PHILIPS

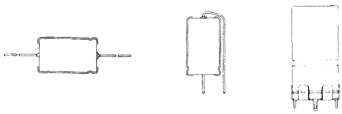
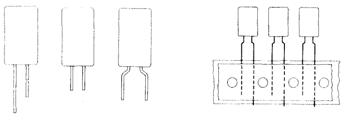
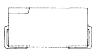
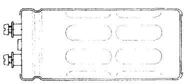
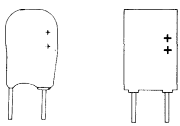
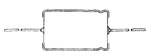
Data handbook

Electronic components and materials

Components and materials

Part 14 March 1984

Electrolytic and solid capacitors

type	application	series number 2222 . . .	characteristic	page
ALUMINIUM ELECTROLYTIC CAPACITORS				
Miniature/small		014	low impedance; LV	39
		021	small dimensions; LV	77, 99
	long-life, general, industrial	030 031 032 033	LV	111
		041 042 043	HV	197
		039	bipolar	189
		065	low leakage current	251
Miniature/small 	extra long-life, industrial	108	acc. to CECC; LV	287
		132	acc. to DIN 41257; LV	341
		133	acc. to DIN 41257; HV	341
Miniature/small 	long-life, general, industrial	035	LV	155
		036	LV	173
		013	low leakage current; LV	23
		116	long-life; LV	325
Miniature; surface mounted 	general	085	LV	273
Large 	long-life, industrial	050	acc. to CECC; LV	217
		051	small dimensions; LV	241
		052	acc. to CECC; HV	217
		053	small dimensions; HV	241
Large 	long-life, industrial, military	114 115	screw terminal	301
SOLID ALUMINIUM CAPACITORS				
Miniature 	very long-life, general, industrial	122	acc. to CECC; resin dipped	379
		124	epoxy potted	421
Small 	very long-life, military, industrial	121	acc. to CECC	361
		123		401

COMPONENTS AND MATERIALS

PART 14 - MARCH 1984

ELECTROLYTIC AND SOLID CAPACITORS

GENERAL

ALUMINIUM ELECTROLYTIC CAPACITORS

SOLID ALUMINIUM CAPACITORS

MAINTENANCE TYPES

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

The several parts contain all pertinent data available at the time of publication, and each is revised and reissued periodically.

Where ratings or specifications differ from those published in the preceding edition they are pointed out by arrows. Where application information is given it is advisory and does not form part of the product specification.

If you need confirmation that the published data about any of our products are the latest available, please contact our representative. He is at your service and will be glad to answer your inquiries.

ELECTRON TUBES (BLUE SERIES)

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

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

T2a **Transmitting tubes for communications, glass types**

T2b **Transmitting tubes for communications, ceramic types**

T3 **Klystrons, travelling-wave tubes, microwave diodes**

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 semiconductors and components**

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**

S4a **Low-frequency power transistors and hybrid modules**

S4b **High-voltage and switching power transistors**

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 **Power MOS transistors**

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

INTEGRATED CIRCUITS (PURPLE SERIES)

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

July 1983

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

C2 **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 **Synchronous motors and gearboxes**

C7 **Variable capacitors**

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**

C16 **Permanent magnet materials**

C17 **Stepping motors and electronics**

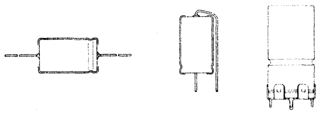
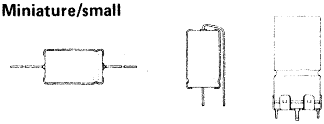
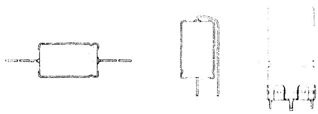
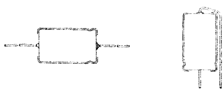
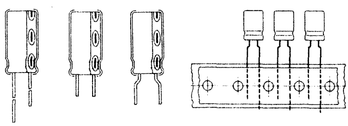
C18 **D.C. motors**

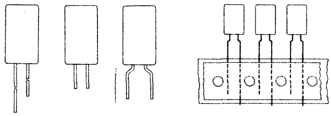
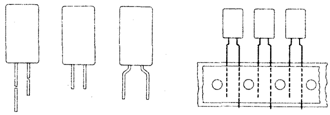
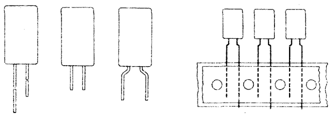
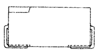
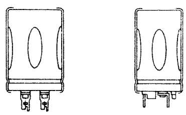
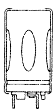
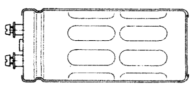
C19 **Piezoelectric ceramics**

GENERAL

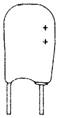
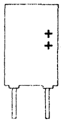
SURVEY

ALUMINIUM ELECTROLYTIC CAPACITORS

type	series number 2222 . . .	application	nominal capacitance µF	rated voltage (U_R) V	page
Miniature/small 	014	long-life, general, industrial; low impedance for s.m.p.s.	1 to 10 000	6,3 to 100	39
Miniature/small 	021	long-life, general, industrial; small dimensions	0,22 to 1 500 220 to 15 000	10 to 100 10 to 63	99 77
Miniature/small 	030 031 032 033	long-life, general, industrial	0,33 to 15 000	6,3 to 100	111
	041 042 043	long-life, general, industrial	1 to 220	160 to 385	197
Small; bipolar 	039	long-life, general, industrial	1 to 47	U_R (a.c.) = 63 V_p U_R (d.c.) = 63 V	189
Miniature 	065	long-life, general, industrial; low leakage current	0,1 to 470	6,3 to 25	251
Small 	108	extra long-life, industrial	2,2 to 2 200	6,3 to 100	287
Miniature/small 	132 133	extra long-life, industrial DIN 41257	1 to 4 700	10 to 350	341
Miniature/small 	035	general	0,1 to 4 700	6,3 to 100	155

type	series number 2222 . . .	application	nominal capacitance μF	rated voltage (U_R) V	page
Miniature 	036	long-life, general, industrial	0,15 to 470	6,3 to 63	173
Miniature 	013	long-life, general, industrial; low leakage current	0,15 to 220	10 to 25	23
Miniature 	116	extra long-life, industrial	0,47 to 470	6,3 to 50	325
Miniature; surface mounted 	085	general	0,1 to 22	6,3 to 63	273
Large 	050 052	long-life, industrial	47 to 68 000	10 to 385	217
Large 	051 053	long-life, industrial; small dimensions	68 to 150 000	10 to 385	241
Large 	114 115	long-life, industrial, military	150 to 220 000	10 to 385	301
Maintenance types	071 073	long-life, industrial	680 to 22 000	6,3 to 63	443
	106 107	long-life, military	1500 to 150 000	6,3 to 100	453

SOLID ALUMINIUM CAPACITORS

type		series number 2222 . . .	application	nominal capacitance μF	rated voltage (U_R) V	page
Miniature; resin dipped		122	very long-life, general, industrial	0,1 to 68	6,3 to 40	379
Miniature; epoxy potted		124	extra long-life, general, industrial	0,1 to 68	6,3 to 40	421
Small		121	very long-life, military, industrial	2,2 to 330	6,3 to 50	361
Small		123	very long-life, military, industrial	2,2 to 2 200	4 to 40	401

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:

$$Q = C \cdot U$$

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:

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

where ϵ_0 = absolute permittivity ($8{,}85 \times 10^{-12}$ 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 aluminium oxide (Al_2O_3) which is formed by an electrochemical oxidizing process of aluminium. This layer withstands 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.

The relative dielectric constant of Al_2O_3 is approx. 8 (dimensionless), its electrical field strength amounts to 7.10^8 V/m.

3. DESCRIPTION

The above-mentioned dielectric layer is electrically contacted on one side by its base metal (aluminium) 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 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 (7.10^8 V/m). 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 aluminium capacitors

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).

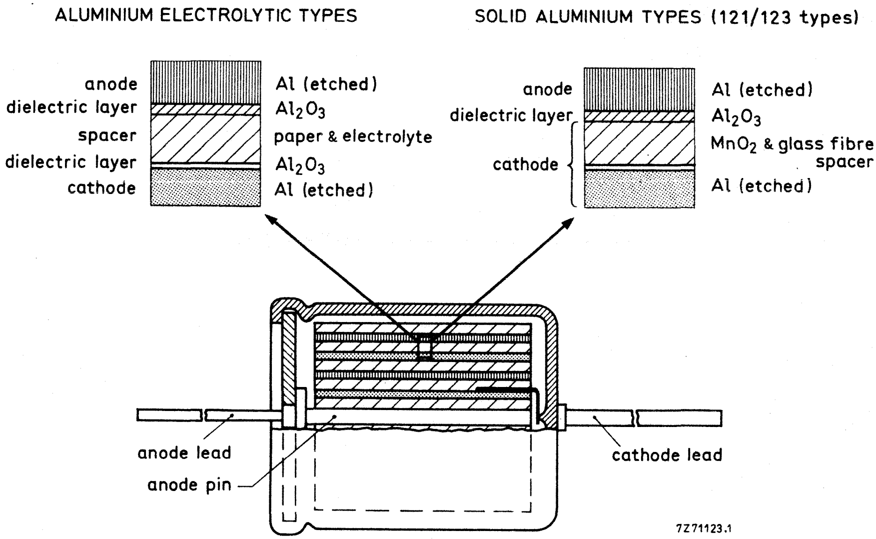


Fig. 1.

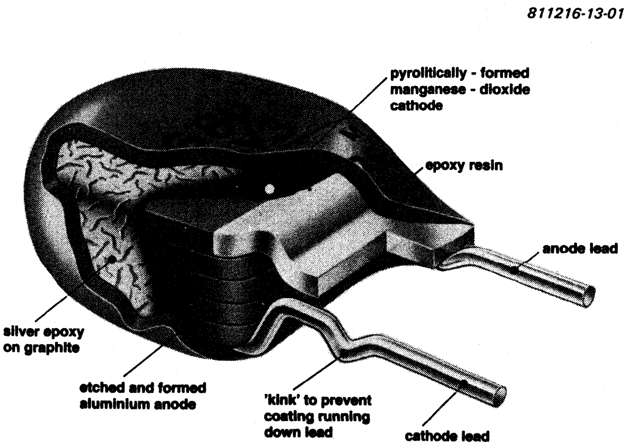


Fig. 2 Solid aluminium type 2222 122.

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 $X = j\omega L$, where L = inductance in H.

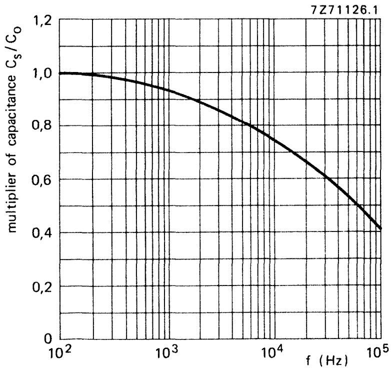


Fig. 3 Typical capacitance as a function of frequency. C_0 = capacitance at 25 °C, 100 Hz.

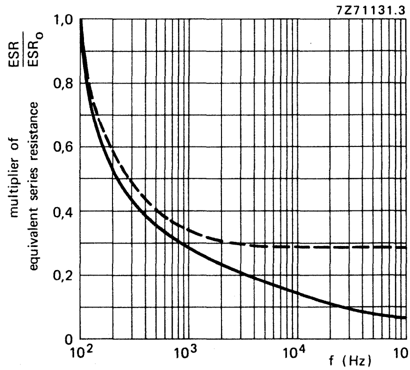


Fig. 4 Typical ESR as a function of frequency; ESR_0 = ESR at 25 °C, 100 Hz.
- - - - - Alumium electrolytic capacitors;
——— Solid aluminium capacitors.

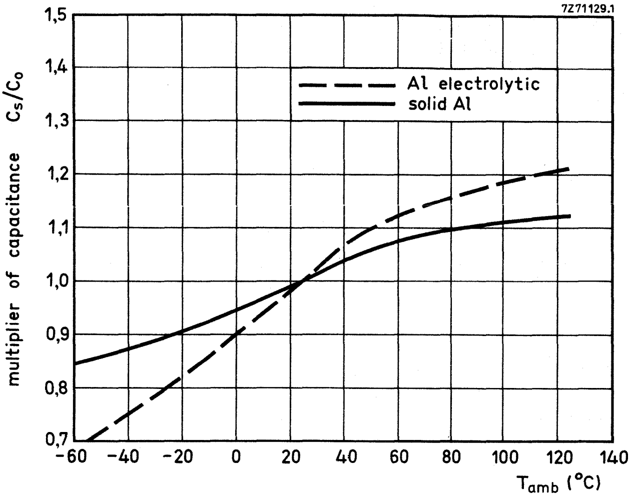


Fig. 5 Typical capacitance as a function of ambient temperature; C_0 = capacitance at 25 °C, 100 Hz.

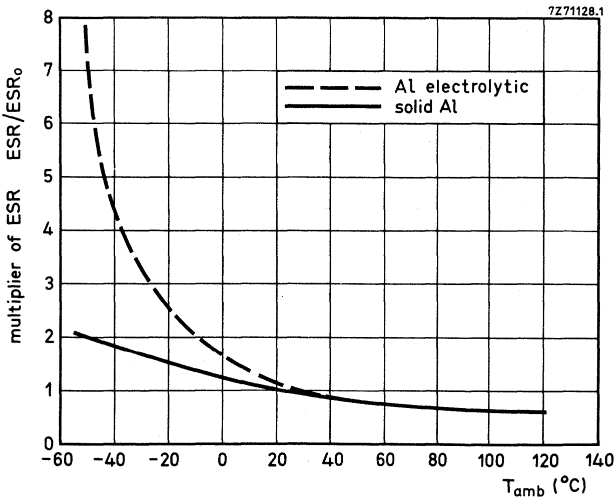


Fig. 6 Typical ESR as a function of ambient temperature. ESR_0 = ESR at 100 Hz, at 25 °C.

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/m^2 °C)
S = heat transfer surface area (m^2)
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_0 (I_0 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_0 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.

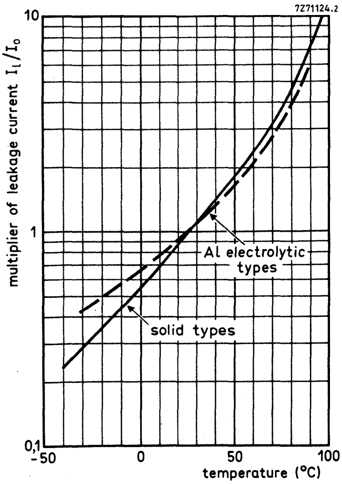


Fig. 7 Typical leakage current as a function of temperature. I_0 = leakage current during continuous operation at T_{amb} = 25 °C.

