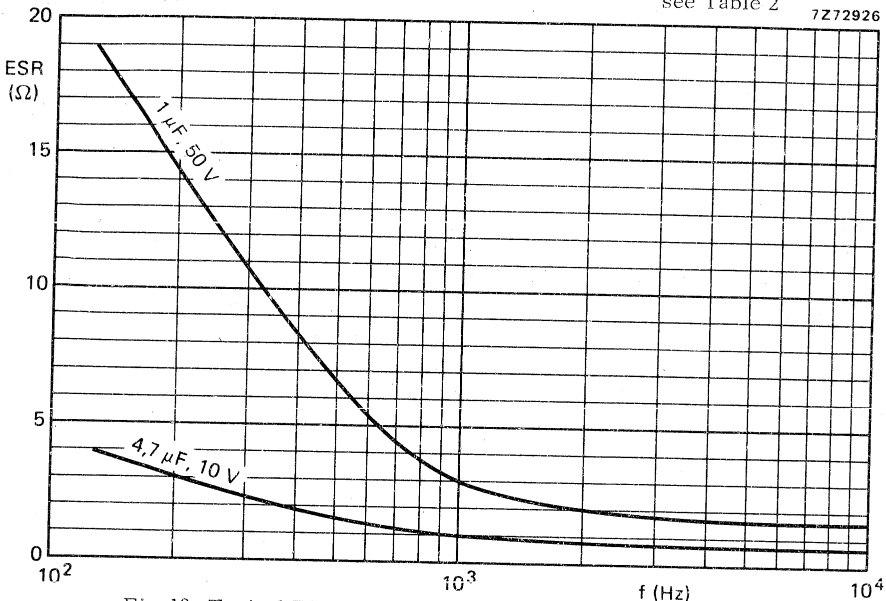


Fig. 13. Typical ESR as a function of frequency; case size A.

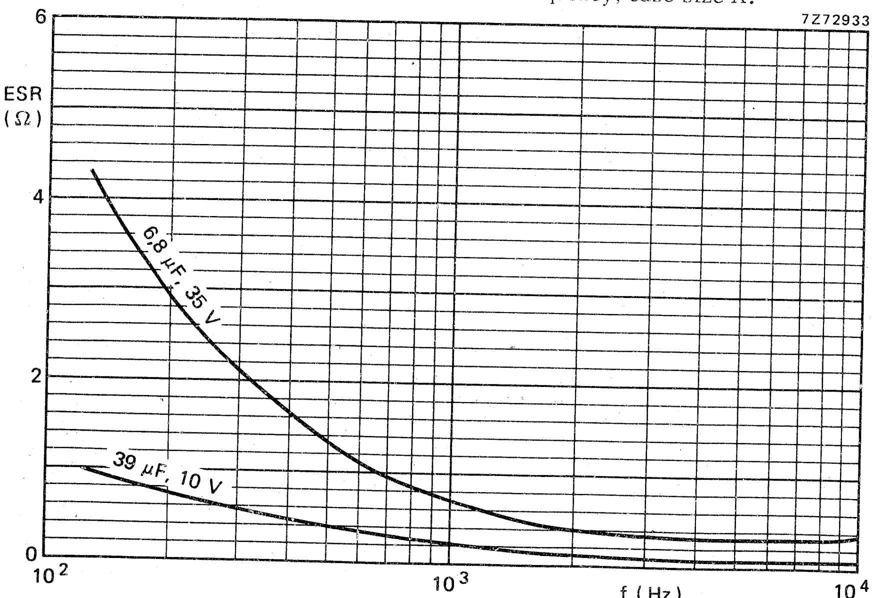


Fig. 14. Typical ESR as a function of frequency; case size B.

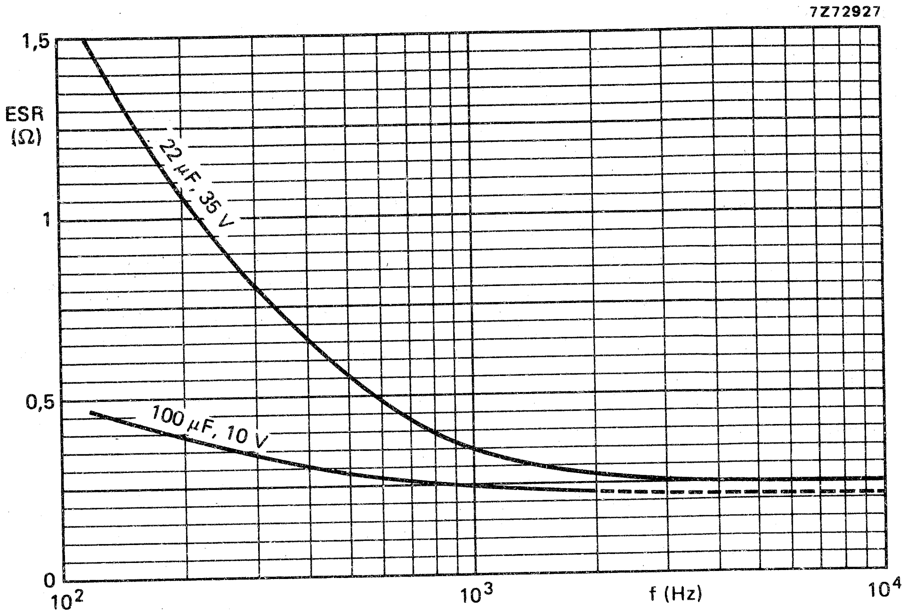


Fig. 15. Typical ESR as a function of frequency; case size C.

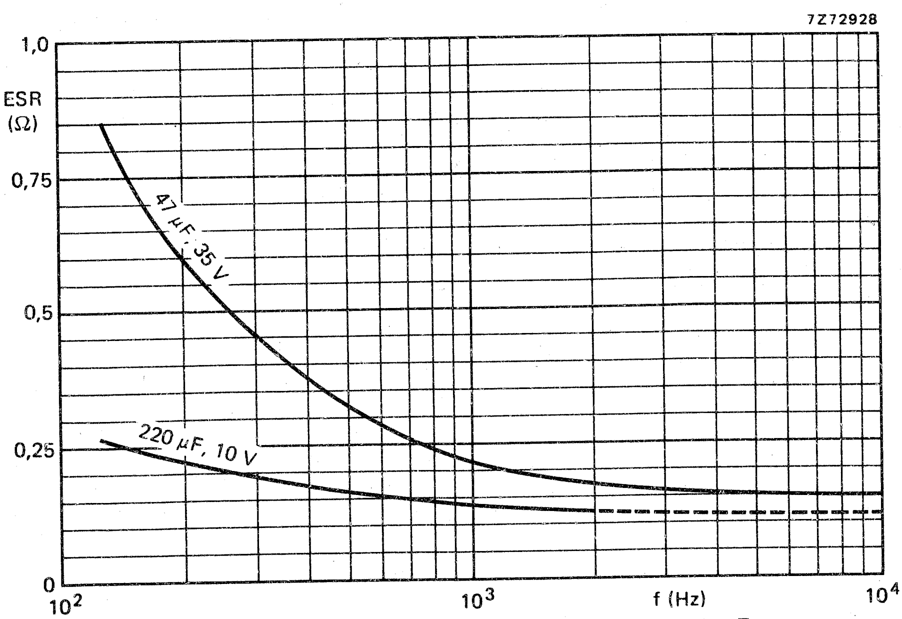


Fig. 16. Typical ESR as a function of frequency; case size D.

OPERATIONAL DATA

Category temperature range

Category temperature range at U_R	−55 to +85 °C
at 0,67 U_R	−55 to +125 °C

Low-impedance applications

A word of caution concerning the use of solid electrolyte tantalum capacitors in low impedance circuits. Solid electrolyte tantalum capacitors do not have the "self-healing" characteristics of the liquid electrolyte types, nor do the solids have the ability to dampen or disperse current surges in the manner of the liquid electrolyte types. Both of these characteristics of solid electrolyte capacitors result in increased failure rates as the circuit impedance, as seen by the capacitor, is reduced. Experience has shown that a circuit resistance of 3 Ω per volt is desirable to limit possible surge damage to the dielectric.

Reliability

The reliability of the solid tantalum capacitor is dependent upon the operating voltage and temperature. This relationship is clearly defined in the reliability alignment chart (Fig. 17). The designer may use this nomogram as an aid in predicting failure rate under conditions of voltage and temperature which are different than those for which the failure rate is known.

Note : The failure rates are normally established at maximum rated conditions (85 °C, rated voltage, maximum circuit impedance 3 Ω). The alignment chart will then give expected failure rate under actual operating conditions. For example, if a particular batch of capacitors has a failure rate of 0,5%/1000 h at 85 °C, rated voltage and if these capacitors are operated at 70% of rated voltage and 83 °C, the failure rate will improve by about 2 orders of magnitude to 0,005%/1000 h. The increase in circuit impedance provides additional improvement in failure rate as shown in Table 4.

Table 4 - Failure rate improvement with circuit impedance.

Circuit impedance (Ω/V)	Failure rate improvement (multiplying factors)
0,1	1,0
0,2	0,8
0,4	0,6
0,6	0,4
0,8	0,3
1,0	0,2
2,0	0,1
3 or greater	0,07

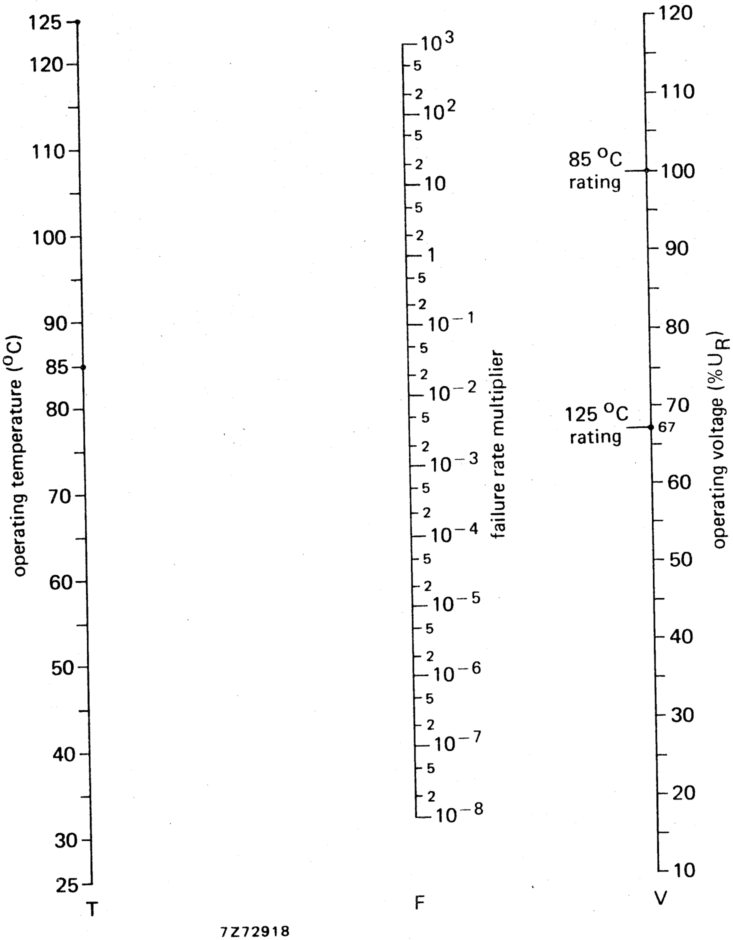


Fig. 17. Reliability alignment chart.
Connect the temperature and applied voltage of interest with a straight edge. The multiplier of rated failure is given at the intersection of this line with the model scale.

PACKING

Capacitors with case size A : 1000 pieces per box;
case size B : 1000 pieces per box;
case size C : 400 pieces per box;
case size D : 300 pieces per box.

TESTS AND REQUIREMENTS

Life test

Capacitors shall be life tested for 2000 h at 85 °C or 125 °C with the appropriate rated voltage applied.
After life test when measured at 25 °C the dissipation factor shall meet the initial requirement. The leakage current shall not be more than 125% of the original requirements and capacitance shall not have changed more than ± 10% from the initial value.
Not more than 1 failure shall be permitted in 25 units tested.

Environmental tests

1. Low-frequency vibration

The capacitors shall be rigidly mounted by suitable case clamps and subjected to a simple harmonic motion having a maximum amplitude of 0,03 in. The frequency shall be varied uniformly over a frequency range of 10 to 55 Hz in approximately 1 min at a uniform rate for a total of 2 h. Rated voltage will be applied to the units during test. During the last ½ hour of test, the test units will be monitored by an instrument capable of detecting intermittent open or short circuits with a duration of 0,5 ms or greater.
After vibration the capacitors shall meet the initial requirements of dissipation factor and leakage current. The capacitance shall not change more than ± 5% from the initial measured value.

1A. High-frequency vibration

The capacitors shall be rigidly mounted by suitable case clamps and subjected to a simple harmonic motion having a maximum amplitude of 0,03 in or 15 g in 2 mutually perpendicular directions (1 parallel and 1 perpendicular to the cylindrical axis).
Capacitors shall withstand vibration from 10 to 10 000 Hz at 15 g without internal damage.
The frequency shall be varied uniformly over a frequency range of 55 to 2000 Hz in approximately 20 min at a uniform rate for a total of 4 h. Rated voltage will be applied to the units during test. During the last ½ hour of test the test units will be monitored by an instrument capable of detecting intermittent open or short circuits with a duration of 0,5 ms or greater.
After vibration the capacitors shall meet the initial requirements of dissipation factor and leakage current. The capacitance shall not change more than ± 5% from the initial measured value.

2. Lead strength

With the body of the capacitor secured, the leads shall withstand a 3 lb load applied in any direction for 30 s.

3. Lead bend

Each capacitor lead shall be capable of withstanding 5 bends. A bend shall be defined as follows :
With the capacitor vertical and 1 lb weight attached to the lead, the capacitor body shall be slowly rotated (in approximately 5 s) to a horizontal position and then rotated to the vertical position. The 4 succeeding bends shall then be made in the same manner but in alternate directions.

4. Moisture resistance

The capacitors shall be tested in accordance with method 106 of MIL Standard 202. The following details and exceptions shall apply:

a. Mounting: the capacitors shall be securely mounted by normal mounting means during the test. This does not apply during measurements.

b. Initial measurements are not applicable.

c. Polarization and loading voltages are not applicable during the test.

d. Final measurements: within 2 to 6 hours after the capacitors have been removed from the humidity chamber following the final cycle, the d.c. leakage, capacitance and dissipation factor shall be measured as specified.

e. Examinations after test: following the final measurements the capacitors shall be examined visually for evidence of corrosion, mechanical damage and obliteration of marking.

5. Insulation sleeves

For insulated capacitors, the insulating sleeves shall be tested as follows for dielectric strength and insulation resistance:
Two wire windings shall be placed around the insulating sleeves $\frac{1}{4}$ in apart. Each winding to consist of 2 close turns of 24 AWG bare copper wire.

5A. Dielectric strength

For dielectric strength a d.c. test potential of 2000 V shall be applied for 1 min between the 2 windings. There shall be no breakdown of case insulation.

5B. Insulation resistance

For insulation resistance a d.c. test potential of 100 V shall be applied for 2 min. The insulation resistance shall not be less than 100 MΩ.

6. Shelf life test

When the capacitors have been exposed to 5000 h shelf life test at 85 °C with no voltage applied, capacitance shall not change more than ±4% from the initial measured value. The dissipation factor shall not exceed 150% of the initial requirement and the leakage current shall meet the initial requirement.

7. Shock

The capacitors shall be tested for shock resistance in accordance with MIL Standard 202 method 213, with the following exceptions.

a. The capacitors shall be rigidly mounted by suitable body clamps.

b. The capacitors shall be subjected to 18 impacts of 100 g with a 6 ms duration, as described under condition I, method 213.

c. Rated voltage shall be applied to the capacitors during the shock test.