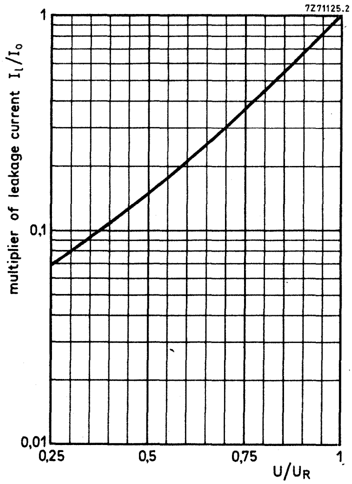


Fig. 8 Typical leakage current as a function of U/U_R. I_0 = leakage current at U_R at a discrete constant temperature within category temperature range, U is working voltage.

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 °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.

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. 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.

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 s l	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)			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;
				2	10 to 55 Hz, 0,75 mm or 10g (whichever is less), 2 directions, 3 h per direction.		ΔC/C ⩽ 5% with respect to initial measurement.
9.11	Eb		Bump	1	**40g, 2 directions, 4000 bumps total.**		No visible damage, no leakage of electrolyte; ΔC/C ⩽ 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 ^{o}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 ^{o}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 ^{o}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 ^{o}C.		No continuous chain of bubbles.
	Climatic sequence				Final measurement		No visible damage, no leakage of electrolyte, marking legible; leakage current ⩽ stated limit; tan δ ⩽ 1,2 x stated limit; ΔC/C ⩽ 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 ⩽ stated limit, tan $\delta \leqslant 1{,}2$ x stated limit, insulation resistance > 100 MΩ, no breakdown or flashover below 1000 V.
					1	$\Delta C/C \leqslant 10\%$.
					2	$\Delta C/C \leqslant 20\%$.
9.14	–	Endurance	1	2000 h** at upper category temperature, U_R applied.		No visible damage, no leakage of electrolyte, marking legible; leakage current ⩽ stated limit, insulation resistance > 100 MΩ, no breakdown or flashover below 1000 V.
					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 ⩽ 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 ⩽ 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 ⩽ stated limit, tan δ ⩽ 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 $\leqslant$ stated limit, tan $\delta \leqslant$ stated limit, $\Delta C/C \leqslant 10\%$.
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 $\leqslant$ 2 x stated limit, tan $\delta \leqslant$ 1,2 x stated limit; $\Delta C/C \leqslant 10\%$.
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 $\leqslant$ stated limit, tan $\delta \leqslant$ stated limit; $\Delta C/C \leqslant 10\%$.
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 $\leqslant$ 7 x value of step 1 for $U_R \leqslant 6{,}3$ V or $U_R > 160$ V, $\leqslant$ 5 x value of step 1 for $6{,}3 < U_R \leqslant 16$ V, $\leqslant$ 4 x value of step 1 for $16 < U_R \leqslant 160$ V.
				Step 3: Measurement at upper category temperature.		Leakage current $\leqslant$ 5 x stated limit at 85 °C, $\leqslant$ 3 x stated limit at 70 °C.
9.21		Charge and discharge		For $U_R \leqslant 160$ 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, $\Delta C/C \leqslant 10\%$.

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, 15 s value of leakage current measured after 5 min.

IEC 384–4 sub clause	IEC 68–2 test method		name of test	procedure (quick reference) type	procedure 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.
	Climatic sequence	D	Damp heat, cyclic		5 cycles of 24 h at 55 ± 2 °C, R.H. 95 to 100%, no voltage applied.		
	Climatic sequence				Final measurement.		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	$\Delta C/C \leqslant 10\%$.
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, 15 s value of leakage current measured after 5 min.

IEC 384–4 sub clause	IEC 68–2 test method	name of test	procedure (quick reference)		requirements	
			type	description	type	description
9.14	–	Endurance	122/123	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	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.		Leakage 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 temperature		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%.

* For capacitors 2222 122, 15 s value of leakage current measured after 5 min.
** 25 V for 40 V versions (capacitors 2222 122).
▲ 40 V for 50 V versions.

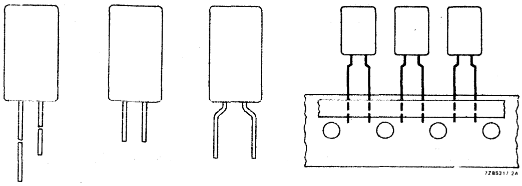
IEC 384–4 sub clause	IEC 68–2 test method	name of test	procedure (quick reference)		requirements	
			type	description	type	description
9.20		Characteristics at high and low temperature		**Step 1:** reference measurement at 20 °C of capacitance, impedance at 100 Hz and tan δ.		
				Step 2: measurement at lower category		Tan δ ⩽ 2 x stated limit, impedance ratio ⩽ 2, ΔC/C ⩽ 20%.
				Step 3: measurement at 85 °C.		Leakage current ⩽ 10 x stated limit,* tan δ ⩽ stated limit, ΔC/C ⩽ 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, ΔC/C ⩽ 5%.

* For capacitors 2222 122, 15 s value of leakage current measured after 1 min.

ALUMINIUM ELECTROLYTIC CAPACITORS

ALUMINIUM ELECTROLYTIC CAPACITORS

- **Low-leakage version of 2222 036 series**
- **Miniature type**
- **Single ended**
- **Long life**
- **General and industrial applications**
- **Alternative for tantalum capacitors**



QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	0,15 to 220 μF
Tolerance on nominal capacitance	−20 to + 20%*
Rated voltage range, U_R (R5 series)	10 to 25 V
Leakage current after 2 min	0,002 CU or 0,7 μA
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, long-life grade DIN 41332/DIN 41259
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
0,15			11
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
15			11
22			11
33		11	13
47	11		13
68	11		13
100		13	
150	13		
220	13		

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

* ± 10% to special order.

APPLICATION

These capacitors are suited for those applications where a low leakage current is required. In many cases they are a cost-effective substitute for tantalum capacitors.
The capacitors are mainly used for 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 suitable for automatic insertion and for cutting and forming equipment.

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 all-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.

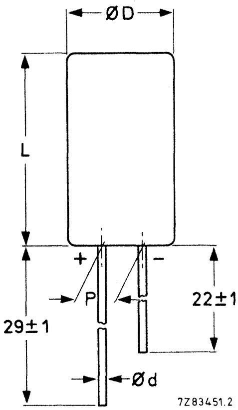


Fig. 1 Style 1; see Table 1 for dimensions d, D, L and P.

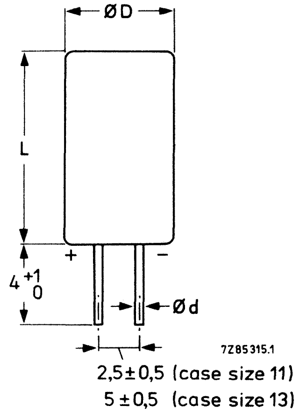


Fig. 2 Style 2; non preferred, see Table 1 for dimensions d, D and L.

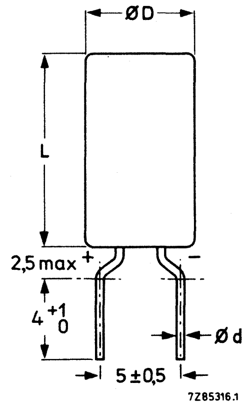


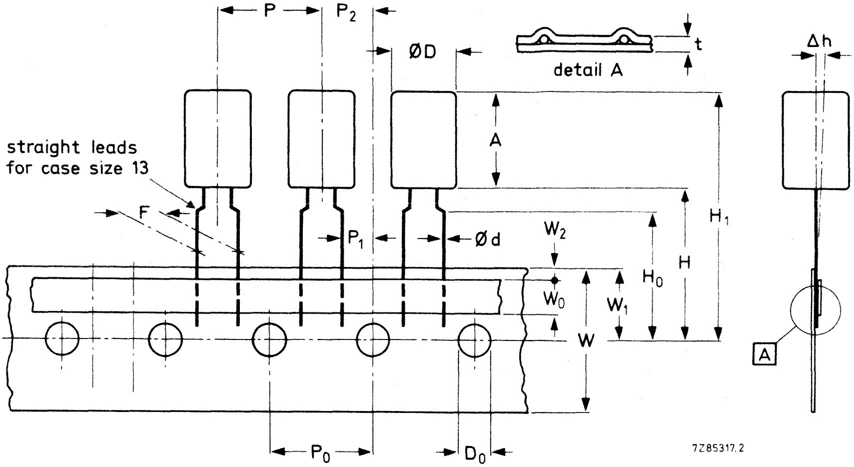
Fig. 3 Style 3; case size 11 only; non preferred, see Table 1 for dimensions d, D and L.

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.

DEVELOPMENT SAMPLE DATA



→ direction of tape transport

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

Table 2

	symbol	case size 11	case size 13	tol.
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	6,0	6,0	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	32,0	32,0	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.

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 (013);
- code letter of manufacturer;
- date code (year and month) according to IEC 62.

Minimum atmospheric pressure 8,5 kPa

WARNING

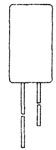
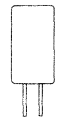
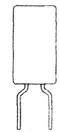
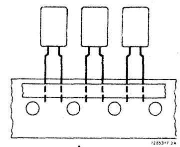
Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled; caution is necessary should the outer case be fractured.

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%.

DEVELOPMENT SAMPLE DATA

Table 3

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 2 min µA	max. tan δ	case size*	catalogue number 2222 013 followed by				
						 style 1	 style 2	 style 3	 on reel style 4	in ammopack style 5
10	47	55	1,0	0,16	11	54479	84479	64479	24479	34479
	68	70	1,4	0,16	11	54689	84689	64689	24689	34689
	150	130	3,0	0,16	13	54151	64151		24151	34151
	220	160	4,4	0,16	13	54221	64221		24221	34221
16	33	50	1,1	0,13	11	55339	85339	65339	25339	35339
	100	120	3,2	0,13	13	55101	65101		25101	35101
25	0,15	5,0	0,7	0,08	11	56157	86157	66157	26157	36157
	0,22	6,5	0,7	0,06	11	56227	86227	66227	26227	36227
	0,33	8,0	0,7	0,06	11	56337	86337	66337	26337	36337
	0,47	9,5	0,7	0,06	11	56477	86477	66477	26477	36477
	0,68	11	0,7	0,06	11	56687	86687	66687	26687	36687
	1,0	13,5	0,7	0,06	11	56108	86108	66108	26108	36108
	1,5	16,5	0,7	0,06	11	56158	86158	66158	26158	36158
	2,2	20	0,7	0,06	11	56228	86228	66228	26228	36228
	3,3	25	0,7	0,06	11	56338	86338	66338	26338	36338
	4,7	29,5	0,7	0,06	11	56478	86478	66478	26478	36478
	6,8	36	0,7	0,06	11	56688	86688	66688	26688	36688
	10	43	0,7	0,06	11	56109	86109	66109	26109	36109
	15	46	0,8	0,08	11	56159	86159	66159	26159	36159
	22	56	1,1	0,08	11	56229	86229	66229	26229	36229
	33	105	1,7	0,06	13	56339	66339		26339	36339
	47	110	2,4	0,08	13	56479	66479		26479	36479
	68	130	3,4	0,08	13	56689	66689		26689	36689

* 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%

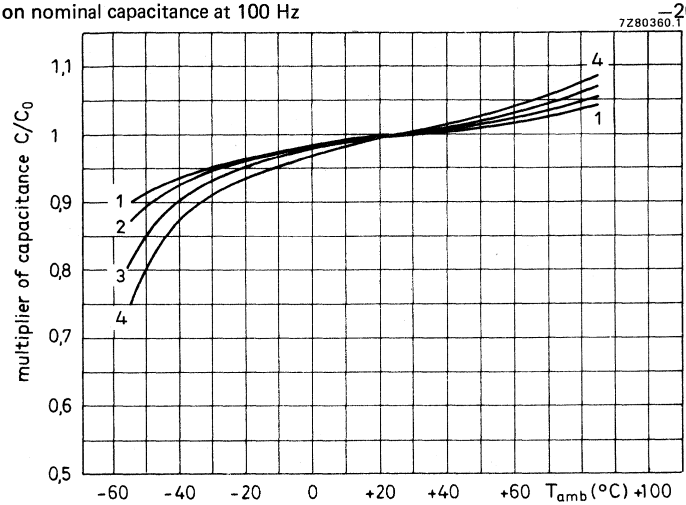


Fig. 5 Typical multiplier of capacitance as a function of ambient temperature;
C_0 = capacitance at 20 °C, 100 Hz.
Curve 1 = 25 V; 0,15 to 2,2 μF;
curve 2 = 25 V, 3,3 to 6,8 μF;
curve 3 = 25 V, 10 to 68 μF;
curve 4 = 10 V/16 V.

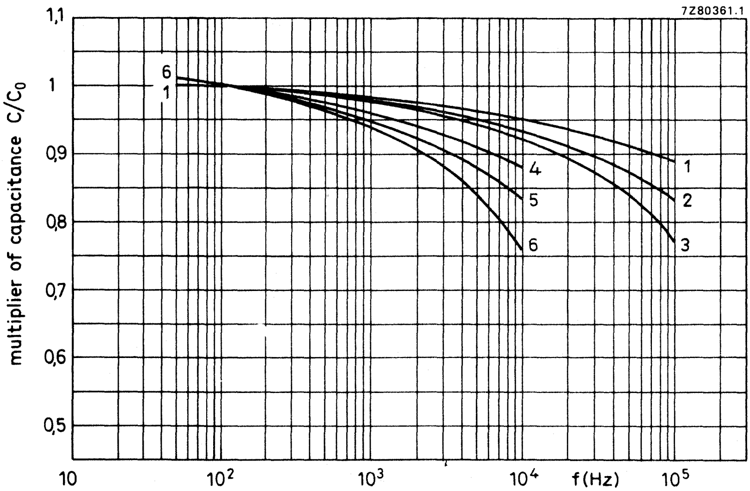


Fig. 6 Typical multiplier of capacitance as a function of frequency;
C_0 = capacitance at 20 °C, 100 Hz.
Curve 1 = 25 V, 0,15 to 2,2 μF;
curve 2 = 25 V, 3,3 to 6,8 μF;
curve 3 = 25 V, 10/15 μF;
curve 4 = 25 V, 22 to 68 μF;
curve 5 = 16 V;
curve 6 = 10 V.

DEVELOPMENT SAMPLE DATA

Voltage

Max. permissible voltage at $T_{amb} \leq 85\ ^oC$	1,6 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	1,6 x U_R
(b) max. peak a.c. voltage without d.c. voltage applied	2 V
(c) momentary value of applied voltage	between 1,6 x U_R and −2 V
Surge voltage = max. permissible voltage for short periods	1,6 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 $T_{amb} = 85\ ^oC$	see Table 3

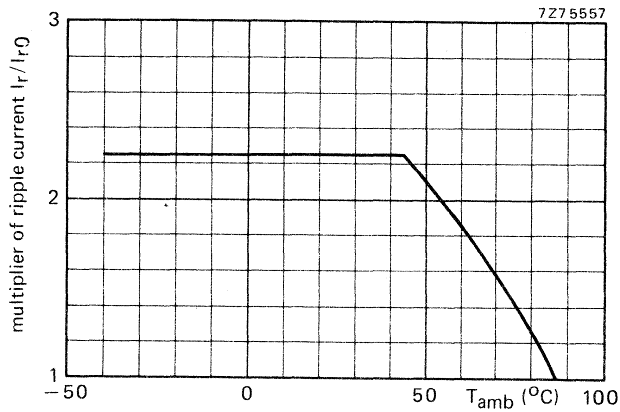


Fig. 7 Typical multiplier of ripple current as a function of ambient temperature; I_{r0} = ripple current at 85 °C, 100 Hz.

* 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.

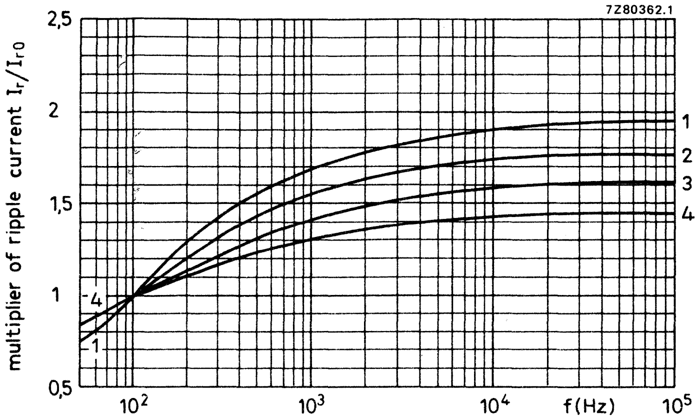


Fig. 8 Typical multiplier of ripple current as a function of frequency;
I_{r0} = ripple current at 85 °C, 100 Hz.
Curve 1 = 25 V, 0,15 to 2,2 μF; curve 2 = 25 V, 3,3 to 6,8 μF; curve 3 = 25 V, 10 to 68 μF; curve 4 = 10 V, 16 V.

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

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 2 min after application of U_R at T_{amb} = 20 °C	see table 3 (0,002 CU or 0,7 μA, whichever is greater)

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.

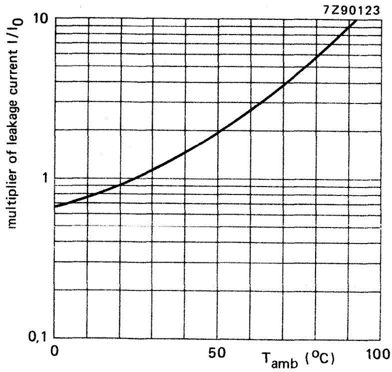


Fig. 9 Multiplier of leakage current as a function of ambient temperature; I_0 = leakage current during continuous operation at 25 °C and U_R.

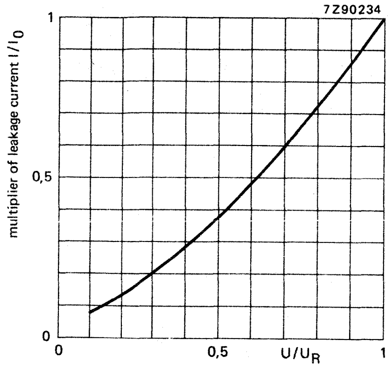


Fig. 10 Multiplier of leakage current as a function of U/U_R; I_0 = leakage current during continuous operation at 25 °C and U_R.

DEVELOPMENT SAMPLE DATA

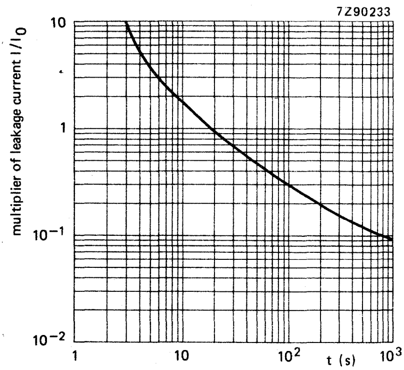


Fig. 11 Multiplier of typical leakage current as a function of time; I_0 is leakage current value as specified in Table 3.

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

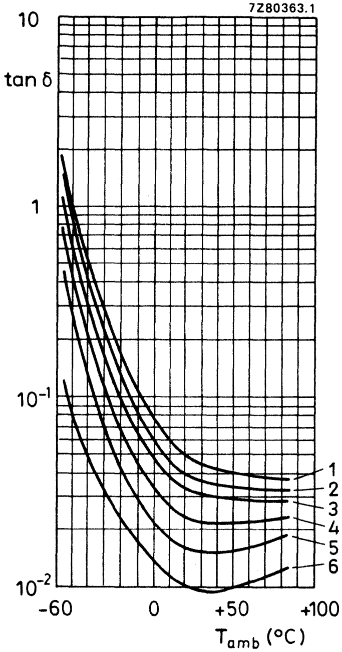


Fig. 12 Typical tan δ at 100 Hz as a function of ambient temperature.
Curve 1 = 10 V;
curve 2 = 16 V;
curve 3 = 25 V, 22 to 68 μF;
curve 4 = 25 V, 10/15 μF;
curve 5 = 25 V, 3,3 to 6,8 μF;
curve 6 = 25 V, 0,15 to 2,2 μF.

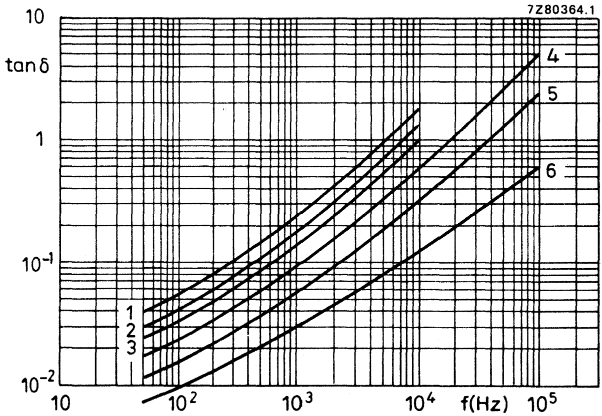


Fig. 13 Typical tan δ as a function of frequency at T_{amb} = 20 °C.
Curve 1 = 10 V;
curve 2 = 16 V;
curve 3 = 25 V, 22 to 68 μF;
curve 4 = 25 V, 10/15 μF;
curve 5 = 25 V, 3,3 to 6,8 μF;
curve 6 = 25 V, 0,15 to 2,2 μF.

Equivalent series resistance (ESR)

ESR = $\tan \delta / \omega C$

Maximum $\tan \delta$ and C at 100 Hz and T_{amb} = 25 °C	see Table 3

Equivalent series inductance (ESL)

Case size 11	typ. 13 nH
Case size 13	typ. 16 nH

Impedance (Z)

Maximum impedance at T_{amb} = 20 °C, −25 °C and −40 °C and 10 kHz, measured by a four-terminal circuit (Thomson circuit)	see Table 4
Maximum ratio between impedances at T_{amb} = −25 °C and + 20 °C at T_{amb} = −40 °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 4

DEVELOPMENT SAMPLE DATA

→ Table 4

U_R (V)	nom. cap. (μF)	case size*	maximum impedance at 10 kHz: T_{amb} = 20 °C (Ω)	T_{amb} = −25 °C (Ω)	T_{amb} = −40 °C (Ω)	maximum impedance ratio at U_R and 100 Hz: $\frac{Z \text{ at } -25\ ^oC}{Z \text{ at } +20\ ^oC}$	$\frac{Z \text{ at } -40\ ^oC}{Z \text{ at } +20\ ^oC}$	$\frac{Z \text{ at } -55\ ^oC}{Z \text{ at } +20\ ^oC}$
10	47	11	2,8	11,9	31,9	2	3	5
	68	11	1,9	8,2	22,1	2	3	5
	150	13	0,9	3,7	10,0	2	3	5
	220	13	0,6	2,6	6,8	2	3	5
16	33	11	2,7	12,1	33,1	1,5	2	4
	100	13	0,9	4,0	11,0	1,5	2	4
25	0,15	11	300	1070	3870	1,5	2	3
	0,22	11	205	727	2636	1,5	2	3
	0,33	11	136	485	1758	1,5	2	3
	0,47	11	96	340	1234	1,5	2	3
	0,68	11	66	235	853	1,5	2	3
	1,0	11	45	160	580	1,5	2	3
	1,5	11	30	107	387	1,5	2	3
	2,2	11	20,5	72,7	264	1,5	2	3
	3,3	11	13,6	48,5	176	1,5	2	3
	4,7	11	9,6	34,0	123	1,5	2	3
	6,8	11	6,6	23,5	85,3	1,5	2	3
	10	11	6,0	25,0	75	1,5	2	3
	15	11	4,0	16,7	50	1,5	2	3
	22	11	3,2	13,6	40,9	1,5	2	3
	33	13	1,4	4,9	17,6	1,5	2	3
	47	13	1,3	5,3	15,6	1,5	2	3
	68	13	1,0	4,4	13,2	1,5	2	3

* Case size 11: ϕ 5 mm x 11 mm; case size 13: ϕ 8,2 mm x 11 mm (nominal dimensions).

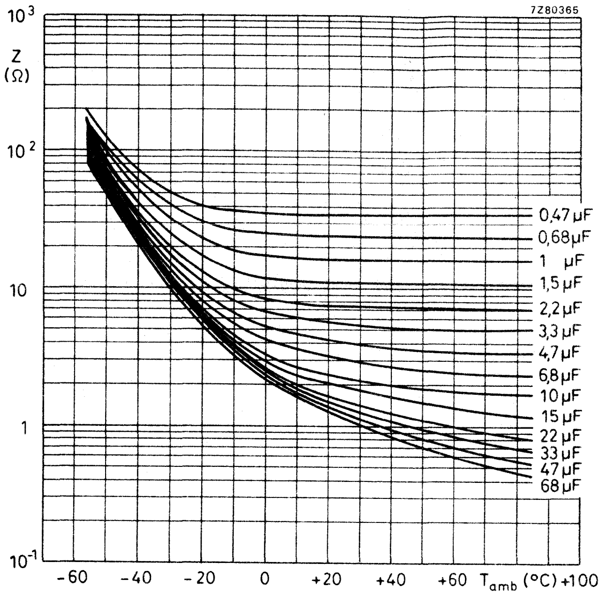


Fig. 14 Typical impedance at 10 kHz as a function of ambient temperature, case size 11.

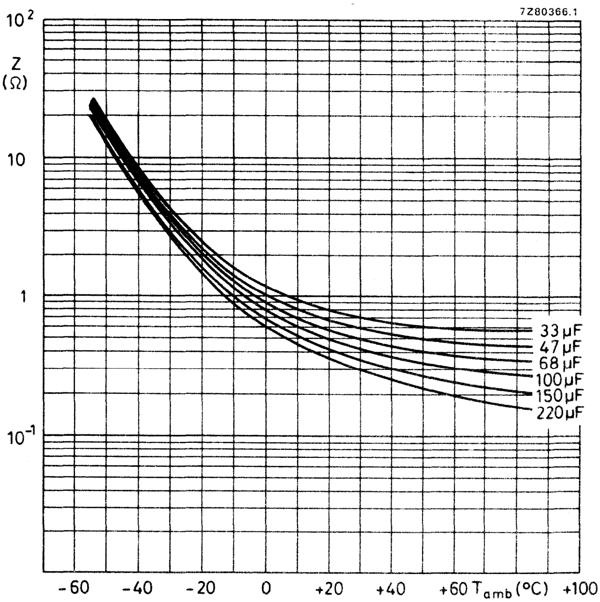


Fig. 15 Typical impedance at 10 kHz as a function of ambient temperature, case size 13.

DEVELOPMENT SAMPLE DATA

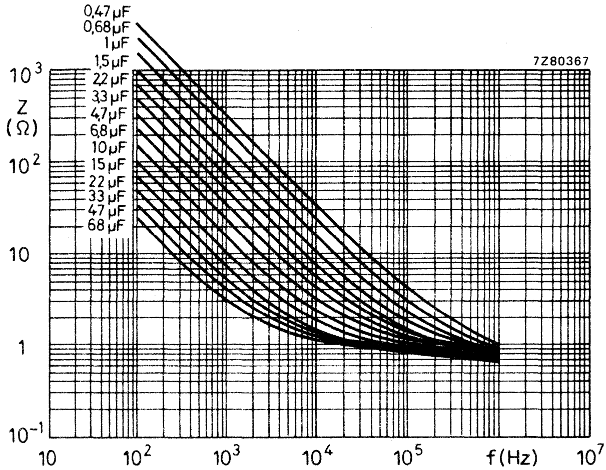


Fig. 16 Typical impedance as a function of frequency at T_{amb} = 20 °C, case size 11.

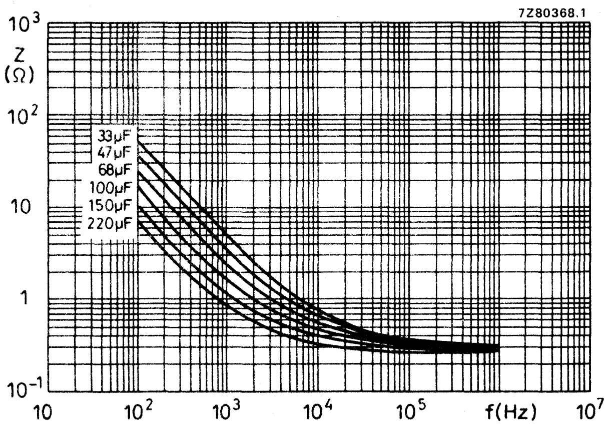


Fig. 17 Typical impedance as a function of frequency at T_{amb} = 20 °C, case size 13.

OPERATIONAL DATA

Category temperature range	−55 to +85 °C
Typical life time	
at T_{amb} = 40 °C	70 000 h
at T_{amb} = 85 °C	3 000 h
at T_{amb} = 95 °C	1 500 h
at T_{amb} = 105 °C	750 h
Shelf life at 0 V and T_{amb} = 85 °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 5.