The test units shall be monitored during test by an instrument capable of detecting intermittent open and short circuits with a duration of 0,5 ms or greater. After test the capacitors shall meet the initial requirements for capacitance, dissipation factor and leakage current.

8. Temperature and immersion cycling

After the capacitors are tested as specified in 8A and 8B, the leakage current shall meet the initial requirement. The capacitance change shall not exceed ± 5% of the value measured prior to test and the dissipation factor shall meet the initial requirement. When examined visually, at least 90% of all exposed metallic surfaces shall show no evidence of harmful corrosion. When examined internally, there shall be no evidence of dye penetration.

8A. Temperature shock

Capacitors shall be tested in accordance with method 107 of MIL Standard 202. The following exceptions and details shall apply:

a. Capacitors should be conditioned at a temperature of 25 °C for 15 min before the first cycle of test one.

b. The B test condition will be followed except that in the third step thereof, the capacitors will be subjected to a test at the highest applicable temperature.

c. Measurements before and after cycling may be omitted.

8B. Immersion cycling

After temperature cycling, a capacitor test should be made following Method 104 set down in MIL Standard 202. The following details and exceptions, however, shall apply:

a. A non-corrosive dye, Rhodamine B (tetraethylrhodamine), or its equivalent, shall be added in both baths in addition to steps provided in test condition B.

b. Measurements after final cycle.
Measurements of leakage current, capacitance and dissipation factor shall be made within 30 min after the capacitors are removed from the final immersion bath.

c. Examinations after test.
The capacitors shall be visually examined for traces of corrosion, mechanical damage, and obliteration of marking. Capacitors shall then be sectioned for evidence of dye penetration.

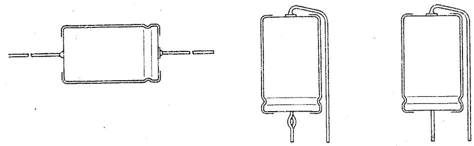
9. Reduced pressure

After the capacitors have been stabilized for 5 min in a vacuum of 22,53 Pa (= $1,69 \times 10^{-1}$ torr), rated voltage shall be applied for 1 min. There shall be no voltage flashover nor shall the end seals show evidence of damage by this test. The capacitance, dissipation factor, and leakage current shall meet the initial requirements.

MAINTENANCE TYPES

ALUMINIUM ELECTROLYTIC CAPACITORS

- Miniature types
- Axial leads (on bandoliers) or single ended
- General and industrial applications



QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	0,47 to 680 μF
Tolerance on nominal capacitance	−10 to + 50%
Rated voltage range, U_R (R5 series)	4 to 100 V
Category temperature range	−40 to + 85 °C
Endurance test at 85 °C	2000 h
Basic specification	IEC 384-4, long-life grade
Climatic category	
IEC 68	40/085/56
DIN 40040	GPF

Selection chart for C_{nom} − U_R and relevant case sizes.

C_{nom} μF	U_R (V) 4	6,3	10	16	25	40	63	100
0,47							3	
1							3	
1,5							3	
2,2							3	3
3,3							3	
4,7							3	4
6,8							3	
10							3	5
15						3	4/5a	
22					3	4/5a	5	6
33				3		4/5a		
47			3		4/5a	5	6	7
68		3		4/5a			7	
100	3		4/5a		5	6		
150		4/5a		5	6	7		
220	4/5a		5	6	7			
330	5		6	7				
470		6	7					
680		7						

case size	nominal dimensions (mm)
3	ϕ 6 x 10
5a	ϕ 8 x 11
4	ϕ 6,5 x 18
5	ϕ 8 x 18
6	ϕ 10 x 18
7	ϕ 10 x 25

APPLICATION

These capacitors are mainly used for smoothing, coupling and decoupling purposes in consumer applications, such as audio and television circuits, and in industrial applications such as measuring and regulating circuits. Other applications are in timing and delay circuits. The taped versions are extremely suitable for automatic insertion and for cutting and forming equipment.

DESCRIPTION

The capacitor has etched aluminium foil electrodes rolled up with a porous paper spacer with separates the anode and the cathode. The spacer is impregnated with an electrolyte which is the electrical connection between dielectric and cathode foil and retains its good characteristics both at low and at high temperatures. The capacitor is housed in an aluminium case, which is insulated with a blue plastic sleeve.

The capacitor is available in 3 styles, all with soldered-copper leads.

Style 1: axial leads; supplied on bandoliers in boxes or on reels;
Style 2: single ended; with self-locking lead;
Style 3: single ended;

MECHANICAL DATA

Dimensions in mm

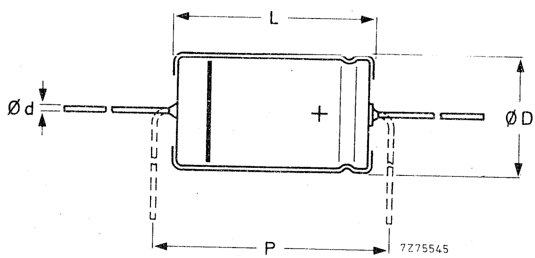
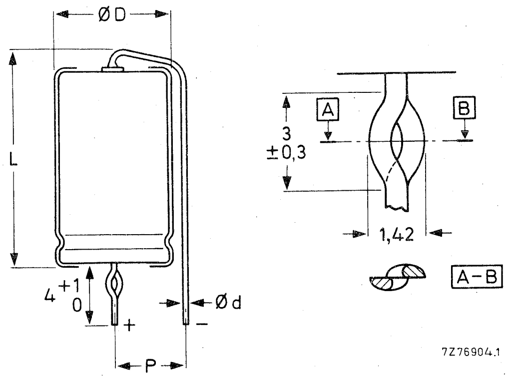


Fig. 1 Style 1; see Table 1a for dimensions d, D, L and P.

Table 1a

case size	d	style 1					mass approx. g
		D_{nom}	L_{nom}	D_{max}	L_{max}	P_{min}	
3	0,6	6,0	10,0	6,3	10,5	15	0,7
5a	0,6	8,0	11,0	8,5	11,5	15	1,1
4	0,8	6,5	18,0	6,9	18,5	25	1,3
5	0,8	8,0	18,0	8,5	18,5	25	1,7
6	0,8	10,0	18,0	10,5	18,5	25	2,5
7	0,8	10,0	25,0	10,5	25,0	30	3,3



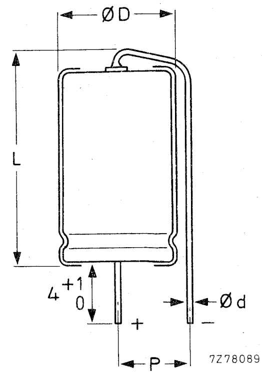


Fig. 2 Style 2, non-preferred; see Table 1b for dimensions d, D, L and P.

Fig. 3 Style 3; see Table 1b for dimensions d, D, L and P.

Table 1b

case size	d	style 2			style 3			mass approx. g
		D_{max}	L_{max}	P	D_{max}	L_{max}	P	
3	0,6				6,3	12,5	3,5-7,5	0,55
5a	0,6				8,5	13,0	5 -10	1,0
4	0,8	6,9	21,5	5 -10	6,9	21,5	5 -10	1,2
5	0,8	8,5	21,5	5 -10	8,5	21,5	5 -10	1,6
6	0,8	10,5	21,5	7,5-12,5	10,5	21,5	7,5-12,5	2,3
7	0,8	10,5	28,0	7,5-12,5	10,5	28,0	7,5-12,5	3,1

Marking

The capacitors are marked with:

nominal capacitance;
tolerance on nominal capacitance;
rated voltage;
grade reference (for long-life grade only);
group number 015 or 016; code for origin;
name of manufacturer;
date code (year and month) according to IEC 62;
band to identify the negative terminal;
+ signs to identify the positive terminal (on case sizes 4 to 7 only).

Mounting

The diameter of the mounting holes in the printed-wiring board is 0,8 + 0,1 mm for case sizes 3 and 5a, and 1 + 0,1 for case sizes 4 to 7, except that of the hole for the anode lead of style 2 capacitors: 1,3 + 0,1 mm.

Minimum atmospheric pressure 8,5 kPa

ELECTRICAL DATA

Table 2 (notes follow the table)

Unless otherwise specified all electrical values in Table 2 apply at an ambient temperature of 20 to 25 °C, a frequency of 100 Hz, an atmospheric pressure of 86 to 106 kPa and a relative humidity of 45 to 75%.

U_R V	nom. cap. μF	max. r.m.s. ripple current at upper cat. temperature mA	max. leakage current at U_R after 5 min μA	typ. ESR Ω	max. tan δ	max. impedance at 10 kHz	case size	catalogue number* 2222 followed by
4	100	44	20	4,0	0,40	2,6	3	015 .2101
4	220	70	44	1,8	0,40	1,2	5a	015 .2221
4	220	85	9	1,8	0,38	1,2	4	016 .2221
4	330	125	12	1,2	0,38	0,8	5	016 .2331
6,3	68	44	22	4,7	0,32	2,9	3	015 .3689
6,3	150	70	48	2,1	0,32	1,3	5a	015 .3151
6,3	150	85	10	2,1	0,30	1,3	4	016 .3151
6,3	470	190	22	0,68	0,30	0,4	6	016 .3471
6,3	680	270	30	0,47	0,30	0,3	7	016 .3681
10	47	44	24	5,4	0,26	3,4	3	015 .4479
10	100	70	50	2,6	0,26	1,6	5a	015 .4101
10	100	85	10	2,6	0,24	1,6	4	016 .4101
10	220	125	18	1,2	0,24	0,7	5	016 .4221
10	330	190	24	0,77	0,24	0,5	6	016 .4331
10	470	270	33	0,54	0,24	0,3	7	016 .4471
16	33	44	27	5,8	0,18	3,6	3	015 .5339
16	68	70	53	2,8	0,18	1,8	5a	015 .5689
16	68	85	11	2,8	0,17	1,8	4	016 .5689
16	150	125	19	1,3	0,17	0,80	5	016 .5151
16	220	190	26	0,87	0,17	0,55	6	016 .5221
16	330	270	36	0,58	0,17	0,36	7	016 .5331
25	22	37	28	7,2	0,15	4,1	3	015 .6229
25	47	60	56	3,4	0,15	1,9	5a	015 .6479
25	47	72	12	3,4	0,14	1,9	4	016 .6479
25	100	105	19	1,6	0,14	0,90	5	016 .6101
25	150	155	27	1,1	0,14	0,60	6	016 .6151
25	220	220	37	0,72	0,14	0,41	7	016 .6221

Table 2 (continued)

U_R V	nom. cap. μF	max. r.m.s. ripple current at upper cat. temperature mA	max. leakage current at U_R after 5 min. μA	typ. ESR Ω	max. tan δ	max. impedance at 10 kHz	case size	catalogue number* 2222 followed by
40	15	37	30	8,5	0,12	4,7	3	015 .7159
40	22	50	44	5,8	0,12	3,2	5a	015 .7229
40	22	60	12	5,8	0,11	3,2	4	016 .7229
40	33	60	60	3,9	0,12	2,1	5a	015 .7339
40	33	72	12	3,9	0,11	2,1	4	016 .7339
40	47	105	16	2,7	0,11	1,5	5	016 .7479
40	100	155	28	1,3	0,11	0,70	6	016 .7101
40	150	220	40	0,85	0,11	0,47	7	016 .7151
63	0,47	7	5	200	0,09	117	3	015 .8477
63	1	10	5	95	0,09	55	3	015 .8108
63	1,5	12	5	64	0,09	37	3	015 90043**
63	2,2	15	7	43	0,09	25	3	015 .8228
63	3,3	17	11	29	0,09	17	3	015 .8338
63	4,7	22	15	20	0,09	12	3	015 90044**
63	6,8	25	22	14	0,09	8,1	3	015 .8688
63	10	30	32	9,6	0,09	5,5	3	015 .8109
63	15	43	48	6,4	0,09	3,7	5a	015 .8159
63	15	55	10	6,4	0,09	3,7	4	016 .8159
63	22	80	13	4,3	0,09	2,5	5	016 .8229
63	47	115	22	2,0	0,09	1,2	6	016 .8479
63	68	165	30	1,4	0,09	0,81	7	016 .8689
100	2,2	25	11	43	0,09	21	3	015 .9228
100	4,7	36	22	20	0,09	9,5	4	016 .9478
100	10	60	50	9,6	0,09	4,5	5	016 .9109
100	22	104	80	4,3	0,09	2,1	6	016 .9229
100	47	145	33	2,0	0,09	0,96	7	016 90106**

* Replace dot in catalogue number by:
2 for style 1 on bandoliers on reel (preferred for case sizes 3 and 4);
3 for style 1 on bandoliers in box (preferred for case sizes 5a, 5, 6 and 7);
7 for style 2 (case sizes 4 to 7); non-preferred;
8 for style 3.

** Catalogue number for style 1 capacitors on bandoliers in box is given. For other packing and styles, see Table 3 for the corresponding catalogue number.

Table 3

last 5 digits of catalogue number			
style 1 capacitors on bandoliers in box	style 1 capacitors on bandoliers on reel	style 2 capacitors	style 3 capacitors
90043	90041		90076
90044	90042		90068
90106		90113	90114

Capacitance

Nominal capacitance values at 100 Hz and T_{amb} = 20 °C	see Table 2
Tolerance on nominal capacitance at 100 Hz	−10 to + 50%

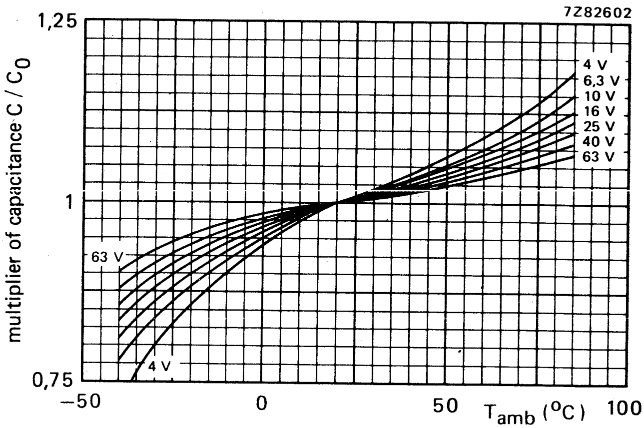


Fig. 4 Typical capacitance as a function of ambient temperature; C_0 = capacitance at 20 °C, 100 Hz.

Voltage

	< 40 °C	40 to 85 °C
Rated voltage = max. permissible voltage	1,1 x U_R	U_R
Ripple voltage* = max. permissible a.c. voltage providing the following three conditions are met:		
a) max. (d.c. + peak a.c.) voltage	≤ 1,1 x U_R	≤ U_R
b) max. peak a.c. voltage with d.c. voltage applied	≤ applied d.c. voltage + 1 V	
c) max. peak a.c. voltage without d.c. voltage applied	1 V	
Surge voltage = max. permissible voltage for short periods	1,15 x U_R	
Reverse voltage = max. d.c. voltage applied in the reverse polarity at the maximum category temperature for short periods	1 V	

Ripple current **

Maximum permissible r.m.s. ripple current

at 100 Hz and T_{amb} = 85 °C	see Table 2
at 100 Hz and T_{amb} = 70 °C	1,7 x values of Table 2
at 100 Hz and T_{amb} < 60 °C	2,2 x values of Table 2

* Ripple voltages are not applicable if the maximum permissible ripple current is exceeded. In that case the ripple current is decisive.

** Ripple currents are not applicable if the maximum permissible ripple voltage is exceeded. In that case the ripple voltage is decisive.