Table 5

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

DEVELOPMENT SAMPLE DATA

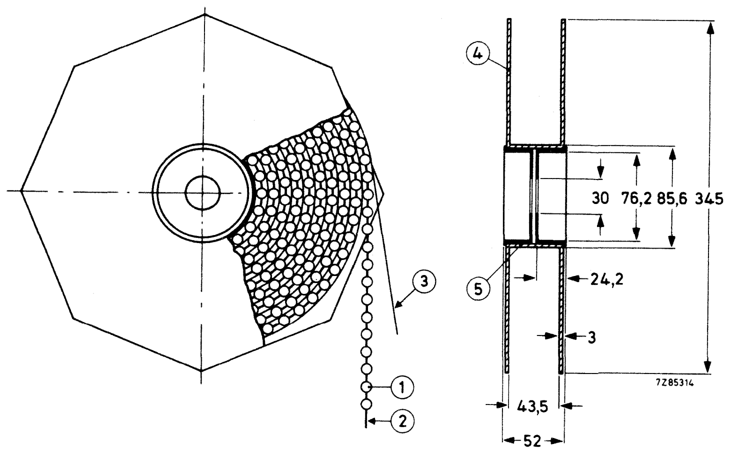


Fig. 18 Capacitors (style 4) on tape on reel.

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

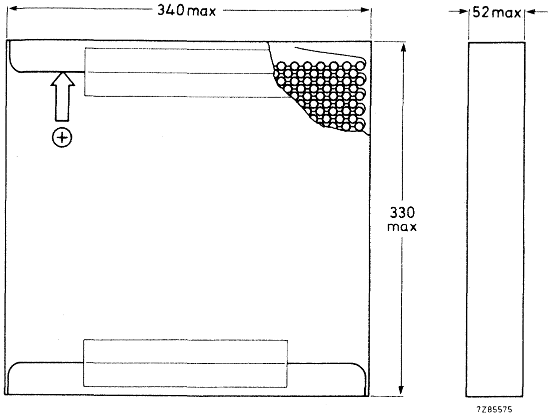


Fig. 19 Capacitors (style 5) on tape in ammunition pack.

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:

$\Delta C/C \leqslant \pm 15\%$;

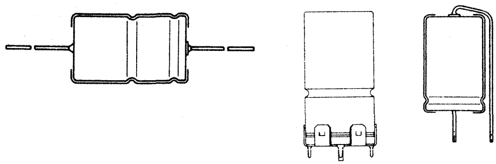
tan $\delta \leqslant 130\%$ of specified value;

leakage current $\leqslant$ specified value.

After *shelf life test, 500 h, 85 °C,* the capacitors meet the same requirements as after endurance test, except for leakage current: $\leqslant 200\%$ of specified value. The rated voltage shall be applied to the capacitors for minimum 30 min., at least 24 h and not more than 48 h before measurements.

Note: Capacitors 2222 013 are miniature, long-life grade.

ALUMINIUM ELECTROLYTIC CAPACITORS



- **Miniature and small types**
- **Axial leads and single ended**
- **Long life**
- **Low impedance, high ripple current**
- **For Switched Mode Power Supplies (SMPS)**

QUICK REFERENCE DATA

Nominal capacitance range (E6 series):	1 to 10 000 μF
Tolerance on nominal capacitance:	−10 to + 50%
Rated voltage range, U_R (R5 series):	6,3 to 100 V
Category temperature range:	−55 to + 85 °C
Endurance test at 85 °C:	2000 h
Shelf life at 0 V; 85 °C:	500 h
Basic specifications:	IEC 384-4, long-life grade DIN 41316 DIN 41240
Climatic category	
IEC 68:	55/085/56
DIN 40040:	FPF

case size	nominal dimensions (mm)	
3	Ø 6 x 10	miniature
5a	Ø 8 x 11	miniature
4	Ø 6,5 x 18	miniature
5	Ø 8 x 18	miniature
6	Ø 10 x 18	miniature
7	Ø 10 x 25	miniature
00	Ø 10 x 30	small
01	Ø 12,5 x 30	small
02	Ø 15 x 30	small
03	Ø 18 x 30	small
04	Ø 18 x 40	small
05	Ø 21 x 40	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
1						3	
1,5						3	
2,2						3	
3,3						3	
4,7						3	3
6,8						3	
10						3	4/5a
15					3	4/5a	5
22					3	4/5a	5
33				3	4/5a	5	6
47			3		4/5a	5	7
68		3	4/5a		5	6	
100	3		4/5a	5	6	7	01
150		4/5a	5	6	7	00	
220	4/5a		5	6	7/00	01	03
330	5		6	7	01	02	
470		6	7	00	01	02	05
680		7	00	01	02	03	
1 000		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	05				

* Case sizes 3 to 7 (miniature types) and all case sizes of the 100 V range are still under development; information on these capacitors are derived from development samples, and does not necessarily imply that they will go into regular production.

APPLICATION

These capacitors with high CU-product per unit volume are designed for use in switched-mode power supplies (SMPS) or other applications where high ripple currents at high frequencies occur. Their low ESR, tan δ and impedance values, even at high frequencies and low temperatures render them suitable for bypass and coupling applications in high-frequency equipment.

DESCRIPTION

The capacitors have etched and oxidized 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 3 styles, all with soldered-copper leads.

Style 1: axial leads; all case sizes; case sizes 3 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 3 to 7 and 00 to 02.

MECHANICAL DATA

Dimensions in mm

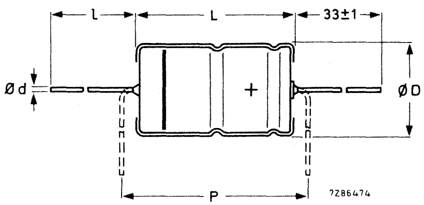


Fig. 1 Style 1; see Table 1a for dimensions d, D, L, l and P.

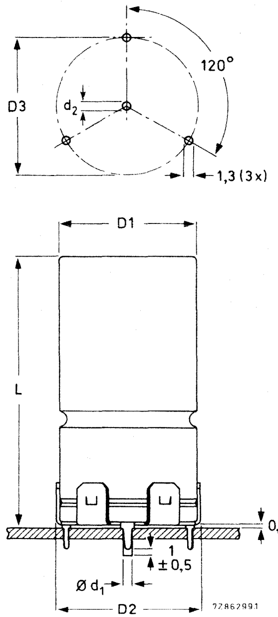
Table 1a

case size	d	l	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	0,70
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 3 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



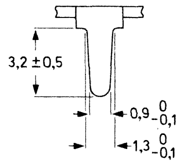


Fig. 2 Style 2; see Table 1b for dimensions d_1, d_2, D1, D2, D3 and L.

Table 1c

case size	d	style 3			mass approx. g
		D_{max}	L_{max}	P	
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

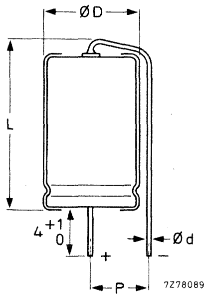


Fig. 3 Style 3 see Table 1c for dimensions d, D, L and P.

Marking

The capacitors are marked with:
- nominal capacitance;
- tolerance on nominal capacitance
- rated voltage;
- group number; 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 3 and 5a).

Mounting

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

Table 1d

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

Minimum atmospheric pressure 8,5 kPa

WARNING

Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled. Caution is necessary should the outer case be fractured.

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 1 min μA	max. tan δ	max. ESR mΩ	max. impedance mΩ at 10 kHz	max. impedance mΩ at 100 kHz	case size	catalogue number* 2222 014 followed by
6,3	100	75	7,8	0,20	3200	1700	1500	3	.3101
	220	135	12,5	0,20	1450	770	680	5a	**
	220	145	12,5	0,20	1450	770	680	4	.3221
	330	200	16,5	0,20	960	520	460	5	.3331
	1500	525	61	0,26	290	250	220	00	.3152
	2200	700	88	0,27	205	180	140	01	.3222
	3300	900	129	0,30	150	100	90	02	.3332
	4700	1170	182	0,32	114	70	80	03	.3472
	6800	1470	261	0,37	91	50	60	04	.3682
	10 000	1800	382	0,43	72	50	60	05	.3103
10	68	70	8,1	0,14	3300	2100	1750	3	.4689
	150	130	13	0,14	1500	930	800	4	.4151
	150	140	13	0,14	1500	930	800	5a	**
	470	325	32	0,14	470	300	260	6	.4471
	680	445	45	0,14	330	210	180	7	.4681
	1000	470	64	0,18	300	180	160	00	.4102
	1500	700	94	0,19	212	160	140	01	.4152
	2200	850	136	0,20	152	100	90	02	.4222
	3300	1000	202	0,22	111	80	70	03	.4332
	4700	1500	286	0,24	85	50	60	04	.4472
	6800	1800	412	0,28	69	50	60	05	.4682
	10 000	2260	604	0,30	50	50	60	05	.4103

* 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 3 and 4) } case sizes 3 to 7
3 for style 1 on bandoliers in box (preferred for case sizes 5a to 7) }
4 for style 2; case sizes 03 to 05;
8 for style 3; case sizes 3 to 02.

** See Table 3.

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. tan δ	max. ESR mΩ	max. impedance mΩ at 10 kHz	at 100 kHz	case size	catalogue number* 2222 014 followed by
16	47	65	8,5	0,11	3700	2100	1700	3	.5479
	68	100	10,5	0,11	2600	1450	1200	5a	**
	68	105	10,5	0,11	2600	1450	1200	4	.5689
	100	125	13,5	0,11	1750	1000	800	5a	**
	100	130	13,5	0,11	1750	1000	800	4	.5101
	150	180	18,5	0,11	1150	670	530	5	.5151
	220	220	25	0,11	800	450	360	5	.5221
	330	305	36	0,11	530	300	240	6	.5331
	470	415	49	0,11	370	210	170	7	.5471
	680	500	70	0,13	320	180	160	00	.5681
	1000	715	100	0,13	218	110	100	01	.5102
	1500	900	148	0,14	156	100	100	02	.5152
	2200	1270	215	0,15	114	70	80	03	.5222
	3300	1560	321	0,17	86	50	60	04	.5332
	4700	1820	455	0,20	71	50	60	05	.5472
	6800	2000	654	0,24	59	50	60	05	.5682
	10 000	2400	984	0,26	44	50	60	05	.5103
25	33	65	9	0,09	4300	2100	1800	3	.6339
	100	165	19	0,09	1450	700	600	5	.6101
	150	230	27	0,09	950	470	400	6	.6151
	220	280	37	0,09	650	320	270	6	.6221
	330	390	54	0,09	430	210	180	7	.6331
	470	540	74	0,11	392	180	160	00	.6471
	680	600	106	0,12	295	130	110	01	.6681
	1000	920	154	0,12	200	100	100	02	.6102
	1500	1040	229	0,13	145	70	80	03	.6152
	2200	1480	334	0,13	99	50	60	04	.6222
	3300	1800	500	0,14	71	50	60	05	.6332
	4700	2140	709	0,15	54	50	60	05	.6472

* 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 3 and 4) } case sizes 3 to 7
3 for style 1 on bandoliers in box (preferred for case sizes 5a to 7) } case sizes 3 to 7
4 for style 2; case sizes 03 to 05;
8 for style 3; case sizes 3 to 02.

** See Table 3.

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. tan δ	max. ESR mΩ	max. impedance mΩ at 10 kHz	max. impedance mΩ at 100 kHz	case size	catalogue number* 2222 014 followed by
40	15	45	7,6	0,08	8500	3300	3000	3	.7159
	22	55	9,3	0,08	5800	2300	2000	3	.7229
	33	85	12	0,08	3900	1500	1350	5a	**
	33	90	12	0,08	3900	1500	1350	4	.7339
	47	95	15,5	0,08	2700	1050	960	5a	**
	47	105	15,5	0,08	2700	1050	960	4	.7479
	68	145	20	0,08	1850	740	660	5	.7689
	100	200	28	0,08	1250	500	450	6	.7101
	150	280	40	0,08	850	330	300	7	.7151
	220	340	57	0,08	580	230	200	7	**
	220	365	57	0,08	600	220	170	00	.7221
	330	500	84	0,08	405	150	120	01	.7331
	470	575	117	0,08	285	110	110	01	.7471
	680	800	167	0,08	197	100	100	02	.7681
	1000	1100	244	0,08	134	70	80	03	.7102
	1500	1330	364	0,10	112	60	70	04	.7152
	2200	1660	532	0,11	84	50	70	05	.7222
	3300	1900	796	0,14	71	50	60	05	.7332
63	1	13	4,4	0,06	95 000	40 000	35 000	3	.8108
	1,5	16	4,6	0,06	64 000	27 000	23 000	3	.8158
	2,2	20	4,8	0,06	43 000	18 000	16 000	3	.8228
	3,3	24	5,2	0,06	29 000	12 000	10 500	3	.8338
	4,7	29	5,8	0,06	20 000	8500	7400	3	.8478
	6,8	35	6,6	0,06	14 000	5900	5100	3	.8688
	10	42	7,8	0,06	9500	4000	3500	3	.8109
	15	63	9,7	0,06	6400	2700	2300	5a	**
	15	68	9,7	0,06	6400	2700	2300	4	.8159
	22	78	12,5	0,06	4300	1800	1600	5a	**
	22	82	12,5	0,06	4300	1800	1600	4	.8229
	33	115	16,5	0,06	2900	1200	1050	5	.8339
	47	135	22	0,06	2000	850	740	5	.8479
	68	190	30	0,06	1400	590	510	6	.8689
	100	260	42	0,06	950	400	350	7	.8101
	150	345	61	0,06	670	370	220	00	.8151
	220	500	87	0,06	457	150	120	01	.8221
	330	650	129	0,06	305	150	120	02	.8331
	470	870	182	0,06	214	100	100	02	.8471
	680	1030	261	0,06	148	80	100	03	.8681
	1000	1600	382	0,06	100	50	70	05	.8102
	1500	1800	571	0,08	89	50	70	05	.8152

* 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 3 and 4) } case sizes 3 to 7
3 for style 1 on bandoliers in box (preferred for case sizes 5a to 7) } case sizes 3 to 7
4 for style 2; case sizes 03 to 05;
8 for style 3; case sizes 3 to 02.

** See Table 3.

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. tan δ	max. ESR mΩ	max. impedance mΩ at 10 kHz	max. impedance mΩ at 100 kHz	case size	catalogue number* 2222 014 followed by
100	4,7	16	6,8	0,05	17 000	7400	6400	3	.9478
	10	55	10	0,05	8000	3500	3000	5a	**
	10	60	10	0,05	8000	3500	3000	4	.9109
	15	85	13	0,05	5300	2300	2000	5	.9159
	22	105	17	0,05	3600	1600	1350	5	.9229
	33	140	24	0,05	2400	1050	910	6	.9339
	47	195	32	0,05	1700	740	640	7	.9479
	100	340	64	0,05	838	315	200	01	.9101
	220	650	139	0,05	381	150	120	03	.9221
	470	1090	286	0,05	178	100	100	05	.9471

Table 3

U_R V	nom. cap. µF	case size	catalogue number style 1 on bandoliers on reel	catalogue number style 1 on bandoliers in box	catalogue number style 3
6,3	220	5a	2222 014 90534	2222 014 90535	2222 014 90536
10	150	5a	2222 014 90501	2222 014 90502	2222 014 90503
16	68	5a	2222 014 90504	2222 014 90505	2222 014 90506
	100	5a	2222 014 90507	2222 014 90508	2222 014 90509
40	33	5a	2222 014 90511	2222 014 90512	2222 014 90513
	47	5a	2222 014 90514	2222 014 90515	2222 014 90516
	220	7	2222 014 90517	2222 014 90518	2222 014 90519
63	15	5a	2222 014 90521	2222 014 90522	2222 014 90523
	22	5a	2222 014 90524	2222 014 90525	2222 014 90526
100	10	5a	2222 014 90527	2222 014 90528	2222 014 90529

* 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 3 and 4) } case sizes 3 to 7
3 for style 1 on bandoliers in box (preferred for case sizes 5a to 7) } case sizes 3 to 7
4 for style 2; case sizes 03 to 05;
8 for style 3; case sizes 3 to 02.

** See Table 3.

Capacitance

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

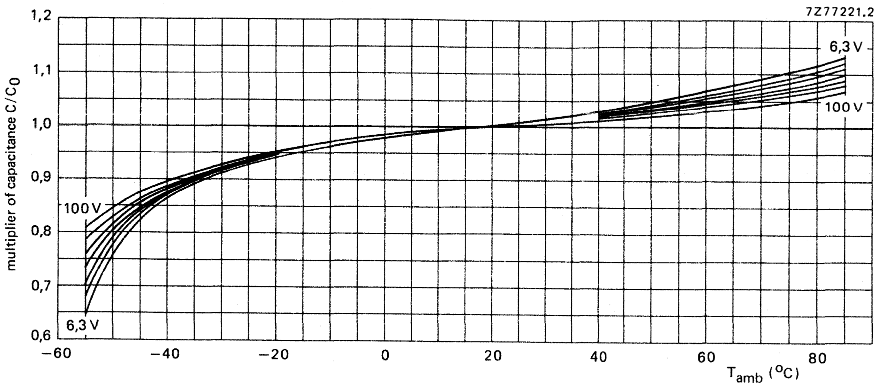


Fig. 4 Multiplier of capacitance as a function of ambient temperature; **case sizes 3 to 7;** C_0 = capacitance at 20 °C, 100 Hz.

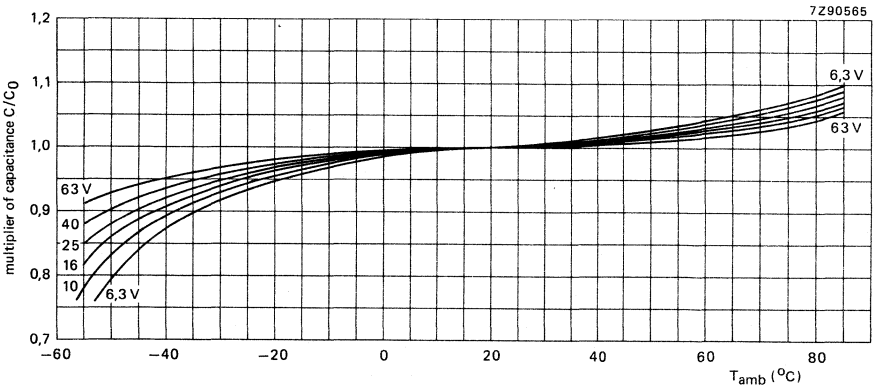


Fig. 5 Multiplier of capacitance as a function of ambient temperature; **case sizes 00 to 05;** C_0 = capacitance at 20 °C, 100 Hz.

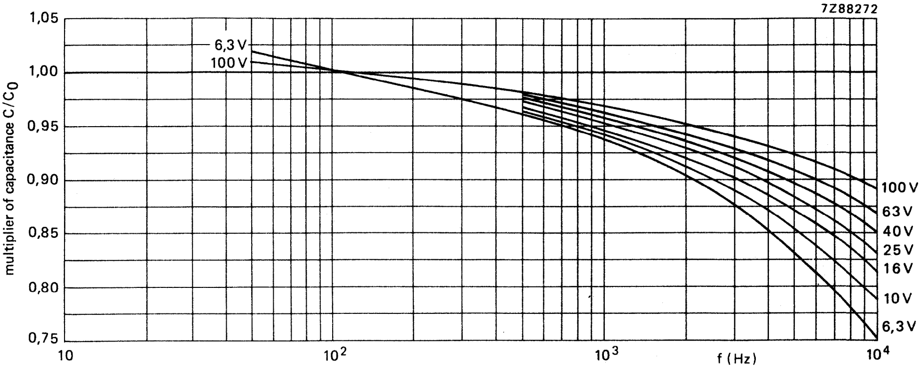


Fig. 6 Multiplier of capacitance as a function of frequency; **case sizes 3 to 7**; C_0 = capacitance at 20 °C, 100 Hz.

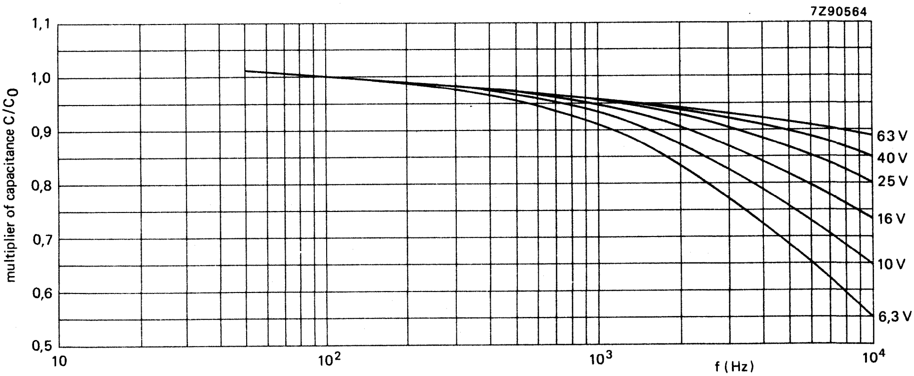


Fig. 7 Multiplier of capacitance as a function of frequency; **case sizes 00 to 05**; C_0 = capacitance at 20 °C, 100 Hz.

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 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	1 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 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

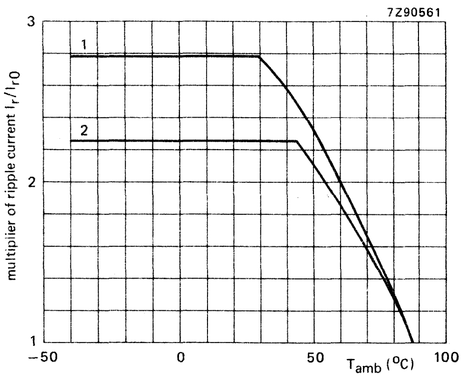


Fig. 8 Multiplier of ripple current as a function of ambient temperature; I_{r0} = ripple current at 85 °C, 100 Hz.

curve 1 = case sizes 3 to 7;
curve 2 = case sizes 00 to 05.

* 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.

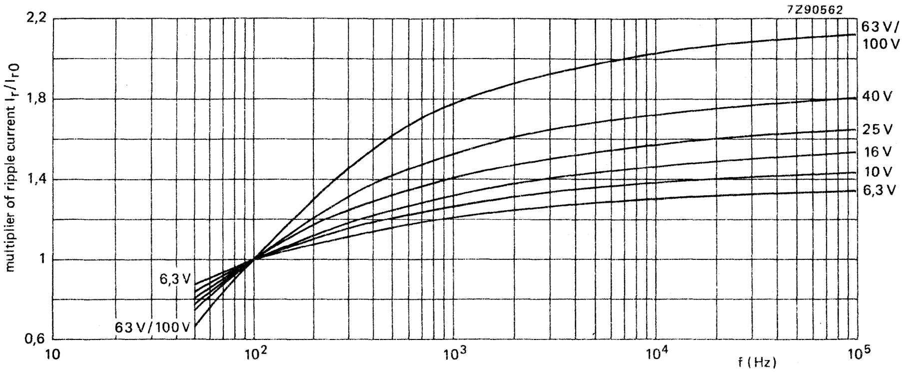


Fig. 9 Multiplier of ripple current as a function of frequency, **case sizes 3 to 7;** I_{r0} = ripple current at 85 °C, 100 Hz.

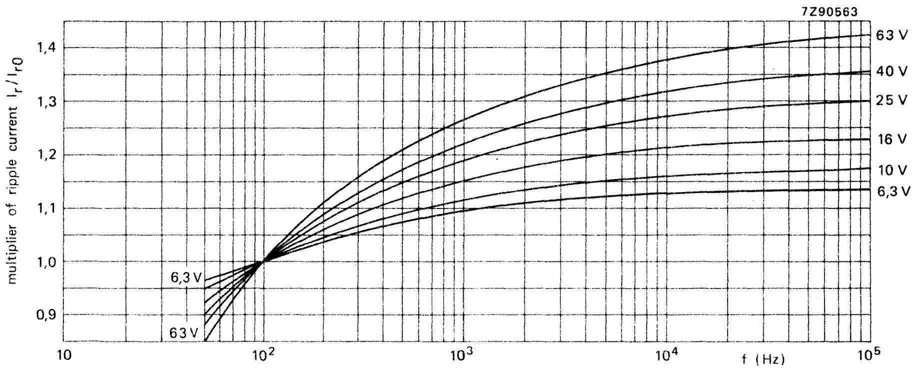


Fig. 10 Multiplier of ripple current as a function of frequency, **case sizes 00 to 05;** I_{r0} = ripple current at 85 °C, 100 Hz.

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;

$\sqrt{r_n} = I_r/I_{r0}$ = 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-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.

Leakage current

Maximum leakage current 1 min after application of U_R, at T_{amb} = 25 °C	see Table 2 (0,006 CU + 4 µA)
Maximum leakage current 5 min after application of U_R, at T_{amb} = 25 °C	0,002 CU + 2 µA
Leakage current during continuous operation at U_R,	
at T_{amb} = 25 °C, case sizes 3 to 7	0,1 x values of Table 2
at T_{amb} = 25 °C, case sizes 00 to 05	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.

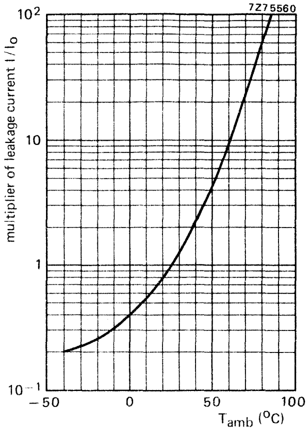


Fig. 11 Multiplier of leakage current as a function of ambient temperature, **case sizes 00 to 05;** I_0 = leakage current during continuous operation at 25 °C and U_R.

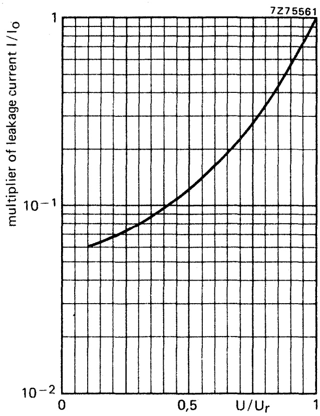


Fig. 12 Multiplier of leakage current as a function of U/U_R, **case sizes 00 to 05;** I_0 = leakage current during continuous operation at 25 °C and U_R.

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

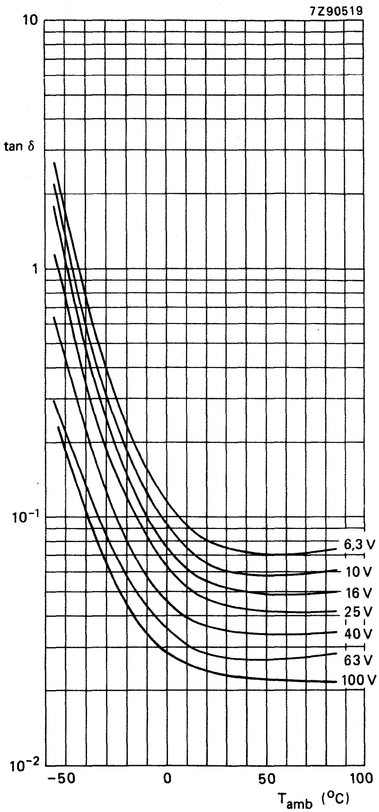


Fig. 13 Typical tan δ as a function of ambient temperature at 100 Hz; **case sizes 3 to 7.**

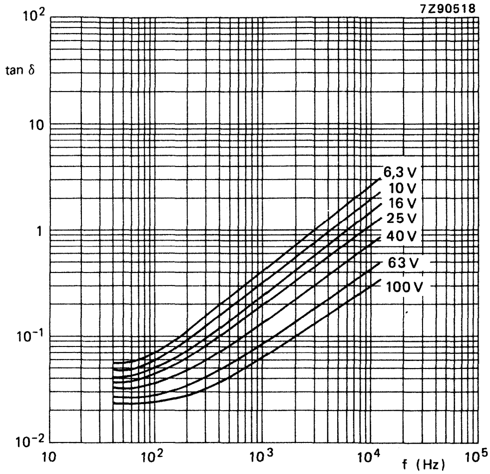


Fig. 14 Typical tan δ as a function of frequency at 25 °C, **case sizes 3 to 7.**

Equivalent series resistance (ESR)

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

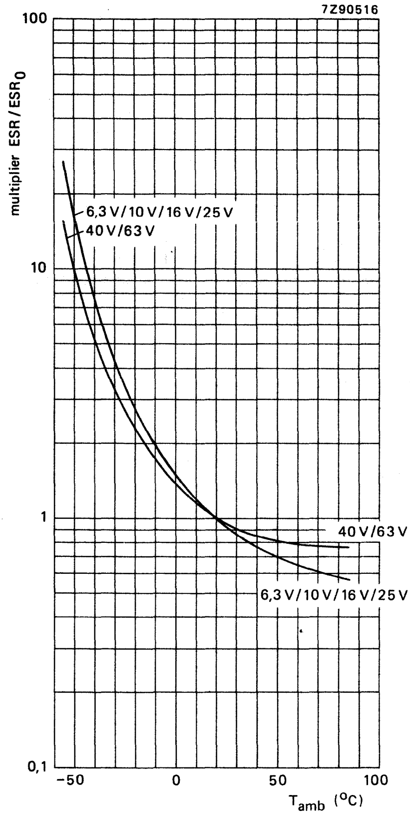


Fig. 15 Multiplier of ESR as a function of ambient temperature, **case sizes 00, 01 and 02**; ESR_0 = typ. ESR at 20 °C, 100 Hz.