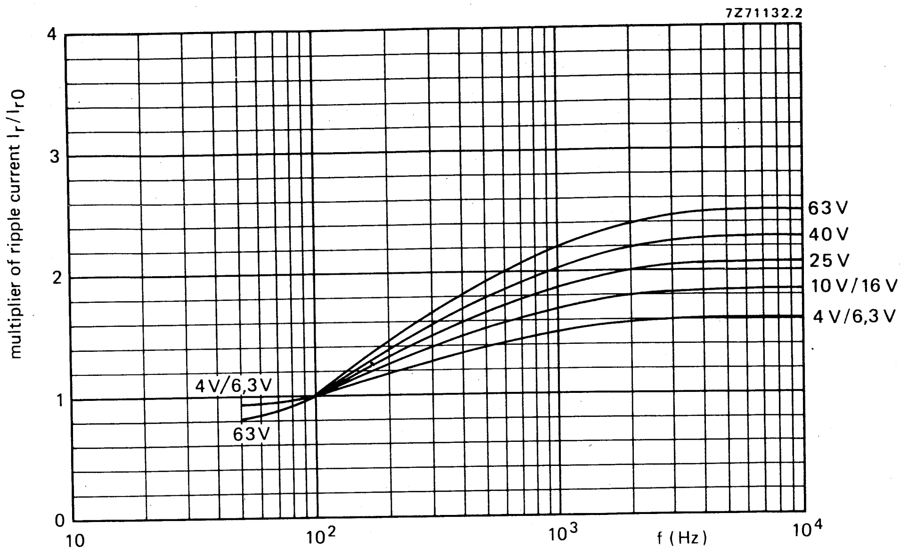


Fig. 5 Typical ripple current as a function of frequency; I_{r0} = ripple current at 100 Hz and 85 °C.

Non-sinusoidal ripple currents have to be analyzed into a number of sinusoidal currents and the following requirements shall then be satisfied:

$$\sum_n \frac{I_n^2}{r_n} \leqslant I_{rmax}^2$$

I_{rmax} = maximum ripple current at 100 Hz and applicable ambient temperature;
I_n = ripple current at a certain frequency;
$\sqrt{r_n} = I_r/I_{ro}$ = multiplying factor at a same frequency.

Charge and discharge current

The capacitors may be charged from a source without internal resistance and they may be discharged by short-circuiting.
If the capacitors are charged and discharged continuously at a rate of several times per minute, the charge and discharge currents have to be considered as ripple currents flowing through the capacitor. The r.m.s. value of these currents should be determined and the value thus found must not exceed the applicable limit.

Leakage current

Maximum leakage current 5 min after application of the rated voltage at T_{amb} = 20 °C	see Table 2 (0,05 CU or 5 μA for CU ⩽ 1000 μC; 0,03 CU + 20 μA for CU > 1000 μC)
Leakage current during continuous operation at U_R,	
at T_{amb} = 20 °C	approx. 0,2 x values of Table 2
at T_{amb} = 85 °C	⩽ values of Table 2

If the leakage current is too high, owing to prolonged storage and/or storage at an excessive temperature (> 40 °C), application of the rated voltage for some hours will cause the leakage current to fall to a value lower than specified in Table 2.

Equivalent series resistance (ESR)

ESR at 100 Hz and T_{amb} = 20 °C — see Table 2

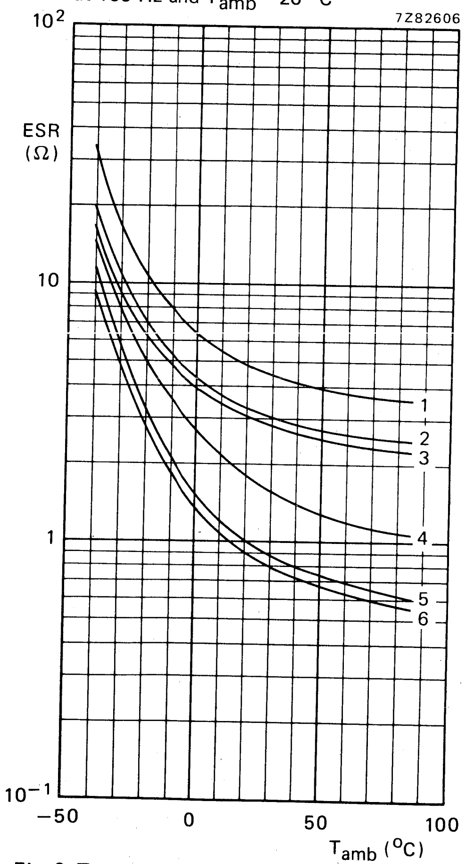


Fig. 6 Typical ESR as a function of ambient temperature at 100 Hz.
curve 1 = case size 3/63 V; curve 2 = case size 4/63V;
curve 3 = case size 5a/63 V; curve 4 = case size 3/4 V;
curve 5 = case size 4/4V; curve 6 = case size 5a/4 V.

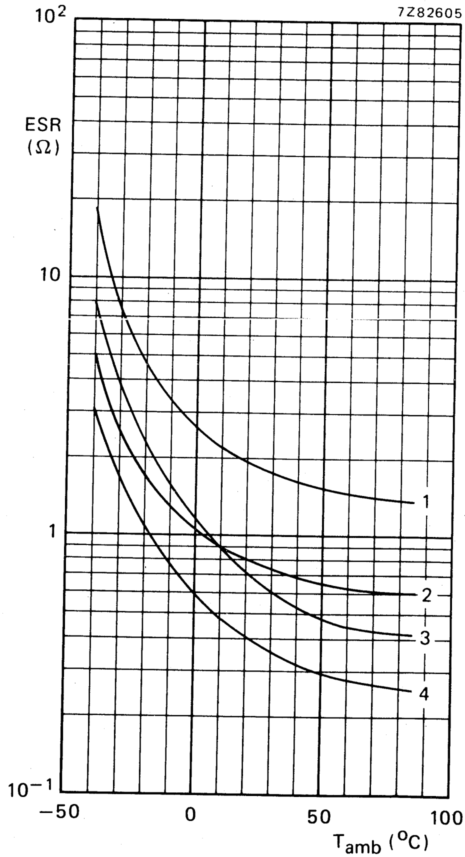


Fig. 7 Typical ESR as a function of ambient temperature at 100 Hz.
curve 1 = case size 5/63V; curve 2 = case size 6/63 V;
curve 3 = case size 5/4 V; curve 4 = case size 7/63 V.

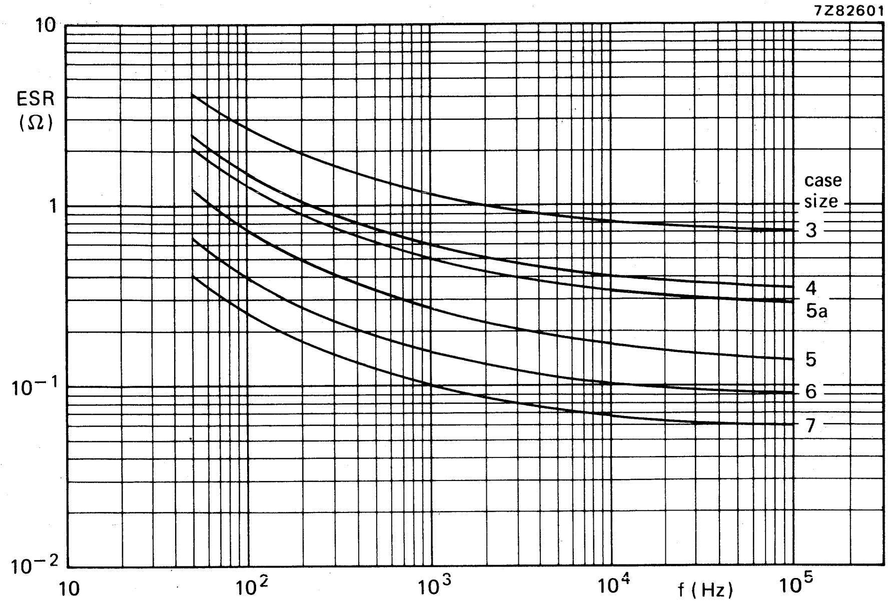


Fig. 8 Typical ESR as a function of frequency at 20 °C; U_R = 40 V.

Tan δ (dissipation factor)

Maximum tan δ at 100 Hz and T_{amb} = 20 °C, measured by means of a four-terminal circuit (Thomson circuit) — see Table 2

Impedance

Maximum impedance at 10 kHz and T_{amb} = 20 °C, measured by means of a four-terminal circuit (Thomson circuit) — see Table 2

$z = Z \times C_{nom}$ — see Table 4

Table 4

T_{amb}	$z = Z \times C_{nom}$ (Ω μF) at U_R							
	4 V	6,3 V	10 V	16 V	25 V	40 V	63 V	100 V
+ 20 °C		200	160	120	90	70	55	45
–25 °C		1200	750	560	400	300	180	130
–40 °C		3200	2000	1500	1100	900	500	350

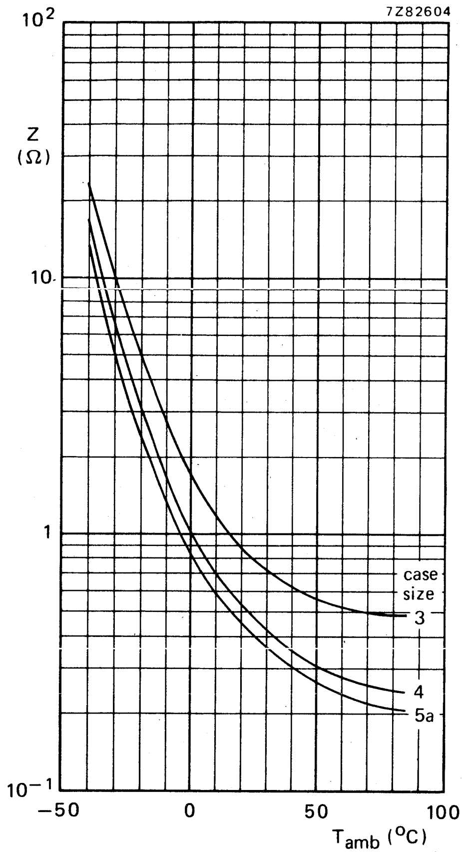


Fig. 9 Typical impedance as a function of ambient temperature at 10 kHz; U_R = 16 V.

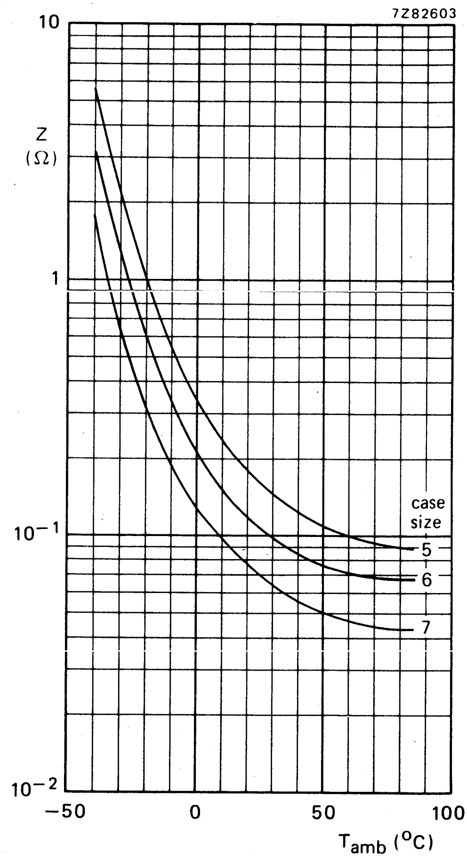


Fig. 10 Typical impedance as a function of ambient temperature at 10 kHz; U_R = 16 V.

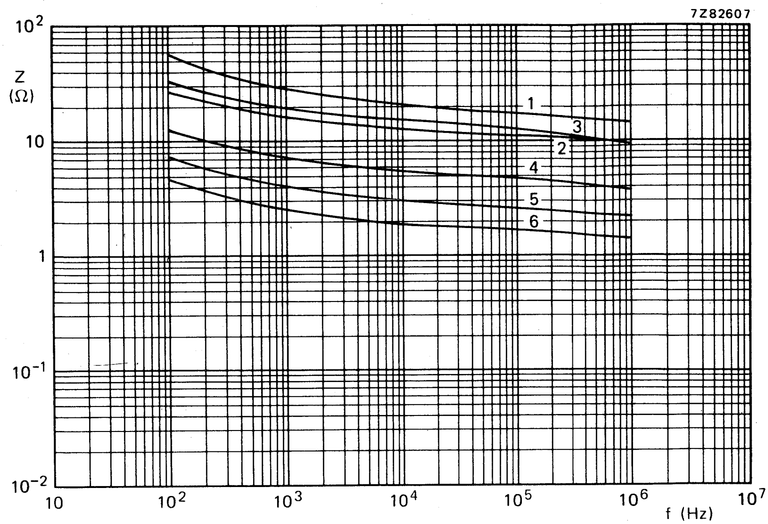


Fig. 11 Typical impedance as a function of frequency at −40 °C; U_R = 16 V.

curve 1 = 33 μF, case size 3;
curve 2 = 68 μF, case size 5a;
curve 3 = 68 μF, case size 4;
curve 4 = 150 μF, case size 5;
curve 5 = 220 μF, case size 6;
curve 6 = 330 μF, case size 7.

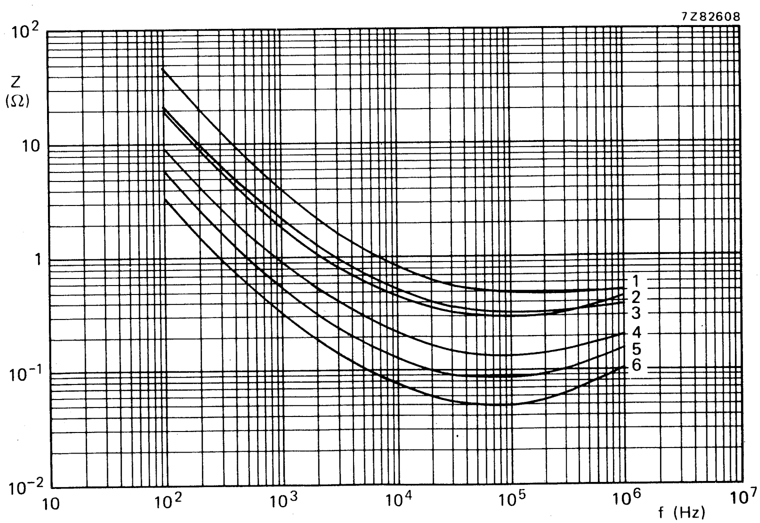


Fig. 12 Typical impedance as a function of frequency at 20 °C; U_R = 16 V.

curve 1 = 33 μF, case size 3;
curve 2 = 68 μF, case size 5a;
curve 3 = 68 μF, case size 4;
curve 4 = 150 μF, case size 5;
curve 5 = 220 μF, case size 6;
curve 6 = 330 μF, case size 7.

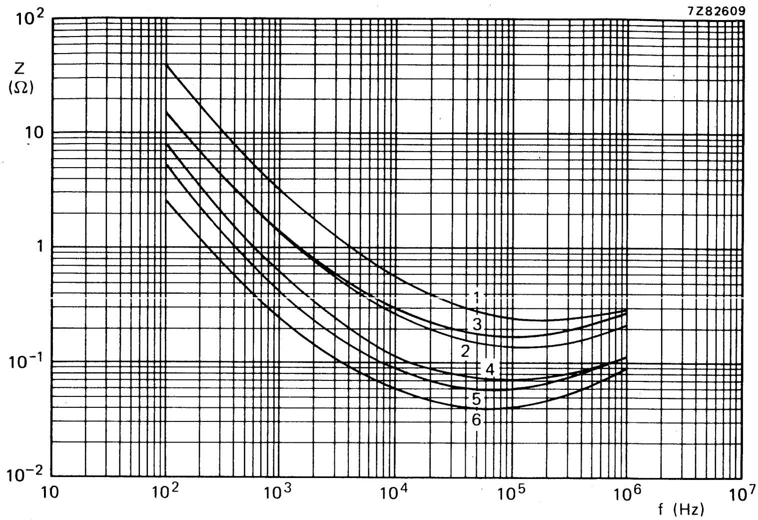


Fig. 13 Typical impedance as a function of frequency at 85 °C; U_R = 16 V.

curve 1 = 33 μF, case size 3;
curve 2 = 68 μF, case size 5a;
curve 3 = 68 μF, case size 4;
curve 4 = 150 μF, case size 5;
curve 5 = 220 μF, case size 6;
curve 6 = 330 μF, case size 7.

OPERATIONAL DATA

Category temperature range —40 to + 85 °C

PACKING

Capacitors of style 1 are supplied on bandoliers in boxes or on reels; capacitors of styles 2 and 3 are supplied in boxes. The number per box or per reel is given in Table 5.

Table 5

case size	number of capacitors		
	style 1 per reel	style 1 per box	styles 2 and 3 per box
3	1000	1000	1000 (only style 3)
4	1000	1000	1000
5a	500	500	1000 (only style 3)
5	500	500	1000
6	500	500	1000
7	500	500	500

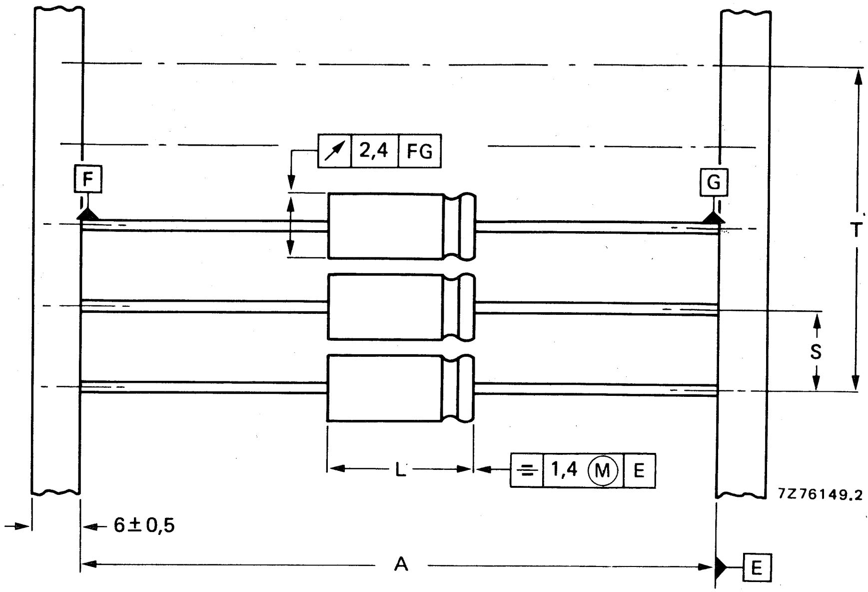


Fig. 14 Style 1 capacitors on bandoliers: the bandolier to which the negative capacitor terminals are connected is blue. See Table 6 for dimensions A, S, T and L.

Table 6; dimensions in mm

case size	A	S	T for number (n) of capacitors		L_{max}
			n < 50	50 < n < 100	
3	63,5 ± 1,6	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	10,5
5a	63,5 ± 1,6	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	11,5
4	73 ± 1,6	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	18,5
5	73 ± 1,6	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	18,5
6	73 ± 1,6	15 ± 0,75	15 (n-1) ± 2	15 (n-1) ± 4	18,5
7	73 ± 1,6	15 ± 0,75	15 (n-1) ± 2	15 (n-1) ± 4	25,0

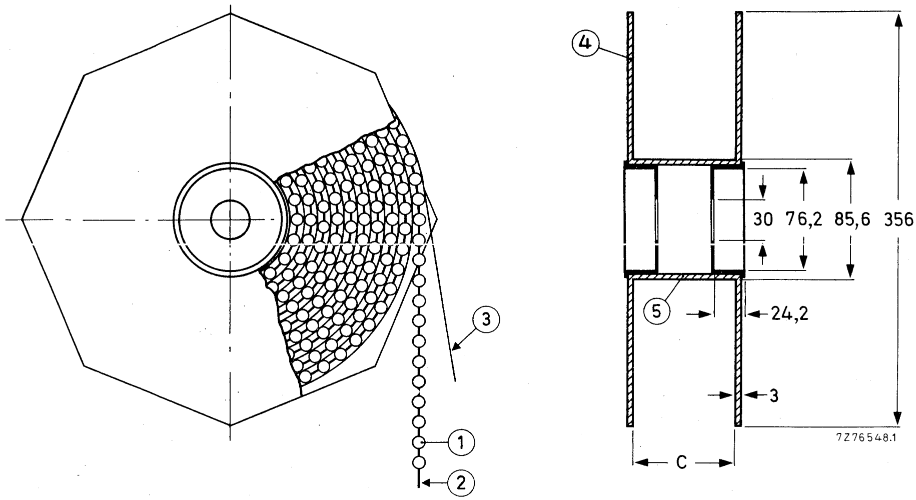


Fig. 15 Style 1 capacitors on bandoliers on reel; dimension C is 84,5 mm for case sizes 3 and 5a, and 88,0 mm for case sizes 4, 5, 6 and 7, the overall width of the reel is 94,5 mm and 99,5 mm respectively.

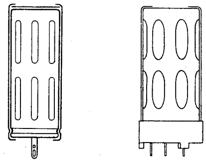
1 = capacitor
2 = bandolier
3 = paper
4 = flange
5 = cylinder

TESTS AND REQUIREMENTS

See Introduction, section 9, under aluminium electrolytic capacitors.

Note: Capacitors 2222 015 and 2222 016 belong to the miniature types, long-life grade.

ALUMINIUM ELECTROLYTIC CAPACITORS



- **Large type**
- **Long life**
- **Industrial applications**

QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	680 to 33 000 μF
Tolerance on nominal capacitance	−10 to + 50%
Rated voltage range, U_R (R5 series)	6,3 to 63 V
Category temperature range	−40 to + 85 °C
Typical life time	> 5000 h at 85 °C
Basic specification	IEC 384-4, long-life grade DIN 41238 (only version with printed-wiring pins)
Climatic category, IEC 68	40/085/56
Approval	U.K. Post Office D2186 (only version with solder tags)

Selection chart for C_{nom}-U_R and relevant case sizes.

C_{nom} μF	U_R (V)					
	6,3	10	16	25	40	63
680						5
1000					5	6
1500						7/8a
2200				5	6	8/9a
3300			5	6	7/8a	9
4700		5	6	7/8a	8/9a	10
6800		6	7/8a	8/9a	9	
10 000	6	7/8a	8/9a	9	10	
15 000	8a	8/9a	9	10		
22 000	9a		10			
33 000	9	10				

case size	nominal dimensions (mm) versions with solder tags	versions with printed-wiring pins
5	ϕ 21 x 50	
6	ϕ 25 x 50	ϕ 25 x 55,5
7	ϕ 25 x 80	
8a	ϕ 30 x 50	ϕ 30 x 55,8
8	ϕ 30 x 80	ϕ 30 x 84,7
9a	ϕ 35 x 50	ϕ 35 x 55,8
9	ϕ 35 x 80	ϕ 35 x 84,7
10	ϕ 40 x 80	ϕ 40 x 84,7

APPLICATION

Especially for smoothing and decoupling purposes in industrial power supplies, where a long life and high ripple currents are required and also for coupling purposes in audio power circuits.

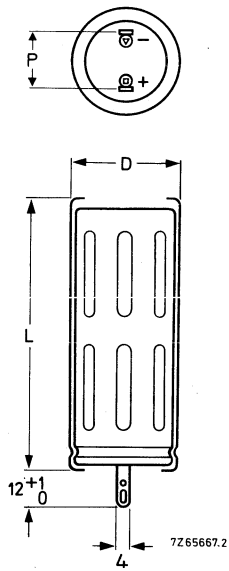
DESCRIPTION

The capacitor winding is housed in an aluminium case, sealed with a rubber-faced paper laminate disc. The electrolyte used is of a special composition to ensure good characteristics at high and low temperatures. The case, which has no electrical function, is covered with a blue synthetic sleeve. The capacitors are available with solder tags or with printed-wiring pins. Each capacitor is provided with a safety vent to release gas pressure under overload conditions.

MECHANICAL DATA

Dimensions in mm

Capacitors with solder tags



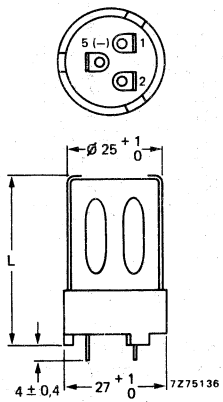
See Table 1 for dimensions D, L and P.

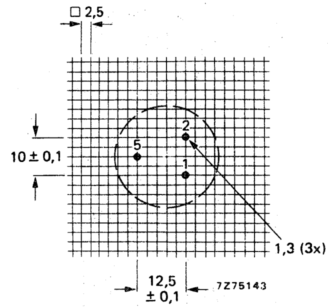
Table 1

case size	D		L		P*		mass approx. g
5	21	+ 0,6	50	+ 1,3	13	± 0,1	20
6	25		50		13		30
7	25		80		13		45
8a	30		50		19		40
8	30		80		19		70
9a	35		50		19		60
9	35		80		19		100
10	40		80		19		130

* P at emergence of terminals.

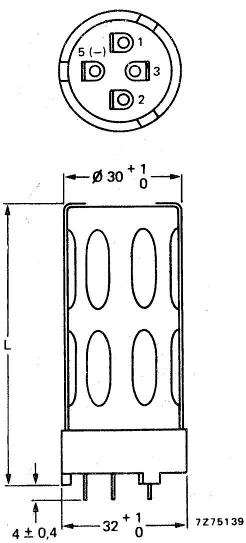
Capacitors with printed-wiring pins

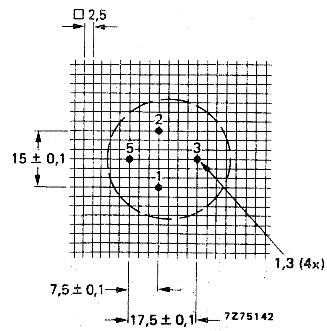




Piercing diagram viewed from component side.

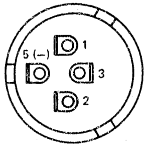
case size	L	mass approx. g
6	55,5 ± 0,8	30

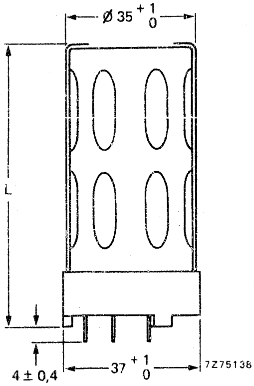


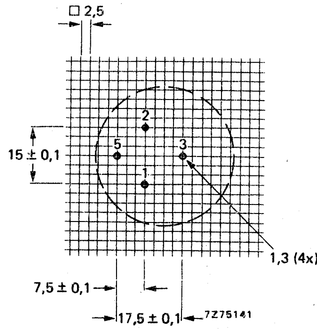


Piercing diagram viewed from component side.

case size	L	mass approx. g
8a	55,8 ± 0,8	40
8	84,7 ± 0,8	70

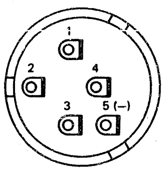


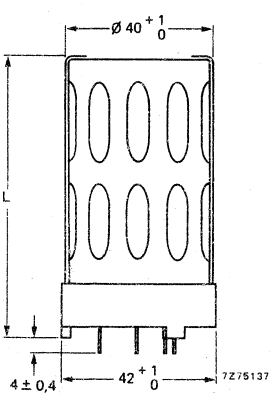


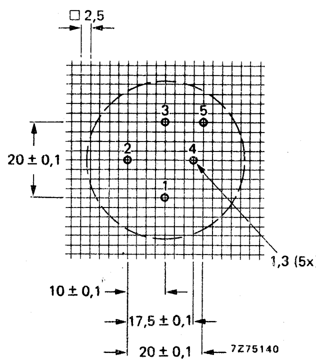


Piercing diagram viewed from component side.

case size	L	mass approx. g
9a 9	55,8 } ± 0,8 84,7 }	60 100







Piercing diagram viewed from component side.

case size	L	mass approx. g
10	84,7 ± 0,8	130

Marking

The capacitors are marked with: nominal capacitance, tolerance on capacitance, rated voltage, temperature range, IEC type, max. permissible ripple current at T_{amb} = 50 °C, catalogue number and date code.

The terminals are marked as shown in the dimensional figures; the negative terminal is also indicated by a hole in the insulation sleeve.

Mounting

The capacitors may be mounted in any position with or without a mounting clamp. When a number of capacitors are connected in a bank, they must not be closer together than 15 mm, when no derating of ripple current and/or temperature is applied. The uninsulated part of the case may only touch objects with the same potential as the negative terminal. See also mounting accessories.

Minimum atmospheric pressure 8,5 kPa

ELECTRICAL DATA

Table 2a Capacitors with solder tags

Unless otherwise specified all electrical values in Table 2a apply at an ambient temperature of 20 to 25 °C, a frequency of 100 Hz, an atmospheric pressure of 86 to 106 kPa and a relative humidity of 45 to 75%.

U_R V	nominal capacitance μF*	max. r.m.s. ripple current at T_{amb} = 85 °C A*	max. leakage current at U_R after 5 min μA*	max. tan δ *	maximum impedance at 100 kHz mΩ*	case size	catalogue number
6,3	10000	1,8	380	0,50	60	6	2222 071 13103
	15000	2,5	570	0,50	50	8a	073 13153
	33000	4,9	1250	0,50	25	9	071 13333
10	4700	1,1	280	0,35	80	5	071 14472
	6800	1,8	410	0,35	60	6	071 14682
	10000	2,7	600	0,35	50	7	071 14103
	10000	2,4	600	0,35	50	8a	073 14103
	15000	3,7	900	0,35	50	8	071 14153
	33000	6,0	1980	0,35	25	10	071 14333
16	3300	1,1	320	0,25	80	5	071 15332
	4700	1,7	450	0,25	60	6	071 15472
	6800	2,6	655	0,25	50	7	071 15682
	6800	2,4	655	0,25	50	8a	073 15682
	10000	3,5	960	0,25	50	8	071 15103
	10000	3,2	960	0,25	30	9a	073 15103
	15000	4,7	1440	0,25	25	9	071 15153
	22000	6,1	2120	0,25	25	10	071 15223
25	2200	1,0	330	0,20	80	5	071 16222
	3300	1,7	495	0,20	60	6	071 16332
	4700	2,4	705	0,20	50	7	071 16472
	4700	2,2	705	0,20	50	8a	073 16472
	6800	3,3	1020	0,20	50	8	071 16682
	6800	2,9	1020	0,20	30	9a	073 16682
	10000	4,3	1500	0,20	25	9	071 16103
	15000	5,7	2250	0,20	25	10	071 16153
40	1000	1,0	240	0,15	125	5	071 17102
	2200	1,3	530	0,15	100	6	071 17222
	3300	2,4	795	0,15	80	7	071 17332
	3300	1,7	795	0,15	80	8a	073 17332
	4700	3,1	1130	0,15	80	8	071 17472
	4700	2,4	1130	0,15	50	9a	073 17472
	6800	4,1	1640	0,15	40	9	071 17682
	10000	5,3	2400	0,15	40	10	071 17103
63	680	0,8	260	0,10	125	5	071 18681
	1000	1,3	380	0,10	100	6	071 18102
	1500	2,0	570	0,10	80	7	071 18152
	1500	1,7	570	0,10	80	8a	073 18152
	2200	2,6	835	0,10	80	8	071 18222
	2200	2,4	835	0,10	50	9a	073 18222
	3300	3,5	1250	0,10	40	9	071 18332
	4700	4,5	1780	0,10	40	10	071 18472

* See also corresponding paragraph.