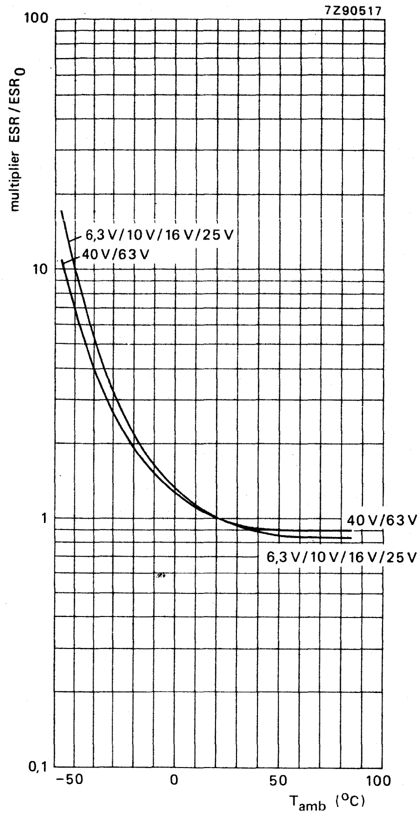


Fig. 16 Multiplier of ESR as a function of ambient temperature, **case sizes 03, 04 and 05**; ESR_0 = typ. ESR at 20 °C, 100 Hz.

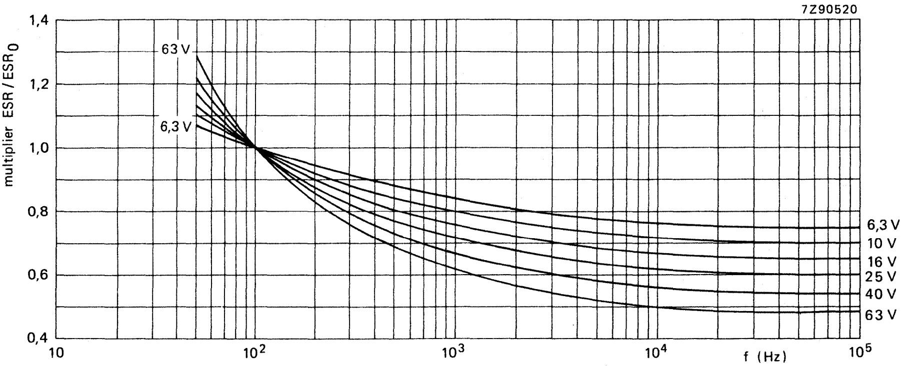


Fig. 17 Multiplier of ESR as a function of frequency, **case sizes 00 to 05**; ESR_0 = typical ESR at 20 °C, 100 Hz.

Impedance

Maximum impedance at T_{amb} = 25 °C and 10 kHz or 100 kHz, measured by means of a four-terminal circuit (Thomson circuit) — see Table 2

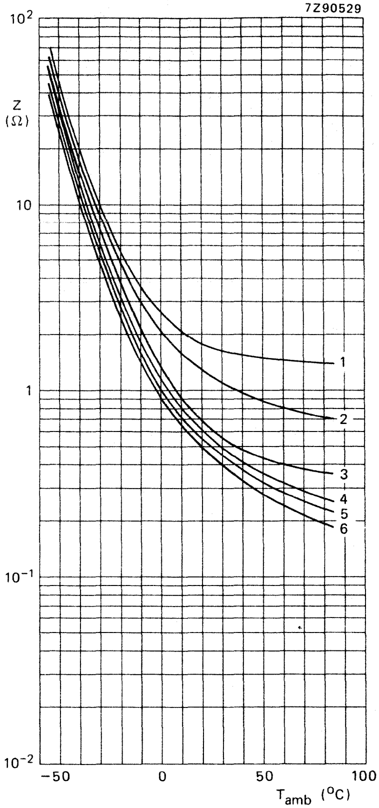


Fig. 18 Typical impedance as a function of ambient temperature at 10 kHz; **case size 3:**

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

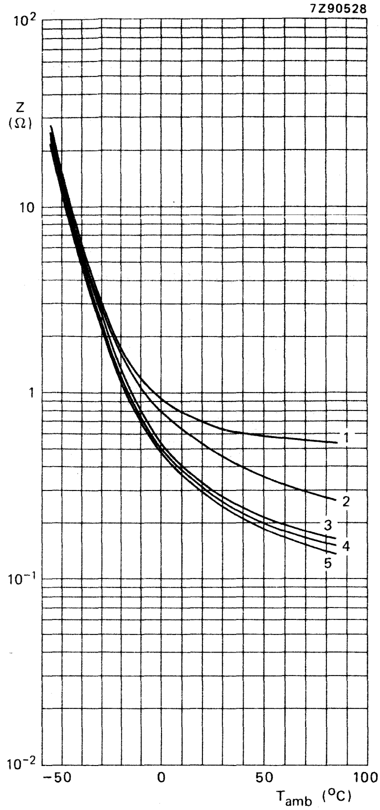


Fig. 19 Typical impedance as a function of ambient temperature at 10 kHz; **case size 5a:**

curve 1 = 22 μF, 63 V;
curve 2 = 47 μF, 40 V;
curve 3 = 100 μF, 16 V;
curve 4 = 150 μF, 10 V;
curve 5 = 220 μF, 6,3 V.

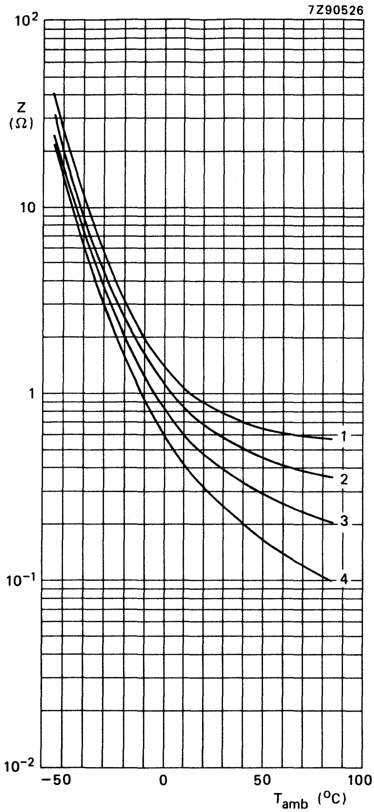


Fig. 20 Typical impedance as a function of ambient temperature at 10 kHz; **case size 4:**

curve 1 = 22 μF, 63 V;
curve 2 = 47 μF, 40 V;
curve 3 = 100 μF, 16 V;
curve 4 = 220 μF, 6,3 V.

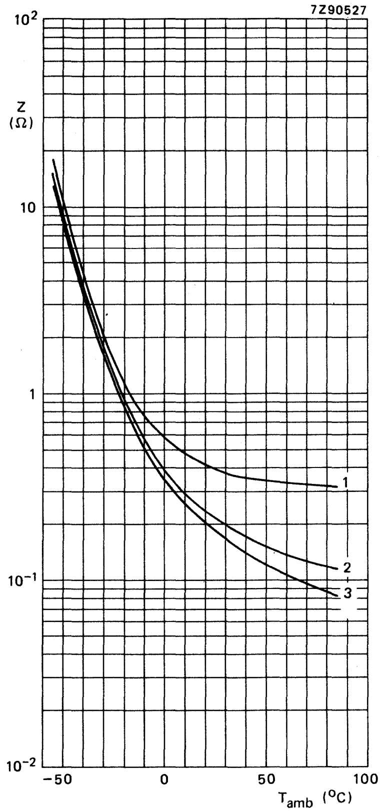


Fig. 21 Typical impedance as a function of ambient temperature at 10 kHz; **case size 5:**

curve 1 = 47 μF, 63 V;
curve 2 = 150 μF, 16 V;
curve 3 = 330 μF, 6,3 V.

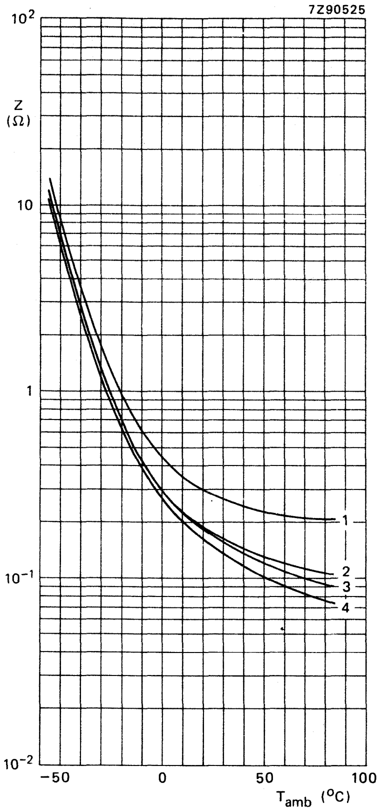


Fig. 22 Typical impedance as a function of ambient temperature at 10 kHz; **case size 6:**

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

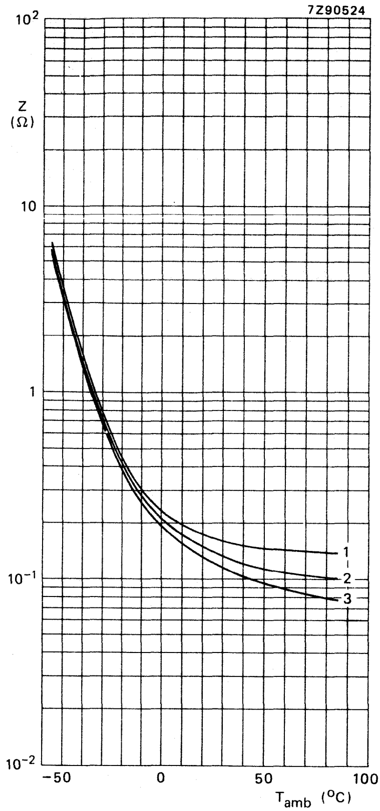


Fig. 23 Typical impedance as a function of ambient temperature at 10 kHz; **case size 7:**

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

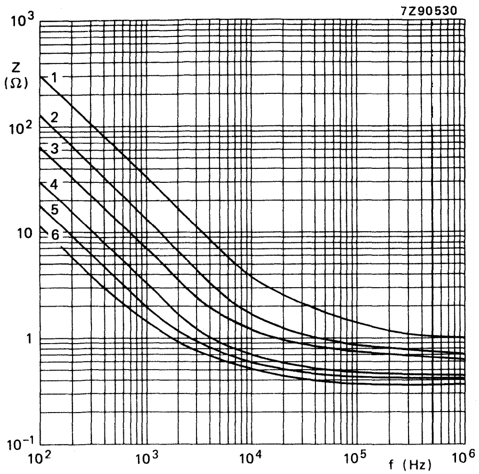


Fig. 24 Typical impedance as a function of frequency at T_{amb} = 20 °C;
case size 3:

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

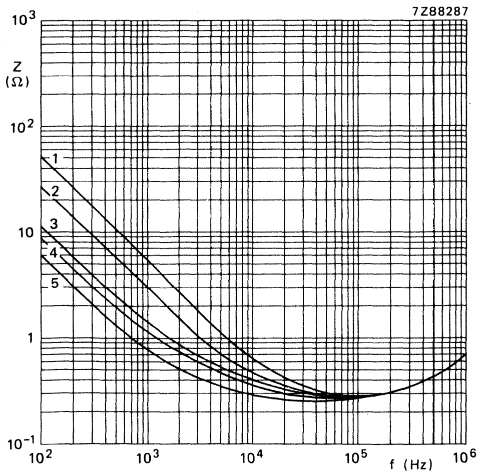


Fig. 25 Typical impedance as a function of frequency at T_{amb} = 20 °C;
case size 5a:

curve 1 = 22 μF, 63 V;
curve 2 = 47 μF, 40 V;
curve 3 = 100 μF, 16 V;
curve 4 = 150 μF, 10 V;
curve 5 = 220 μF, 6,3 V.

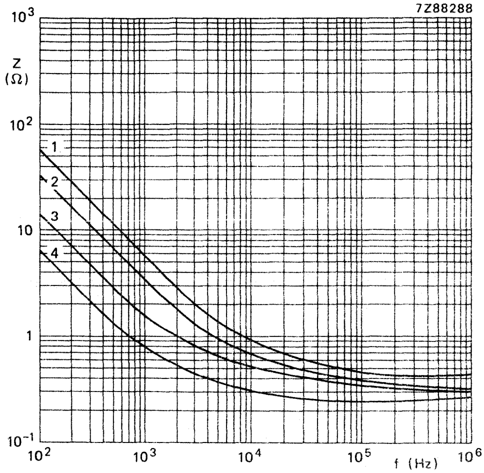


Fig. 26 Typical impedance as a function of frequency at T_{amb} = 20 °C;
case size 4:

curve 1 = 22 μF, 63 V;
curve 2 = 47 μF, 40 V;
curve 3 = 100 μF, 16 V;
curve 4 = 220 μF, 6,3 V.

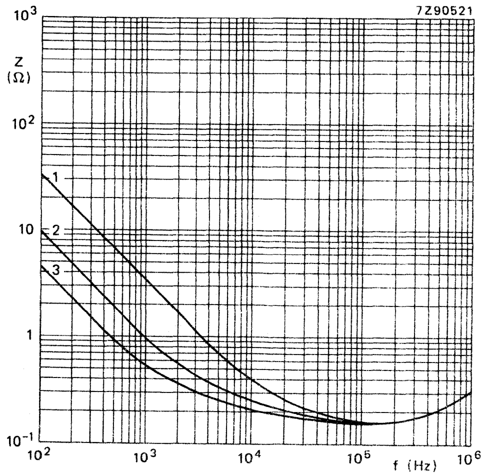


Fig. 27 Typical impedance as a function frequency at T_{amb} = 20 °C;
case size 5:

curve 1 = 47 μF, 63 V;
curve 2 = 150 μF, 16 V;
curve 3 = 330 μF, 6,3 V.