Table 2b Capacitors with printed-wiring pins

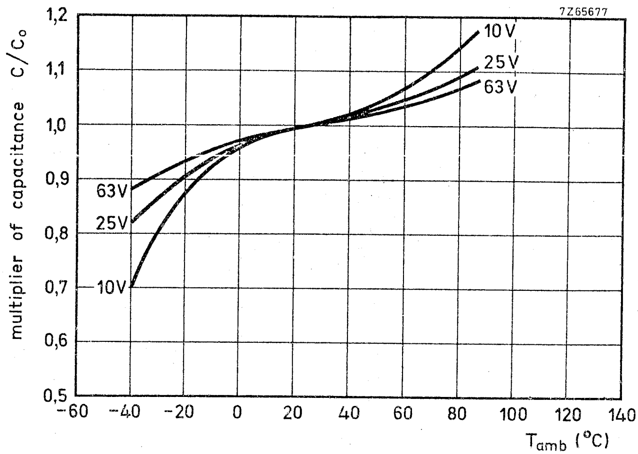
Unless otherwise specified all electrical values in Table 2b apply at an ambient temperature of 20 to 25 °C, a frequency of 100 Hz, an atmospheric pressure of 86 to 106 kPa and a relative humidity of 45 to 75%.

U_R V	nominal capacitance µF*	max. r.m.s. ripple current at T_{amb} = 85 °C A*	max. leakage current at U_R after 5 min µA*	max. tan δ*	maximum impedance at 100 kHz mΩ*	case size	catalogue number
6,3	10000	1,8	380	0,50	60	6	2222 071 53103
	15000	2,5	570	0,50	50	8a	073 53153
	22000	3,3	840	0,50	30	9a	073 53223
10	6800	1,8	410	0,35	60	6	071 54682
	15000	3,3	900	0,35	30	9a	073 54153
	33000	6,0	1980	0,35	25	10	071 54333
16	4700	1,7	450	0,25	60	6	071 55472
	6800	2,4	655	0,25	50	8a	073 55682
	10000	3,5	960	0,25	50	8	071 55103
25	3300	1,7	495	0,20	60	6	071 56332
	4700	2,2	705	0,20	50	8a	073 56472
	6800	2,9	1020	0,20	30	9a	073 56682
	10000	4,3	1500	0,20	25	9	071 56103
40	2200	1,3	530	0,15	100	6	071 57222
	3300	1,7	795	0,15	80	8a	073 57332
	4700	3,1	1130	0,15	80	8	071 57472
	4700	2,4	1130	0,15	50	9a	073 57472
	6800	4,1	1640	0,15	40	9	071 57682
	10000	5,3	2400	0,15	40	10	071 57103
63	1000	1,3	380	0,10	100	6	071 58102
	1500	1,7	570	0,10	80	8a	073 58152
	2200	2,4	835	0,10	50	9a	073 58222
	4700	4,5	1780	0,10	40	10	071 58472

* See also corresponding paragraph.

Capacitance

Nominal capacitance values at 100 Hz and 20 °C	see Table 2a or 2b
Tolerance on nominal capacitance at 100 Hz	−10 to + 50%



Typical capacitance as a function of ambient temperature C_0 = capacitance at 25 °C, 100 Hz.

Voltage

Rated voltage = maximum permissible voltage
- at < 40 °C: 1,1 x U_R
- at 40 °C up to 85 °C: U_R

Ripple voltage* = maximum permissible a.c. voltage providing the following three conditions are met:

	< 40 °C	40 °C up to 85 °C
a) max. (d.c. + peak a.c.) voltage	≤ 1,1 x U_R	≤ U_R
b) max. peak a.c. voltage with d.c. voltage applied	≤ applied d.c. voltage + 1 V	
c) max. peak a.c. voltage without d.c. voltage applied	1 V	

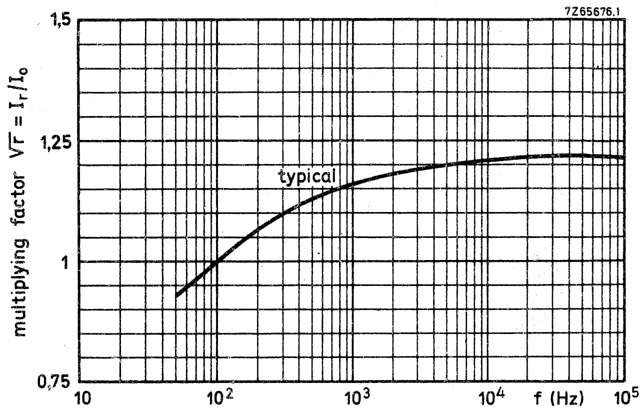
Surge voltage = maximum permissible voltage for short periods (see also "Tests and requirements") 1,15 x U_R

Reverse voltage = maximum d.c. voltage applied in the reverse polarity at the maximum category temperature for short periods 1 V

* Ripple voltages are not applicable if the maximum permissible ripple current is exceeded. In that case the ripple current is decisive.

Ripple current

Maximum permissible r.m.s. ripple current at 100 Hz and T_{amb} = 85 °C	see Table 2a or 2b
at T_{amb} = 80 °C	1,4 x values of Table 2a and 2b
at T_{amb} = 75 °C	1,7 x values of Table 2a and 2b
at T_{amb} ≤65 °C	2,2 x values of Table 2a and 2b



Multiplying factor as a function of frequency, for calculation of maximum ripple current.
I_0 = maximum ripple current at 85 °C, 100 Hz.

Non-sinusoidal ripple currents have to be analyzed into a number of sinusoidal currents and the following requirements shall then be satisfied:

$$\sum_n \frac{I_n^2}{r_n} \leqslant I_{r\,max}^2$$

$I_{r\,max}$ = maximum ripple current at 100 Hz and applicable ambient temperature
I_n = ripple current at a certain frequency
$\sqrt{r_n}$ = multiplying factor at a same frequency

Note

These ripple currents are not applicable if the maximum permissible ripple voltage is exceeded. In that case the ripple voltage is decisive.

Charge and discharge current

The capacitors may be charged from a source without internal resistance and they may be discharged by short-circuiting.
If the capacitors are charged and discharged continuously at a rate of several times per minute, the charge and discharge currents have to be considered as ripple currents flowing through the capacitor. The r.m.s. value of these currents should be determined and the value thus found must not exceed the applicable limit.

Leakage current

Maximum leakage current 5 min. after application of the rated voltage at T_{amb} = 20 °C	see Table 2a or 2b (0,006 CU + 4 μA)
Leakage current during continuous operation at U_R, at T_{amb} = 20 °C	approx. 0,2 of value stated in Table 2a or 2b
at T_{amb} = 85 °C	$\leqslant$ value stated in Table 2a or 2b

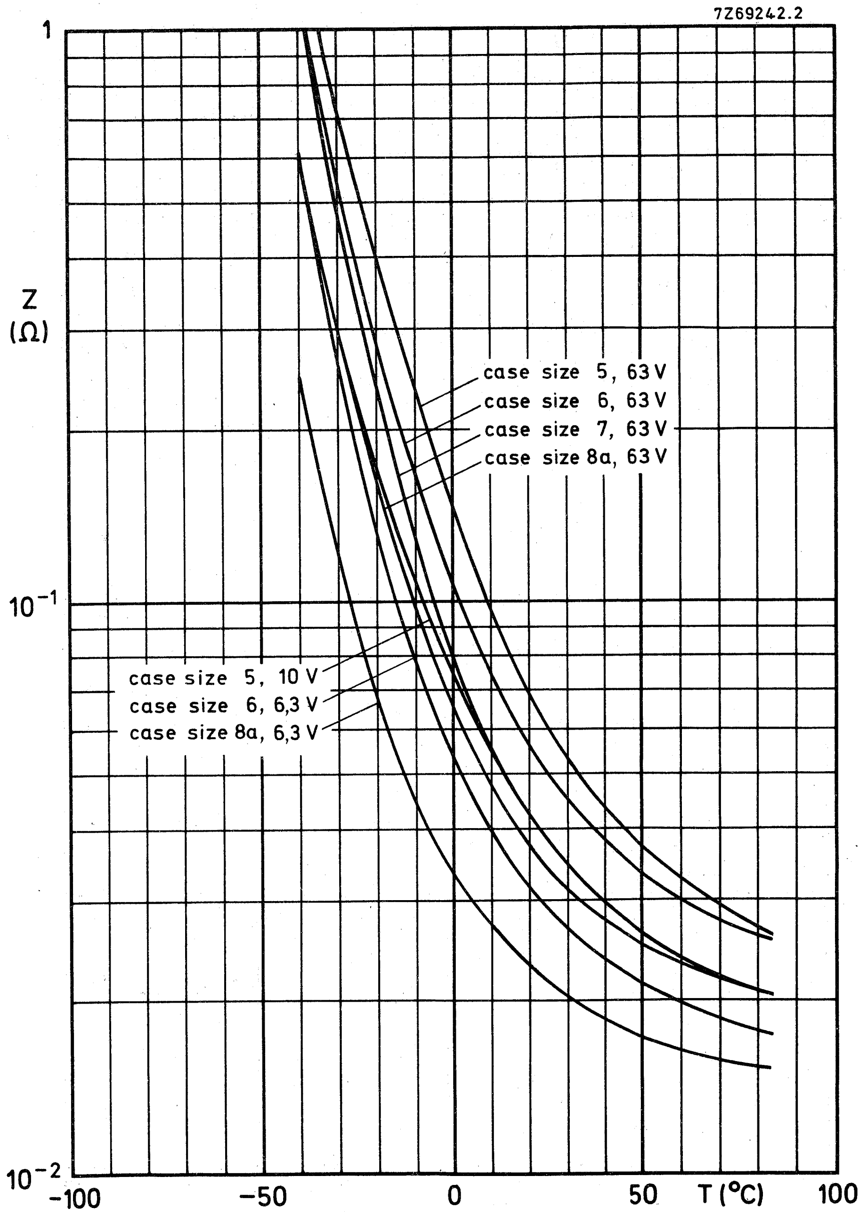
If owing to prolonged storage and/or storage at an excessive temperature the leakage current is too high, application of the rated voltage for some hours will cause the leakage current to fall to a value lower than specified in Table 2.

Tan δ (dissipation factor)

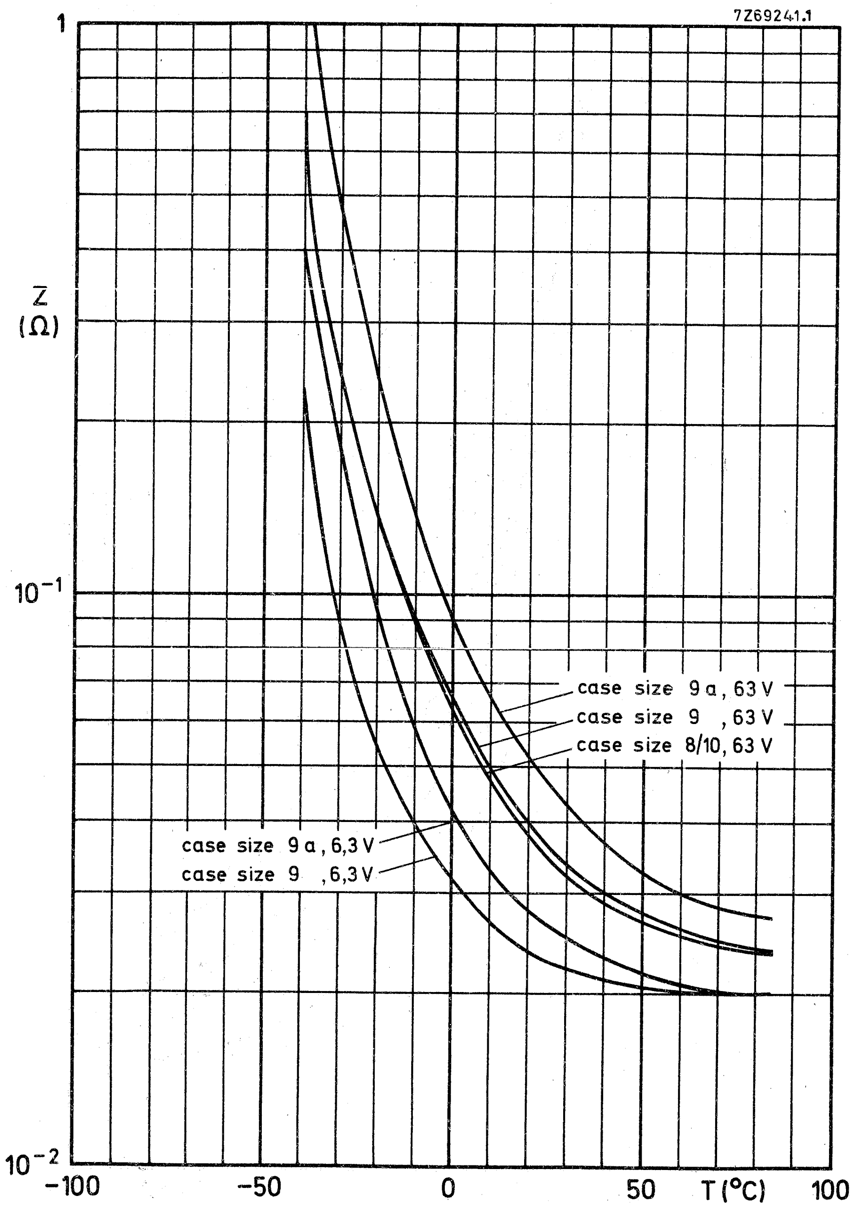
Tan δ at 100 Hz and 20 °C, measured by means of a four-terminal circuit (Thomson circuit)	see Table 2a or 2b

Impedance

Impedance at 100 kHz and T_{amb} = 20 °C, measured by means of a four-terminal circuit (Thomson circuit)	see Table 2a or 2b

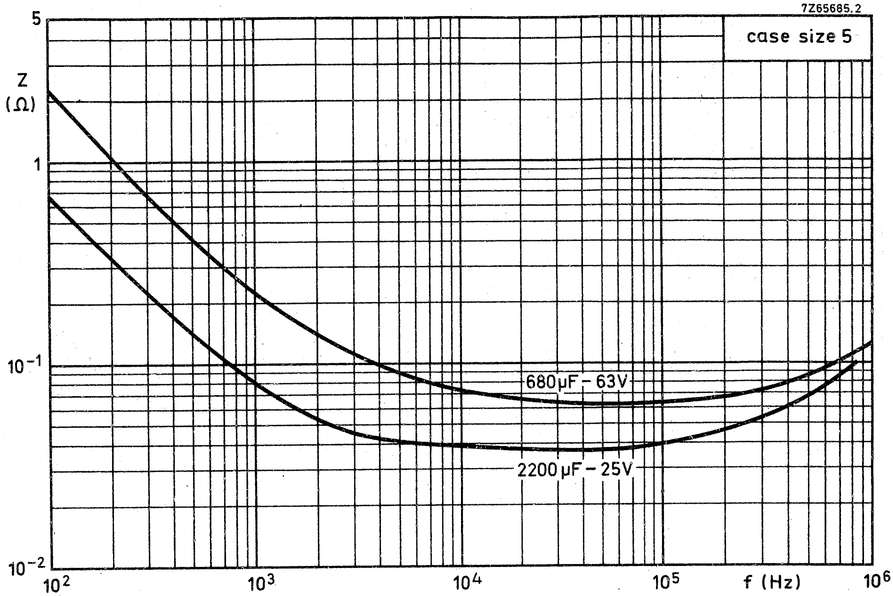


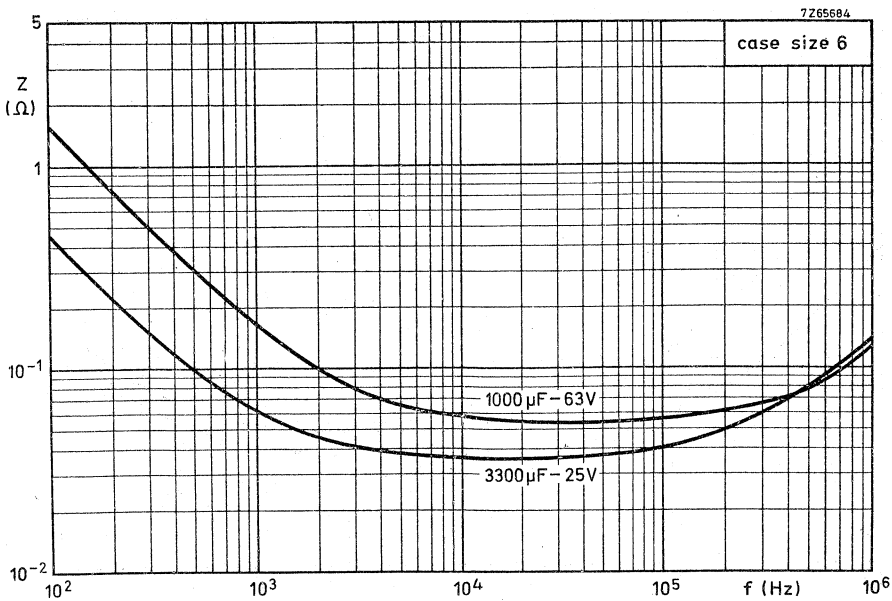
Typical impedance as a function of temperature at 100 kHz.



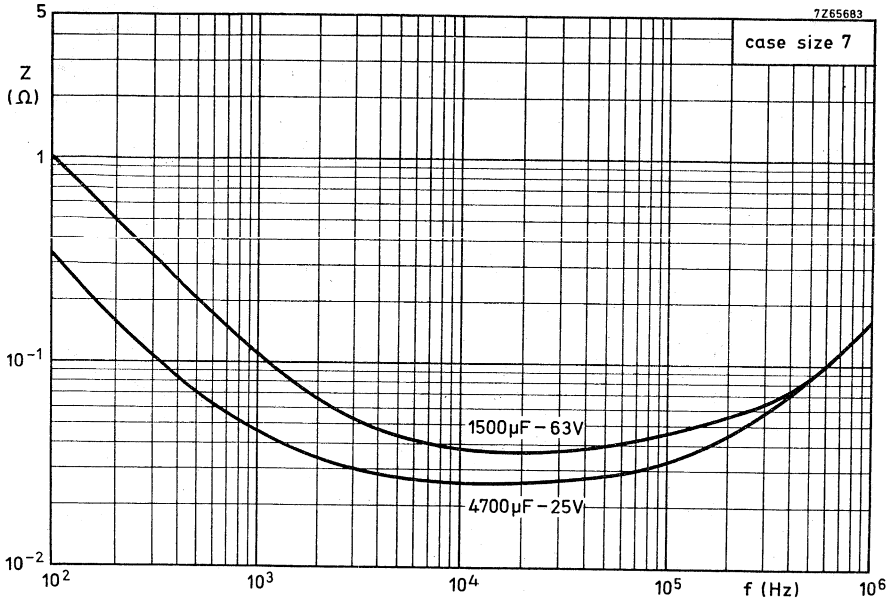
Typical impedance as a function of temperature at 100 kHz.

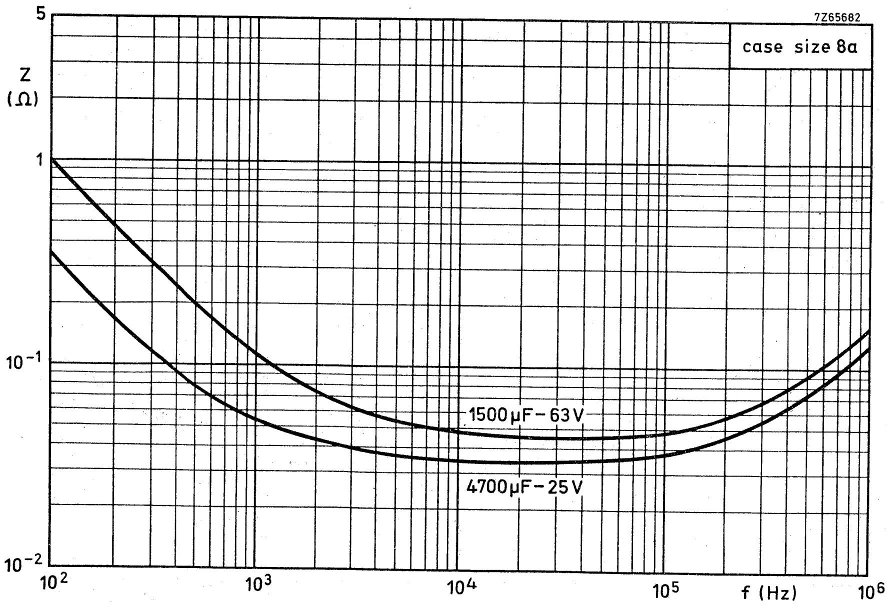
Typical impedance as a function of frequency at different voltages and T_{amb} = + 20 °C.



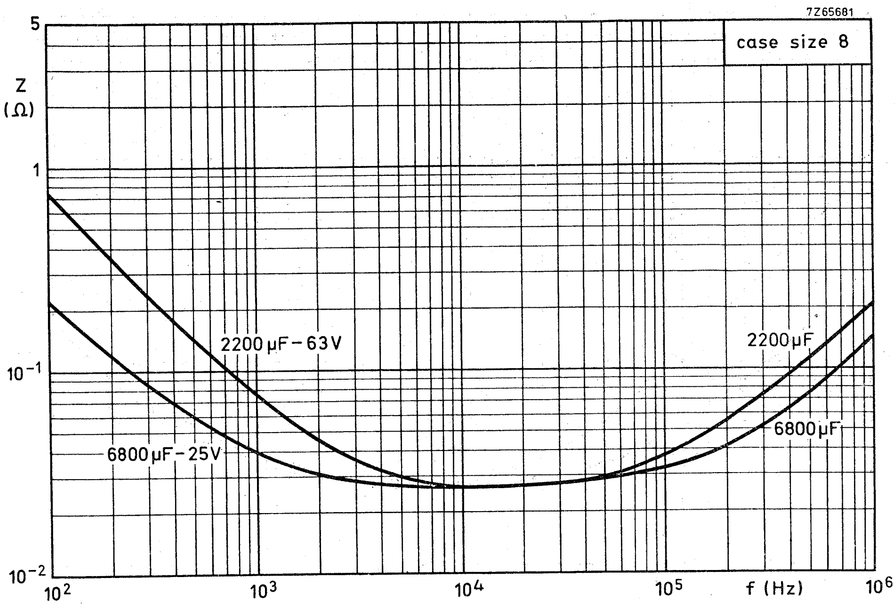


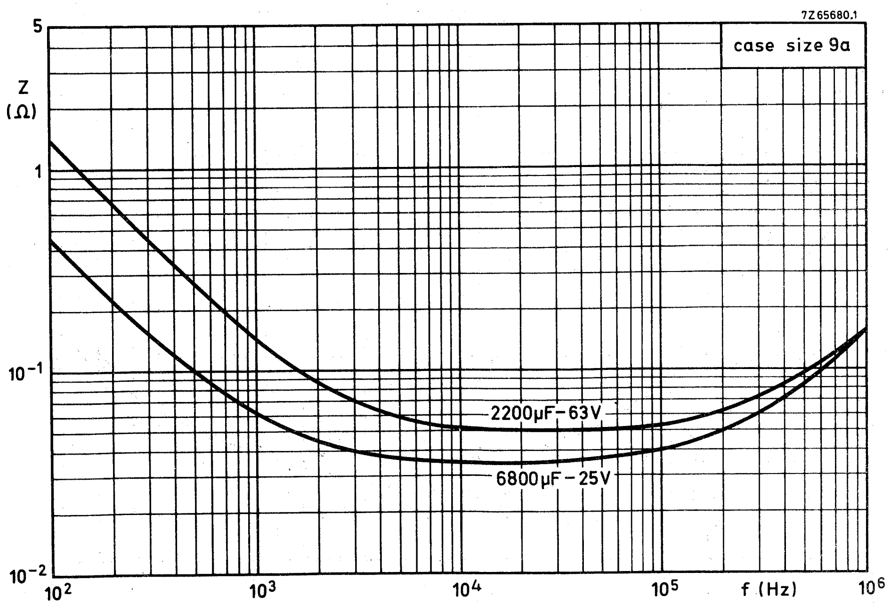
Typical impedance as a function of frequency at different voltages and T_{amb} = + 20 °C.



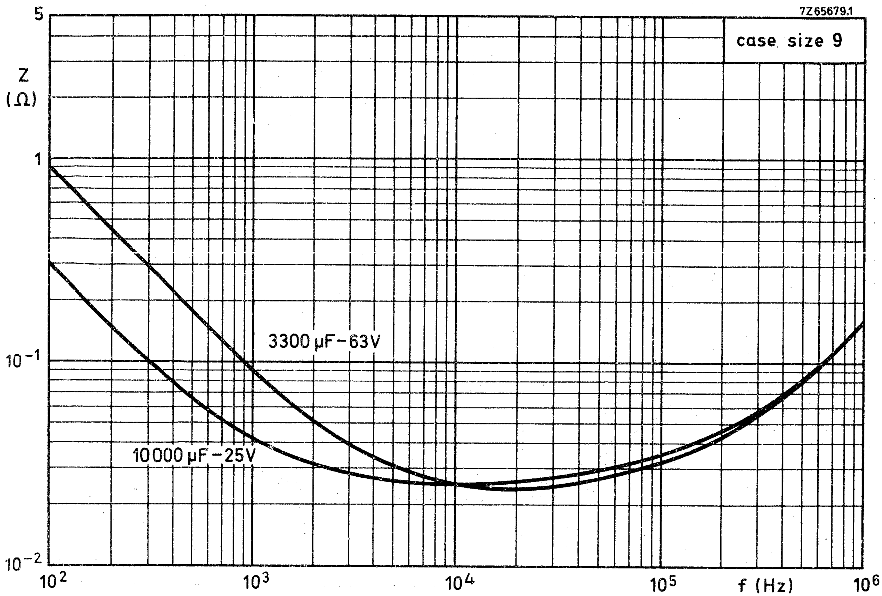


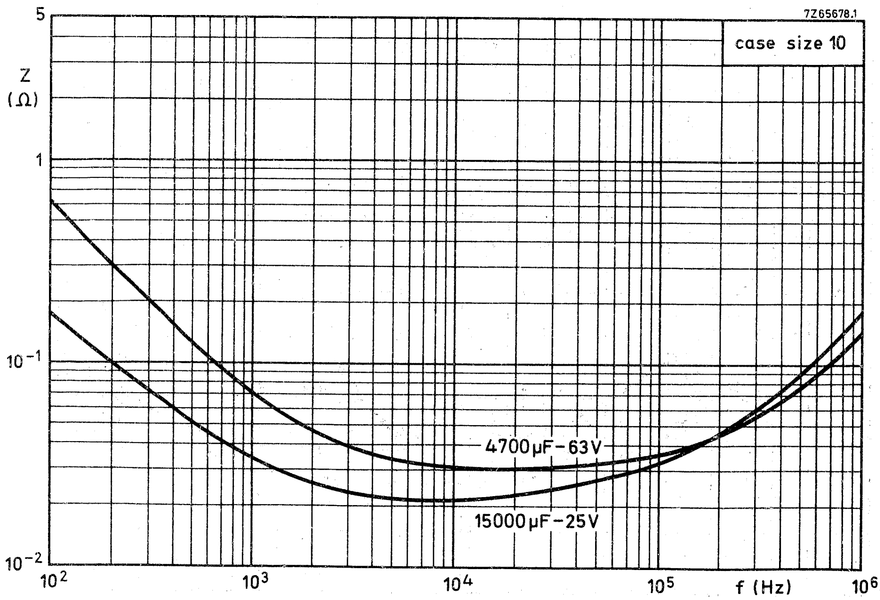
Typical impedance as a function of frequency at different voltages and T_{amb} = + 20 °C.





Typical impedance as a function of frequency at different voltages and T_{amb} = + 20 °C.





Equivalent series resistance (ESR = tan $\delta/\omega C$)

Tan δ and C at 100 Hz and T_{amb} = 20 °C	see Table 2

OPERATIONAL DATA

Category temperature range

For rated voltage	−40 to +85 °C

Life expectancy

Typical lifetime	
at T_{amb} = 85 °C	> 5000 h
at T_{amb} = 25 °C	> 15 years

PACKING

100 pieces per box.

TESTS AND REQUIREMENTS

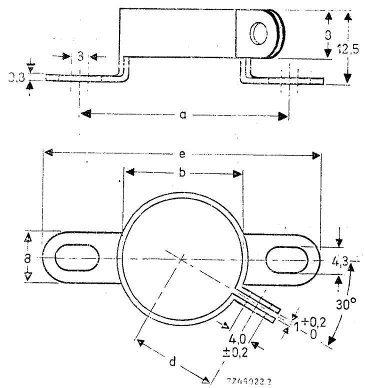
See Introduction, section 9, under aluminium electrolytic capacitors.

Note: Capacitors 2222 071 and 2222 073 are large types, long-life grade.

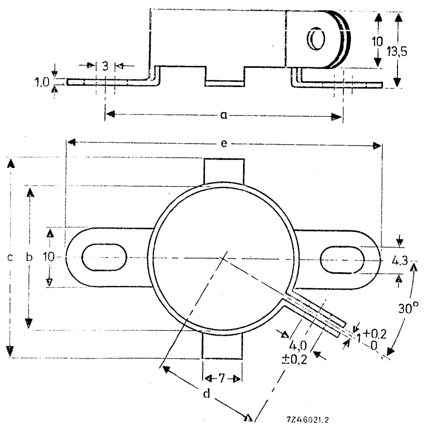
MOUNTING ACCESSORIES

Clamps

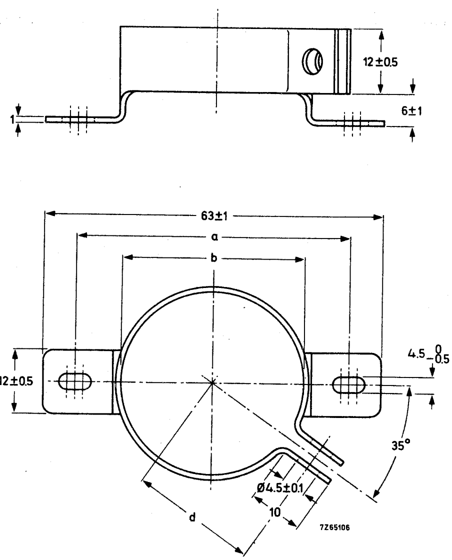
To facilitate vertical mounting, a series of rigid clamps made of cadmium-plated steel are available. They can easily be slid over the capacitor and then fixed to it with a nut and bolt. They are provided with two mounting lugs.
Five types are available, one for each case diameter of the capacitor range. They are delivered without nuts or bolts.



For case size 5.



For case sizes 6, 7, 8, 8a and 10.