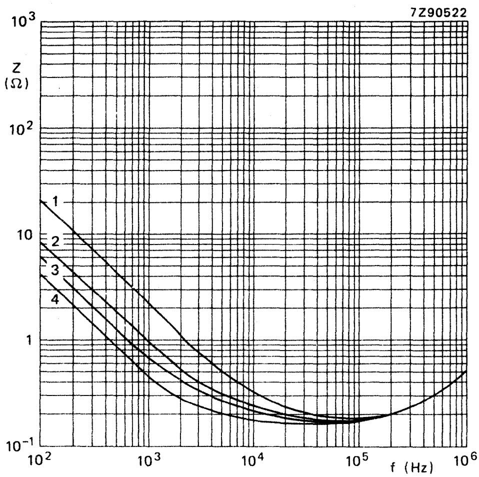


Fig. 28 Typical impedance as a function of frequency at T_{amb} = 20 °C;
case size 6:

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

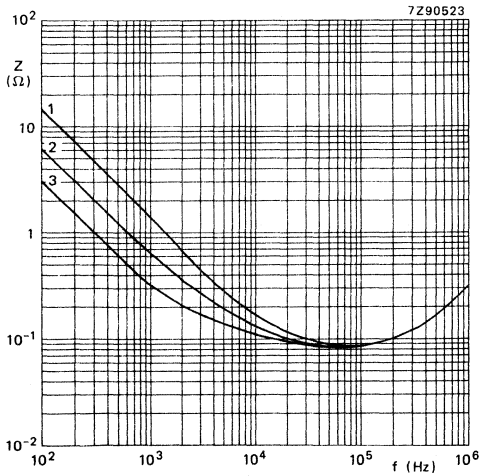


Fig. 29 Typical impedance as a function of frequency at T_{amb} = 20 °C;
case size 7:

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

Fig. 30 Typical impedance as a function of frequency at T_{amb} = 20 °C, **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.

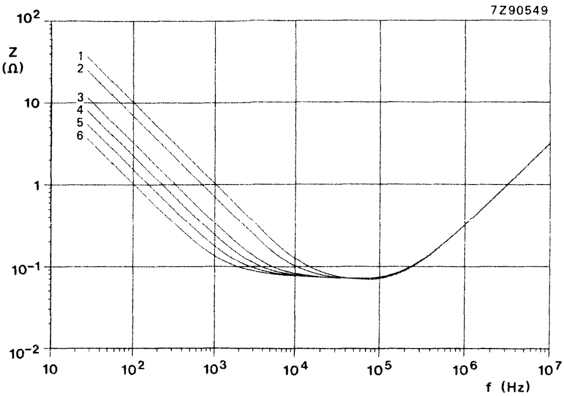


Fig. 31 Typical impedance as a function of frequency at T_{amb} = 20 °C, **case size 01.**

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;
curve 7 = 2200 μF, 6,3 V.

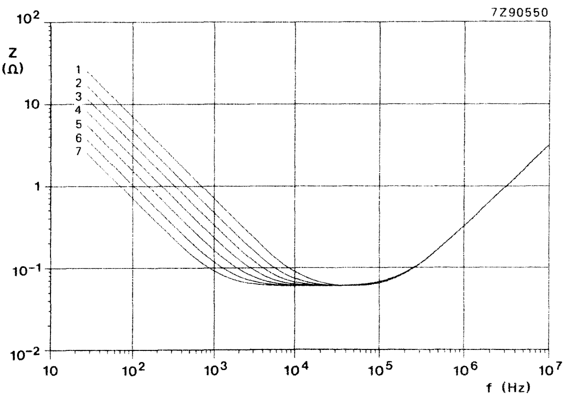
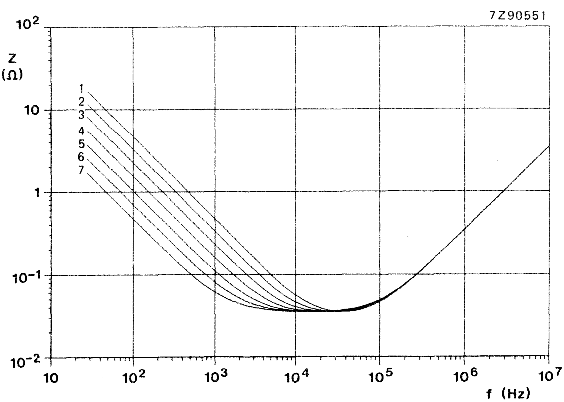


Fig. 32 Typical impedance as a function of frequency at T_{amb} = 20 °C, **case size 02.**

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;
curve 7 = 3300 μF, 6,3 V.



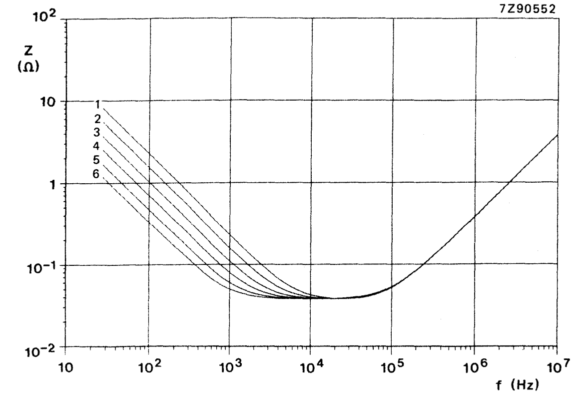


Fig. 33 Typical impedance as a function of frequency at T_{amb} = 20 °C, **case size 03.**

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;
curve 6 = 4700 μF, 6,3 V.

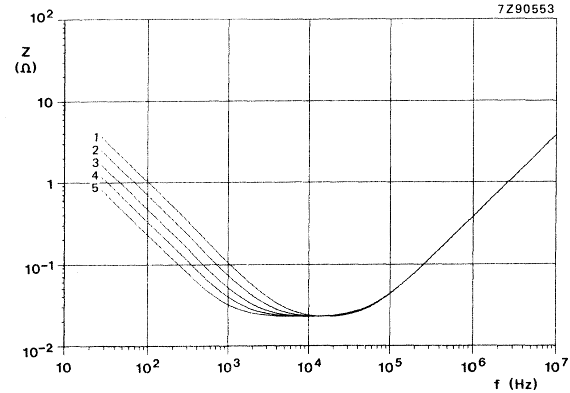


Fig. 34 Typical impedance as a function of frequency at T_{amb} = 20 °C, **case size 04.**

curve 1 = 1500 μF, 40 V;
curve 2 = 2200 μF, 25 V;
curve 3 = 3300 μF, 16 V;
curve 4 = 4700 μF, 10 V;
curve 5 = 6800 μF, 6,3 V.

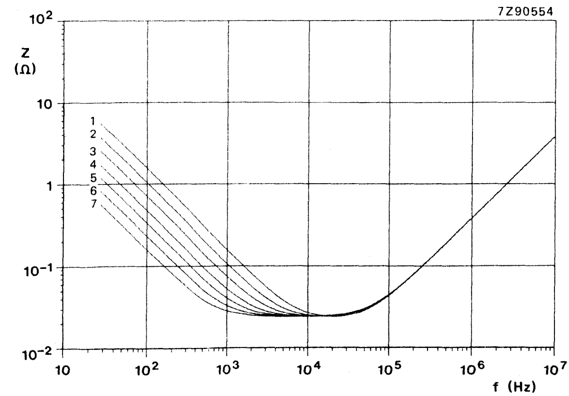


Fig. 35 Typical impedance as a function of frequency at T_{amb} = 20 °C, **case size 05.**

curve 1 = 1000 μF, 63 V;
curve 2 = 1500 μF, 63 V;
curve 3 = 2200 μF, 40 V;
curve 4 = 3300 μF, 25 and 40 V;
curve 5 = 4700 μF, 16 and 25 V;
curve 6 = 6800 μF, 10 and 16 V;
curve 7 = 10 000 μF, 6,3, 10 and 16 V.

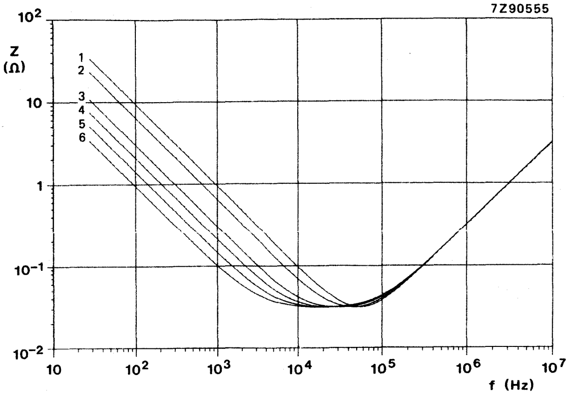


Fig. 36 Typical impedance as a function of frequency at T_{amb} = 85 °C, **case size 00.**
curve 1 = 150 μF, 63 V;
curve 2 = 220 μF, 40 V;
curve 3 = 470 μF, 25 V;
curve 4 = 680 μF, 16 V;
curve 5 = 1000 μF, 10 V;
curve 6 = 1500 μF, 6,3 V.

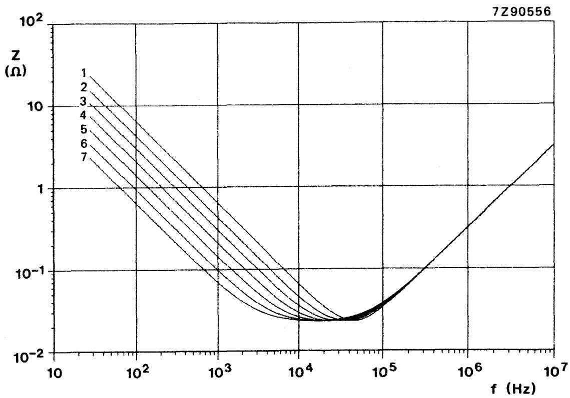


Fig. 37 Typical impedance as a function of frequency at T_{amb} = 85 °C, **case size 01.**
curve 1 = 220 μF, 63 V;
curve 2 = 330 μF, 40 V;
curve 3 = 470 μF, 40 V;
curve 4 = 680 μF, 25 V;
curve 5 = 1000 μF, 16 V;
curve 6 = 1500 μF, 10 V;
curve 7 = 2200 μF, 6,3 V.

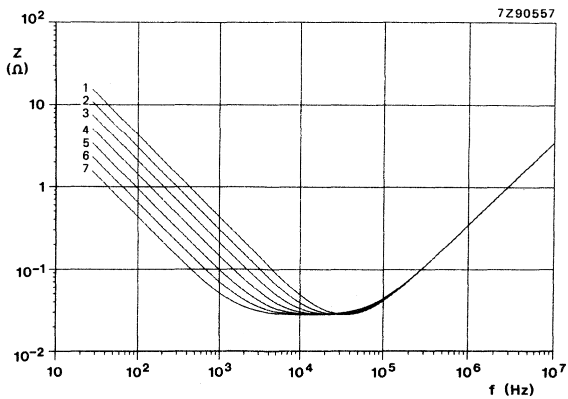


Fig. 38 Typical impedance as a function of frequency at T_{amb} = 85 °C, **case size 02.**
curve 1 = 330 μF, 63 V;
curve 2 = 470 μF, 63 V;
curve 3 = 680 μF, 40 V;
curve 4 = 1000 μF, 25 V;
curve 5 = 1500 μF, 16 V;
curve 6 = 2200 μF, 10 V;
curve 7 = 3300 μF, 6,3 V.

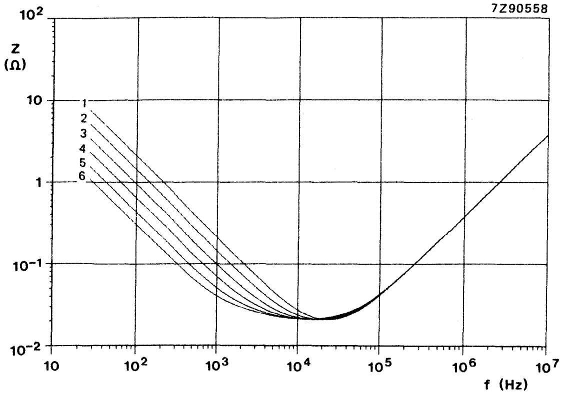


Fig. 39 Typical impedance as a function of frequency at T_{amb} = 85 °C, **case size 03.**
curve 1 = 680 μF, 63 V;
curve 2 = 1000 μF, 40 V;
curve 3 = 1500 μF, 25 V;
curve 4 = 2200 μF, 16 V;
curve 5 = 3300 μF, 10 V;
curve 6 = 4700 μF, 6,3 V.

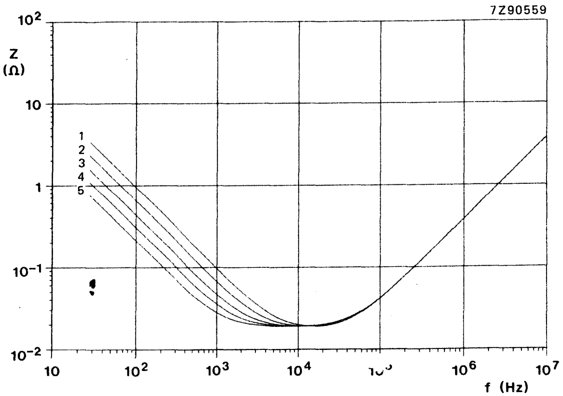


Fig. 40 Typical impedance as a function of frequency at T_{amb} = 85 °C, **case size 04.**
curve 1 = 1500 μF, 40 V;
curve 2 = 2200 μF, 25 V;
curve 3 = 3300 μF, 16 V;
curve 4 = 4700 μF, 10 V;
curve 5 = 6800 μF, 6,3 V.

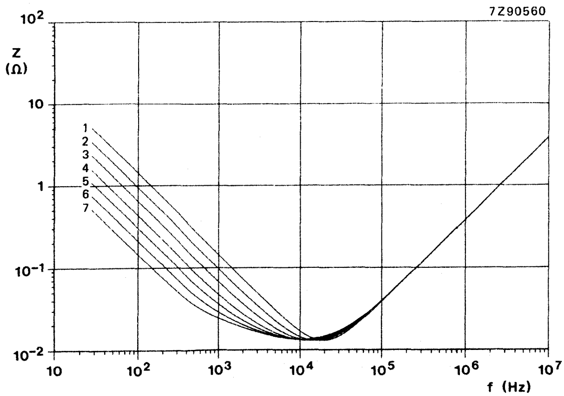


Fig. 41 Typical impedance as a function of frequency at T_{amb} = 85 °C, **case size 05.**
curve 1 = 1000 μF, 63 V;
curve 2 = 1500 μF, 63 V;
curve 3 = 2200 μF, 40 V;
curve 4 = 3300 μF, 25 and 40 V;
curve 5 = 4700 μF, 16 and 25 V;
curve 6 = 6800 μF, 10 and 16 V;
curve 7 = 10 000 μF, 6,3, 10 and 16 V.