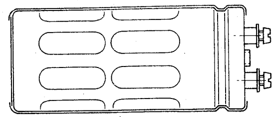


For case sizes 9 and 9a.

case size	dimensions in mm					catalogue number
	a	b	c	d	e	
→ 5	37,0 ± 0,2	21	–	15,5	49	4322 043 03291
6, 7	41,5 ± 0,2	25	35	18,5	56	03301
8, 8a	46,5 ± 0,2	30	40	21	61	03311
9, 9a	51,5 ± 0,2	35	–	23,5	63	04272
10	56,5 ± 0,2	40	50	26	71	03331

ALUMINIUM ELECTROLYTIC CAPACITORS

- **Large type with screw terminals**
- **Long life**
- **Military and industrial applications**



QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	1500 to 150 000 μF
Tolerance on nominal capacitance	−10 to +50%
Rated voltage range, U_R (R5 series)	6,3 to 100 V
Category temperature range	
2222 106	−40 to +85 °C
2222 107	−25 to +85 °C
Typical life time at 85 °C	>5000 h
Basic specification	IEC 384-4, long-life grade
Climatic category	
IEC 68 } 2222 106	40/085/56
DIN 40040 } 2222 106	GPF (56 days)
NF C93-001 } 2222 106	554
IEC 68 } 2222 107	25/085/56
DIN 40040 } 2222 107	GPF (56 days)
NF C93-001 } 2222 107	654
Approvals	U.K. Post Office D 2186 Ministry of Defence (Navy) DEF5134-1 FOA/FTL (Sweden)

Selection chart for C_{nom}-U_R and relevant case sizes.

C_{nom} μF	U_R (V)						
	6,3	10	16	25	40	63	100
1500							11
2200						11	12
3300						12	14
4700					11	14	15
6800				11	12	15	
10 000			11	12	14		16
15 000		11	12	14	15	16	
22 000	11	12	14	15			
33 000	12	14	15		16		
47 000	14	15		16			
68 000	15		16				
100 000		16					
150 000	16						

case size	nominal dimensions (mm)
11	Ø 35 x 80
12	Ø 35 x 112
14	Ø 50 x 80
15	Ø 50 x 112
16	Ø 65 x 112

APPLICATION

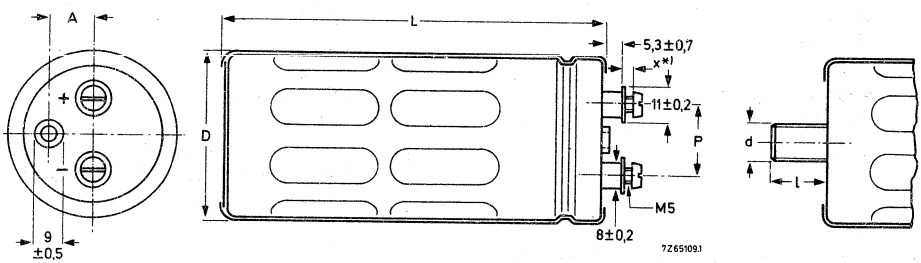
Because of their high reliability and long service life these capacitors are recommended not only for industrial but also for military applications. Their extremely low resistance and inductance values and high resistance to shock and vibration render them very suitable for applications such as:
- switched-mode power supplies;
- power supplies in digital equipment;
- energy storage in pulse systems;
- filters in measuring and control apparatus.

DESCRIPTION

The low values of impedance and inductance are achieved by a special construction with multiple internal anode and cathode connections.
The high resistance to shock and vibration is achieved by the longitudinal rills and special internal construction.
The capacitors are completely cold-welded and charge/discharge proof.
The aluminium cases are fully insulated and sealed by a synthetic resin disc with a vent.
In the case of over-pressure the vent releases this pressure and closes again; the proper operation of the capacitor remains guaranteed.
The capacitors are delivered with screws and washers.

MECHANICAL DATA

Dimensions in mm



See Table 1 for dimensions D, L, P and A.

*) Maximum permissible torque which may be applied to the termination screws at various heights (X in drawing):

2	4	6	X (mm)
1,5	1	0,5	max. permissible torque (Nm)

Table 1

case size	D + 1,5	L + 3	P ± 0,1	A ± 0,2	d x 1	approx. mass (g)
11	35	80	15	8,4	M8 x 12	105
12	35	112	15	8,4	M8 x 12	140
14	50	80	22	14,3	M12 x 16	200
15	50	112	22	14,3	M12 x 16	280
16	65	112	31	19,0	M12 x 16	480

Marking

The capacitors are marked with: nominal capacitance, tolerance on nominal capacitance, rated voltage, temperature range, IEC type, maximum permissible ripple current at 50 °C, catalogue number and date code.

Mounting

The capacitor may be mounted upright or lying down, with or without mounting clamp. To ensure good working of the vent, this device should be on the upper side when the capacitor is mounted lying down. When a number of capacitors are connected to form a capacitor bank, the proximity to one another must not be less than 15 mm when no de-rating of ripple current and/or temperature is applied.
See also mounting accessories.

Minimum atmospheric pressure 8, 5 kPa

ELECTRICAL DATA

Table 2

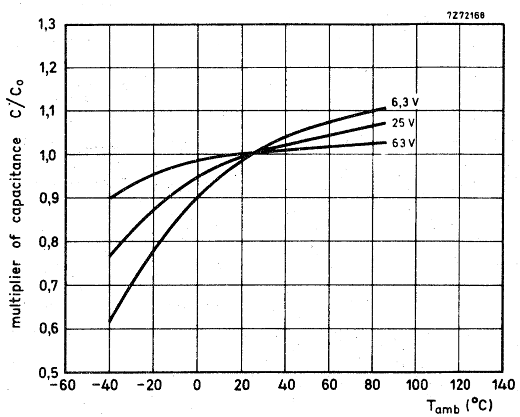
Unless otherwise specified all electrical values in Table 2 apply at an ambient temperature of 20 to 25 °C, a frequency of 100 Hz, an atmospheric pressure of 86 to 106 kPa and a relative humidity of 45 to 75%.

U_R (V)	nom. cap. (μF)	max. r.m.s. ripple current at T_{amb} = 85 °C (A) 1)	max. leakage current at U_R after 5 min (mA) 1)	typ. ESR (mΩ) 1)	max. tan δ 1)	impedance at 20 kHz (mΩ) 1) typ.	impedance at 20 kHz (mΩ) 1) max.	case size	catalogue number 2)
6,3	22000	5,5	0,9	13,0	0,32	8,5	13,0	11	2222 106 33223
	33000	7,9	1,3	8,5	0,32	7,0	10,5	12	33333
	47000	9,4	1,8	6,5	0,35	5,5	8,0	14	33473
	68000	13,2	2,6	4,5	0,35	4,0	6,0	15	33683
	150000	21,3	5,7	2,5	0,45	3,5	5,5	16	33154
10	15000	5,3	0,9	14,0	0,23	8,5	13,0	11	34153
	22000	7,5	1,4	9,5	0,23	7,0	10,5	12	34223
	33000	9,1	2,0	7,0	0,25	5,5	8,0	14	34333
	47000	12,8	2,9	5,0	0,25	4,0	6,0	15	34473
	100000	20,5	6,0	2,5	0,27	3,5	5,5	16	34104
16	10000	5,0	1,0	16,0	0,16	8,5	13,0	11	35103
	15000	7,1	1,5	10,5	0,16	7,0	10,5	12	35153
	22000	8,6	2,2	8,0	0,18	5,5	8,0	14	35223
	33000	12,4	3,2	5,0	0,18	4,0	6,0	15	35333
	68000	19,7	6,6	2,5	0,19	3,5	5,5	16	35683
25	6800	4,7	1,1	18,0	0,12	8,5	13,0	11	36682
	10000	6,7	1,5	12,0	0,12	7,0	10,5	12	36103
	15000	8,2	2,3	8,5	0,13	5,5	8,0	14	36153
	22000	11,6	3,3	6,0	0,13	4,0	6,0	15	36223
	47000	18,7	7,1	3,0	0,14	3,5	5,5	16	36473
40	4700	4,3	1,2	21,0	0,10	11,5	17,0	11	37472
	6800	6,0	1,7	14,5	0,10	8,5	13,0	12	37682
	10000	7,4	2,4	10,5	0,10	6,0	9,0	14	37103
	15000	10,6	3,6	7,0	0,10	4,5	7,0	15	37153
	33000	17,6	8,0	3,5	0,11	3,5	5,5	16	37333
63	2200	3,6	0,9	30,0	0,065	11,5	17,0	11	38222
	3300	5,2	1,3	20,0	0,065	8,5	13,0	12	38332
	4700	6,3	1,8	14,5	0,070	6,0	9,0	14	38472
	6800	8,8	2,6	10,0	0,070	4,5	7,0	15	38682
	15000	14,8	5,7	5,0	0,075	3,5	5,5	16	38153
100	1500	3,1	0,9	270	0,40	200	300	11	2222 107 30152
	2200	4,5	1,4	180	0,40	130	200	12	30222
	3300	5,4	2,0	120	0,40	90	140	14	30332
	4700	7,7	2,9	80	0,40	60	90	15	30472
	10000	12,6	6,0	40	0,40	40	60	16	30103

1) See also corresponding paragraph.
2) Replace 8th digit by 5 for bolt version.

Capacitance

Nominal capacitance values at 100 Hz and T_{amb} = 25 °C	see Table 2
Tolerance on nominal capacitance at 100 Hz	-10 to +50%



Typical capacitance as a function of ambient temperature;
C_0 = capacitance at T_{amb} = 25 °C, 100 Hz.

Voltage

Rated voltage = max. permissible voltage
- at < 40 °C: $1,1 \times U_R$
- at 40 °C up to 85 °C: U_R

Ripple voltage *) = max. permissible a.c. voltage providing the following three conditions are met:

	< 40 °C	40 °C up to 85 °C
a) max. (d.c. + peak a.c.) voltage	≤ $1,1 \times U_R$	≤ U_R
b) max. peak a.c. voltage, with d.c. voltage applied	≤ applied d.c. voltage + 1 V	
c) max. peak a.c. voltage, without d.c. voltage applied	1 V	

Surge voltage = max. permissible voltage for short periods (see also "Tests and requirements") — $1,15 \times U_R$

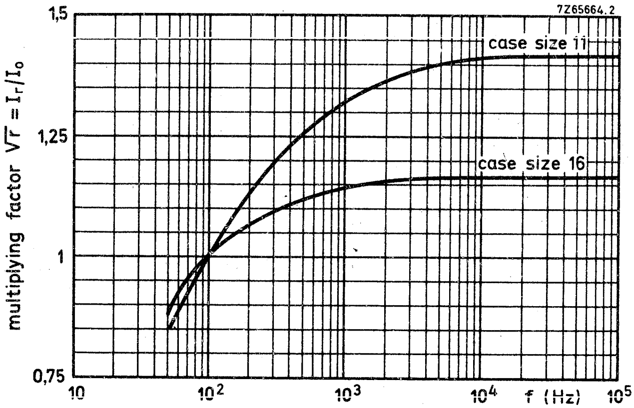
Reverse voltage = max. d.c. voltage applied in the reverse polarity at the maximum category temperature (for short periods) — 1 V

*) Ripple voltages are not applicable if the maximum permissible ripple current is exceeded. In that case the ripple current is decisive.

Ripple current

Maximum permissible r.m.s. ripple current

at 100 Hz and T_{amb} = 85 °C	see Table 2
at T_{amb} = 80 °C	1,4 x values stated in Table 2
at T_{amb} = 75 °C	1,7 x values stated in Table 2 [1]
at T_{amb} ≤ 65 °C	2,2 x values stated in Table 2 [1]



Multiplying factor as a function of frequency, for calculation of max. ripple current [1].
I_0 = maximum ripple current at 85 °C, 100 Hz.

Non-sinusoidal ripple currents have to be analyzed into a number of sinusoidal currents and the following requirements shall then be satisfied:

$$\sum_n \frac{I_n^2}{r_n} \leq I_{r\,max}^2.$$

$I_{r\,max}$ = max. ripple current at 100 Hz and applicable ambient temperature;

I_n = ripple current at a certain frequency;

$\sqrt{r_n}$ = multiplying factor at same frequency.

Note

Ripple currents are not applicable if the maximum permissible ripple voltage is exceeded. In that case the ripple voltage is decisive.

[1]) With a maximum of 30 A.

Charge and discharge current

The capacitors may be charged from a source without internal resistance and they may be discharged by short-circuiting.
If the capacitors are charged and discharged continuously at a rate of several times per minute, the charge and discharge currents have to be considered as ripple currents flowing through the capacitor. The r.m.s. value of these currents should be determined and the value thus found must not exceed the applicable limit.

Leakage current

Maximum leakage current 5 min after application of the rated voltage at T_{amb} = 20 °C	see Table 2 (0,006 CU + 4 μA)
Leakage current during continuous operation at U_R, at T_{amb} = 20 °C	approx. 0,125 of value stated in Table 2
at T_{amb} = 85 °C	≤ value stated in Table 2

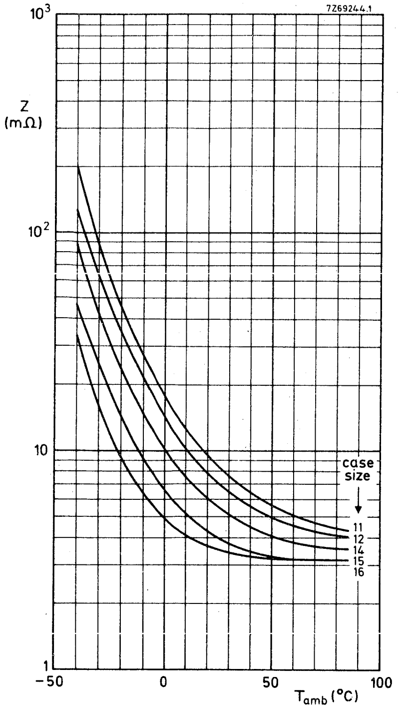
If owing to prolonged storage and/or storage at an excessive temperature the leakage current is too high, application of the rated voltage for some hours will cause the leakage current to fall to a value lower than specified in Table 2.

Tan δ (dissipation factor)

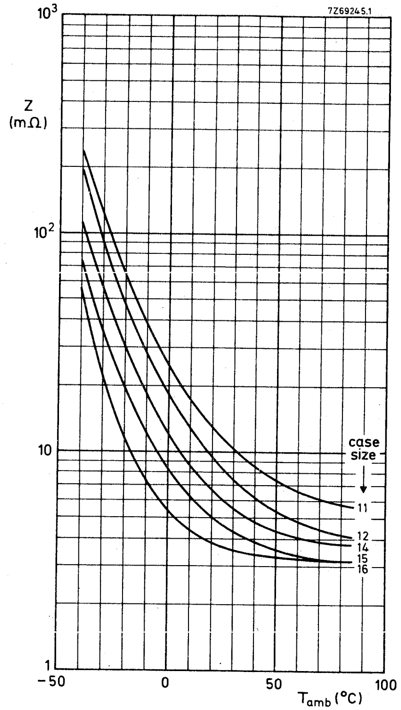
Tan δ at 100 Hz and T_{amb} = 25 °C, measured by means of a four-terminal circuit (Thomson circuit)	see Table 2

Impedance

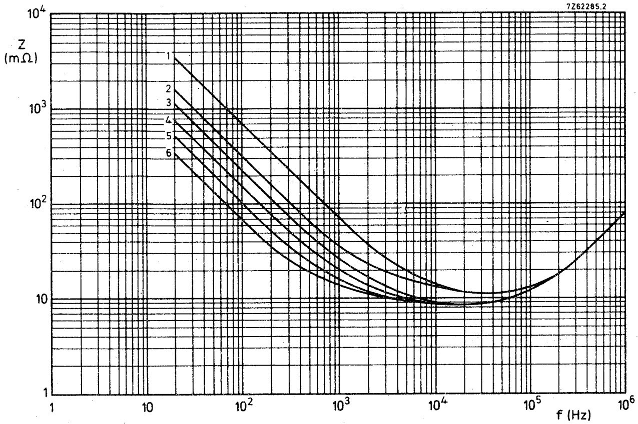
Impedance at 20 kHz and T_{amb} = 25 °C, measured by means of a four-terminal circuit (Thomson circuit)	see Table 2



Typical impedance as a function of temperature at 20 kHz for 6,3 V to 25 V types.



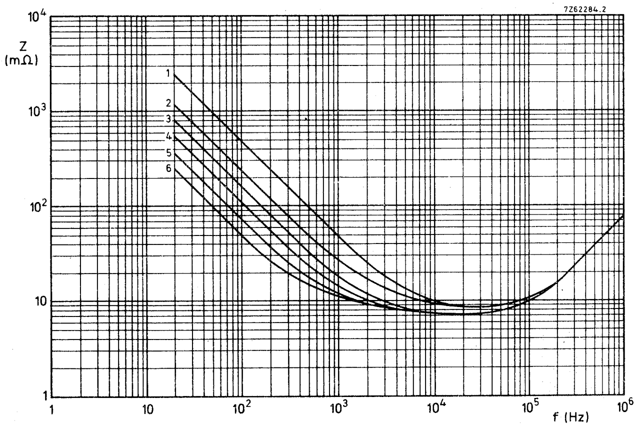
Typical impedance as a function of temperature at 20 kHz for 40 V and 63 V types.



Typical impedance as a function of frequency at T_{amb} = 25 °C.

case size 11

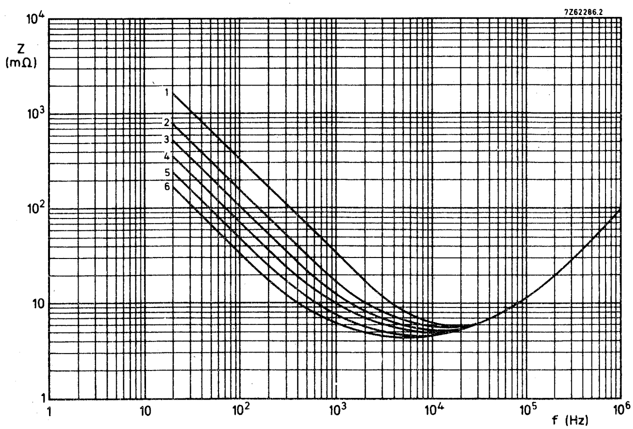
curve 1 = 2200 µF, 63 V
2 = 4700 µF, 40 V
3 = 6800 µF, 25 V
4 = 10 000 µF, 16 V
5 = 15 000 µF, 10 V
6 = 22 000 µF, 6,3 V



Typical impedance as a function of frequency at T_{amb} = 25 °C.

case size 12

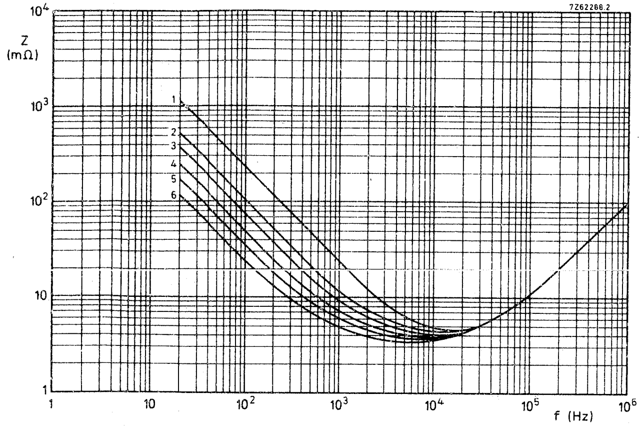
curve 1 = 3300 µF, 63 V
2 = 6800 µF, 40 V
3 = 10 000 µF, 25 V
4 = 15 000 µF, 16 V
5 = 22 000 µF, 10 V
6 = 33 000 µF, 6,3 V



Typical impedance as a function of frequency at T_{amb} = 25 °C.

case size 14

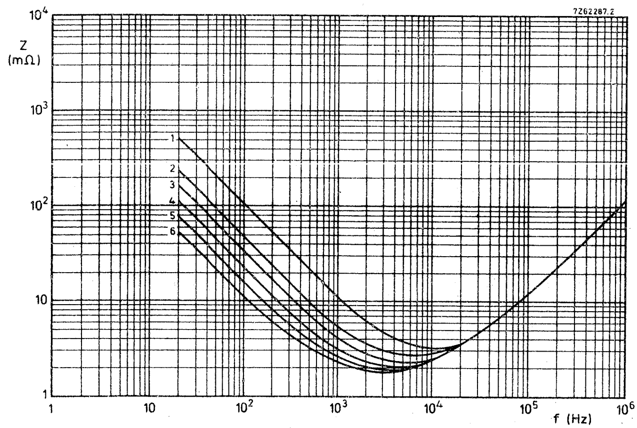
curve 1 = 4700 µF, 63 V
2 = 10 000 µF, 40 V
3 = 15 000 µF, 25 V
4 = 22 000 µF, 16 V
5 = 33 000 µF, 10 V
6 = 47 000 µF, 6,3 V



Typical impedance as a function of frequency at T_{amb} = 25 °C.

case size 15

curve 1 = 6800 μF, 63 V
2 = 15 000 μF, 40 V
3 = 22 000 μF, 25 V
4 = 33 000 μF, 16 V
5 = 47 000 μF, 10 V
6 = 68 000 μF, 6,3 V



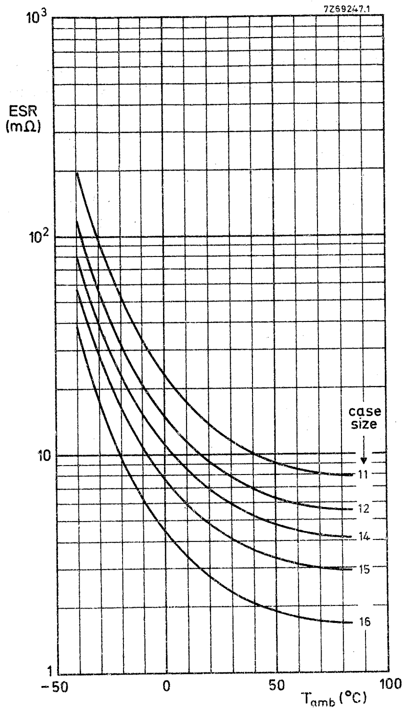
Typical impedance as a function of frequency at T_{amb} = 25 °C.

case size 16

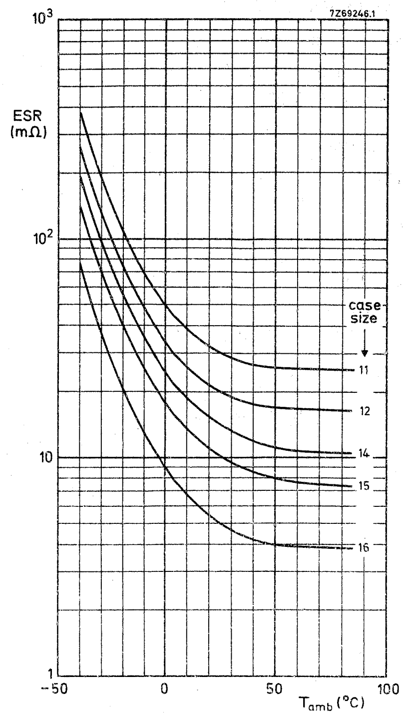
curve 1 = 15 000 μF, 63 V
2 = 33 000 μF, 40 V
3 = 47 000 μF, 25 V
4 = 68 000 μF, 16 V
5 = 100 000 μF, 10 V
6 = 150 000 μF, 6,3 V

Equivalent series resistance (ESR = tan $\delta/\omega C$)

ESR at 100 Hz and T_{amb} = 25 °C — see Table 2



Typical ESR as a function of temperature at 100 Hz for 6,3 V types.



Typical ESR as a function of temperature at 100 Hz for 63 V types.

Inductance

case size	typical inductance
11 and 12	12 nH
14 and 15	15 nH
16	18 nH

OPERATIONAL DATA

Category temperature range

for rated voltage, 2222 106	–40 to +85 °C
for rated voltage, 2222 107	–25 to +85 °C

Life expectancy

Typical lifetime	
at T_{amb} = 85 °C	>5000 h
at T_{amb} = 25 °C	>15 years

PACKING

Case sizes 11, 12, 14 and 15: 50 pieces per box.
Case size 16: 25 pieces per box.

TESTS AND REQUIREMENTS

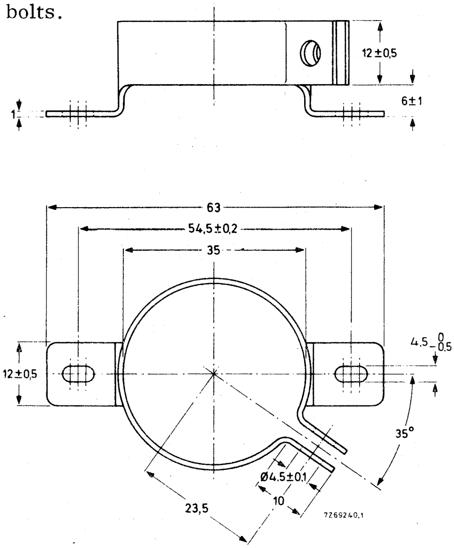
See Introduction, section 9, under aluminium electrolytic capacitors.

Note: Capacitors 2222 106 and 2222 107 belong to the large types with screw terminals, long-life grade.

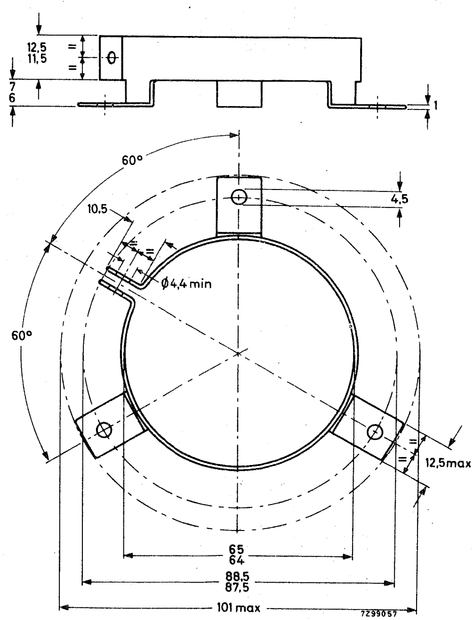
MOUNTING ACCESSORIES

Clamps

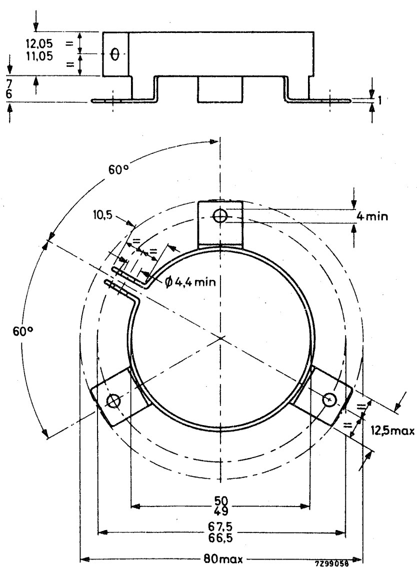
To facilitate vertical mounting, a series of rigid clamps made of cadmium-plated steel are available. They can easily be slid over the capacitor and then fixed to it with a nut and bolt. They are provided with two or three mounting lugs. Three types are available, one for each case diameter of the capacitor range. They are delivered without nuts or bolts.



Clamp for case diameter of 35 mm.
Catalogue number: 4322 043 04272.



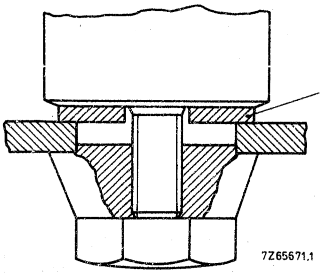
Clamp for case diameter of 65 mm.
Catalogue number 4322 043 04291.

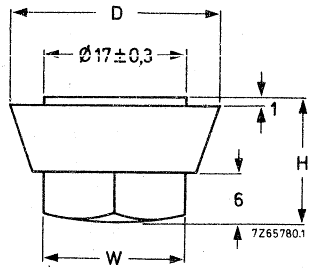


Clamp for case diameter of 50 mm.
Catalogue number 4322 043 04281.

Bolt/nut

When mounting by means of the bolt, which is an integral part of the case, normal metal M8 and M12 nuts and washers can be used.
If an insulated mounting is required a synthetic nut and rubber washers are available.

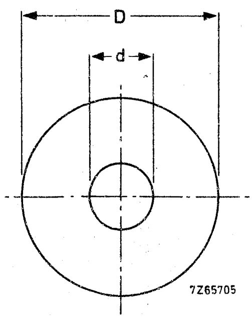




Synthetic cap nut

dimensions in mm

M	D	H	W *)	min. threaded depth	catalogue number
8	25	15	17	11,5	4322 043 05561
12	30	20	19	15,5	4322 043 05571



Rubber washer with thickness of 2 mm

dimensions in mm

D	d	catalogue number
34	8,4	4322 043 05591
49	13	4322 043 05531
64	13	4322 043 05521

*) W measured across flats.

ELECTROLYTIC AND SOLID CAPACITORS

GENERAL

ALUMINIUM ELECTROLYTIC CAPACITORS

SOLID ALUMINIUM CAPACITORS

SOLID TANTALUM CAPACITORS

MAINTENANCE TYPES

STANDARD SERIES OF VALUES IN A DECADE
for resistances and capacitances
according to I E C publication 63

E192	E96	E48	E192	E96	E48	E192	E96	E48	E192	E96	E48
100	100	100	169	169	169	284			481		
101			172			287	287	287	487	487	487
102	102		174	174		291			493		
104			176			294	294		499	499	
105	105	105	178	178	178	298			505		
106			180			301	301	301	511	511	511
107	107		182	182		305			517		
109			184			309	309		523	523	
110	110	110	187	187	187	312			530		
111			189			316	316	316	536	536	536
113	113		191	191		320			542		
114			193			324	324		549	549	
115	115	115	196	196	196	328			556		
117			198			332	332	332	562	562	562
118	118		200	200		336			569		
120			203			340	340		576	576	
121	121	121	205	205	205	344			583		
123			208			348	348	348	590	590	590
124	124		210	210		352			597		
126			213			357	357		604	604	
127	127	127	215	215	215	361			612		
129			218			365	365	365	619	619	619
130	130					370			626		
132			221	221		374	374		634	634	
133	133	133	223			379			642		
135			226	226	226	383	383	383	649	649	649
137	137		229			388			657		
138			232	232		392	392		665	665	
140	140	140	234			397			673		
142			237	237	237	402	402	402	681	681	681
143	143		240			407			690		
145			243	243		412	412		698	698	
147	147	147	246			417			706		
149			249	249	249	422	422	422	715	715	715
150	150		252			427			723		
152			255	255		432	432		732	732	
154	154	154	258			437			741		
156			261	261	261	442	442	442	750	750	750
158	158		264			448			759		
160			267	267		453	453		768	768	
162	162	162	271			459			777		
164			274	274	274	464	464	464	787	787	787
165	165		277			470			796		
167			280	280		475	475		806	806	

E192	E96	E48
816		
825	825	825
835		
845	845	
856		
866	866	866
876		
887	887	
898		
909	909	909
920		
931	931	
942		
953	953	953
965		
976	976	
988		

E24	E12	E6	E3
10	10	10	10
11			
12	12		
13			
15	15	15	
16			
18	18		
20			
22	22	22	22
24			
27	27		
30			
33	33	33	
36			
39	39		
43			
47	47	47	47
51			
56	56		
62			
68	68	68	
75			
82	82		
91			

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