Fig. 42 Typical impedance as a function of frequency at T_{amb} = −25 °C, **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.

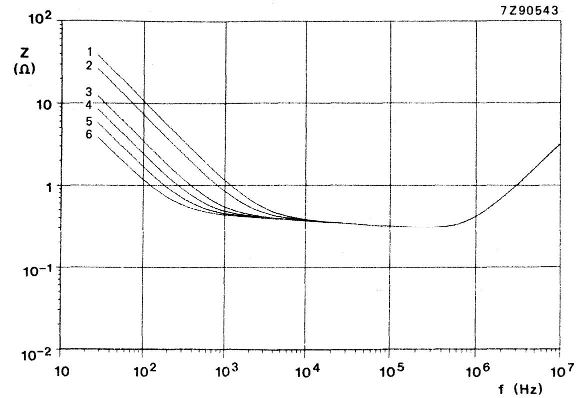


Fig. 43 Typical impedance as a function of frequency at T_{amb} = −25 °C, **case size 01.**
curve 1 = 220 μF, 63 V;
curve 2 = 330 μF, 40 V;
curve 3 = 470 μF, 40 V;
curve 4 = 680 μF, 25 V;
curve 5 = 1000 μF, 16 V;
curve 6 = 1500 μF, 10 V;
curve 7 = 2200 μF, 6,3 V.

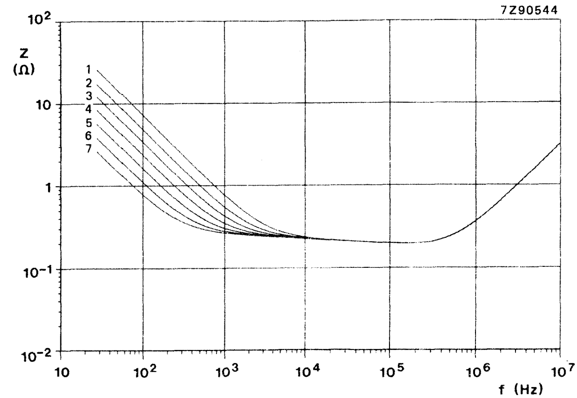
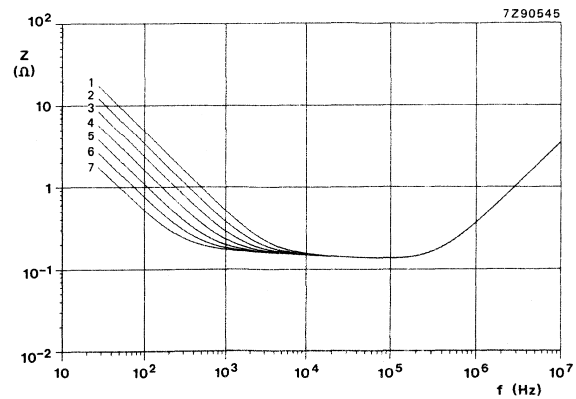


Fig. 44 Typical impedance as a function of frequency at T_{amb} = −25 °C, **case size 02.**
curve 1 = 330 μF, 63 V;
curve 2 = 470 μF, 63 V;
curve 3 = 680 μF, 40 V;
curve 4 = 1000 μF, 25 V;
curve 5 = 1500 μF, 16 V;
curve 6 = 2200 μF, 10 V;
curve 7 = 3300 μF, 6,3 V.



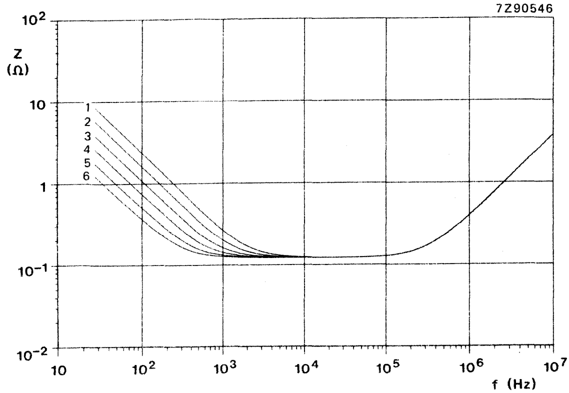


Fig. 45 Typical impedance as a function of frequency at T_{amb} = −25 °C, **case size 03.**

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;
curve 6 = 4700 μF, 6,3 V.

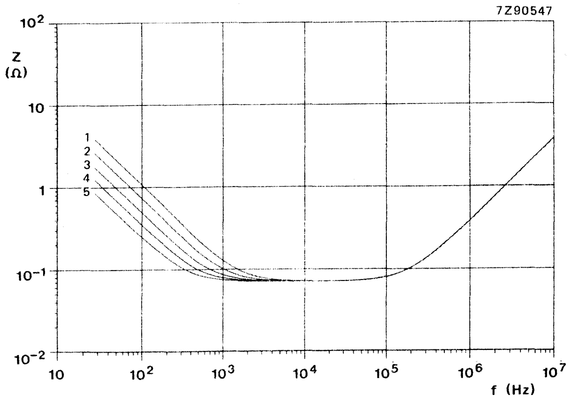


Fig. 46 Typical impedance as a function of frequency at T_{amb} = −25 °C, **case size 04.**

curve 1 = 1500 μF, 40 V;
curve 2 = 2200 μF, 25 V;
curve 3 = 3300 μF, 16 V;
curve 4 = 4700 μF, 10 V;
curve 5 = 6800 μF, 6,3 V.

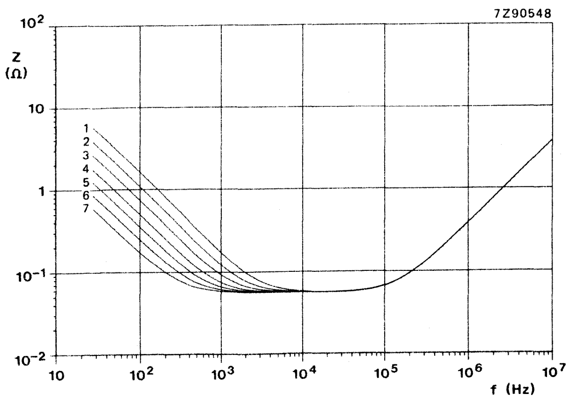
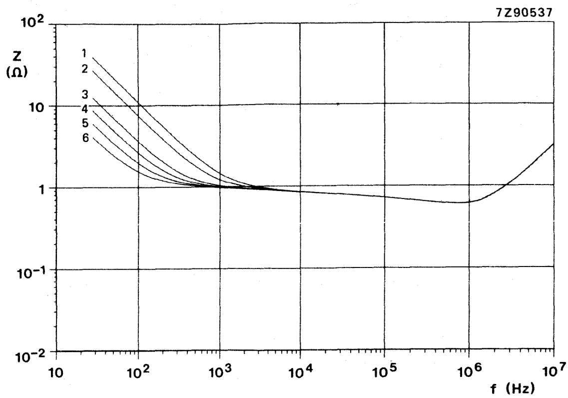


Fig. 47 Typical impedance as a function of frequency at T_{amb} = −25 °C, **case size 05.**

curve 1 = 1000 μF, 63 V;
curve 2 = 1500 μF, 63 V;
curve 3 = 2200 μF, 40 V;
curve 4 = 3300 μF, 25 and 40 V;
curve 5 = 4700 μF, 16 and 25 V;
curve 6 = 6800 μF, 10 and 16 V;
curve 7 = 10 000 μF, 6,3, 10 and 16 V.

Fig. 48 Typical impedance as a function of frequency at T_{amb} = −40 °C, **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.



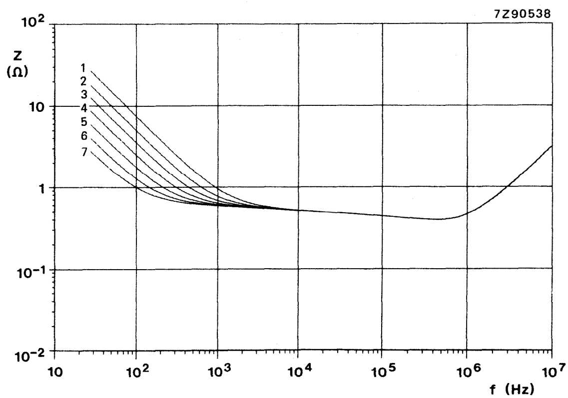


Fig. 49 Typical impedance as a function of frequency at T_{amb} = −40 °C, **case size 01.**
curve 1 = 220 μF, 63 V;
curve 2 = 330 μF, 40 V;
curve 3 = 470 μF, 40 V;
curve 4 = 680 μF, 25 V;
curve 5 = 1000 μF, 16 V;
curve 6 = 1500 μF, 10 V;
curve 7 = 2200 μF, 6,3 V.

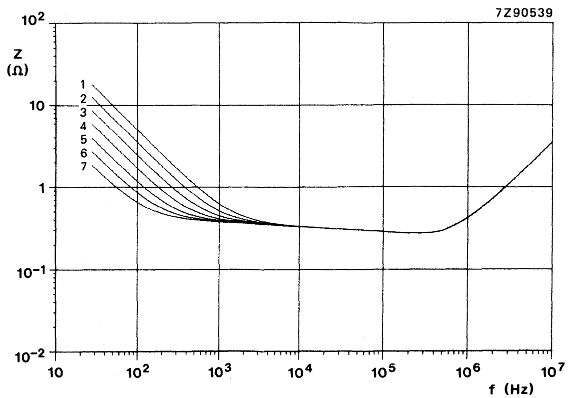


Fig. 50 Typical impedance as a function of frequency at T_{amb} = −40 °C, **case size 02.**
curve 1 = 330 μF, 63 V;
curve 2 = 470 μF, 63 V;
curve 3 = 680 μF, 40 V;
curve 4 = 1000 μF, 25 V;
curve 5 = 1500 μF, 16 V;
curve 6 = 2200 μF, 10 V;
curve 7 = 3300 μF, 6,3 V.

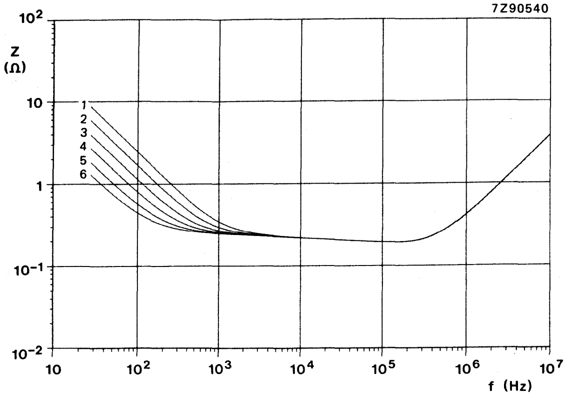


Fig. 51 Typical impedance as a function of frequency at T_{amb} = −40 °C, **case size 03.**

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;
curve 6 = 4700 μF, 6,3 V.

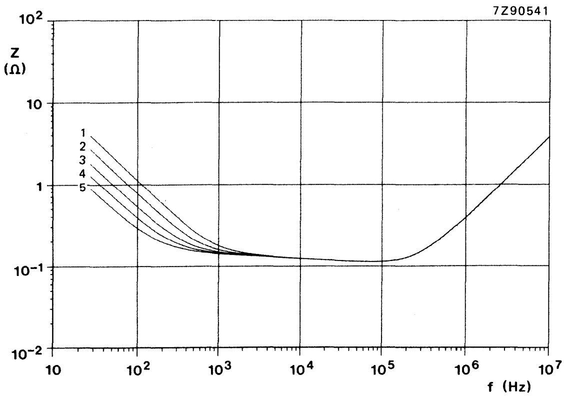


Fig. 52 Typical impedance as a function of frequency at T_{amb} = −40 °C, **case size 04.**

curve 1 = 1500 μF, 40 V;
curve 2 = 2200 μF, 25 V;
curve 3 = 3300 μF, 16 V;
curve 4 = 4700 μF, 10 V;
curve 5 = 6800 μF, 6,3 V.

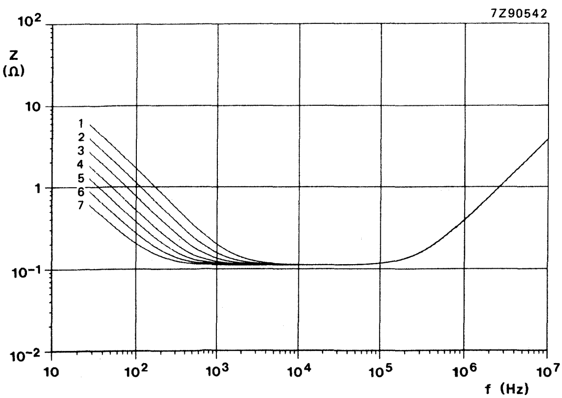


Fig. 53 Typical impedance as a function of frequency at T_{amb} = −40 °C, **case size 05.**

curve 1 = 1000 μF, 63 V;
curve 2 = 1500 μF, 63 V;
curve 3 = 2200 μF, 40 V;
curve 4 = 3300 μF, 25 and 40 V;
curve 5 = 4700 μF, 16 and 25 V;
curve 6 = 6800 μF, 10 and 16 V;
curve 7 = 10 000 μF, 6,3, 10 and 16 V.

Fig. 54 Typical impedance as a function of frequency at $T_{amb} = -55$ °C, **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.

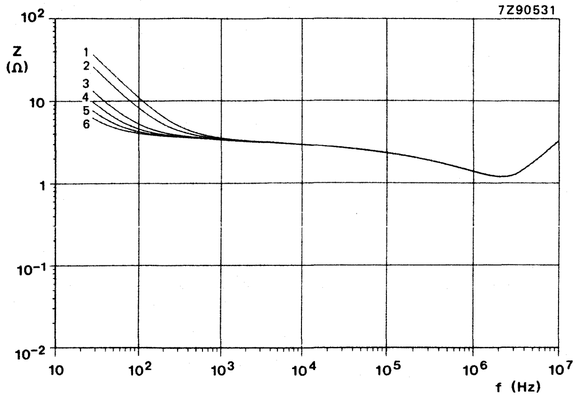


Fig. 55 Typical impedance as a function of frequency at $T_{amb} = -55$ °C, **case size 01.**
curve 1 = 220 μF, 63 V;
curve 2 = 330 μF, 40 V;
curve 3 = 470 μF, 40 V;
curve 4 = 680 μF, 25 V;
curve 5 = 1000 μF, 16 V;
curve 6 = 1500 μF, 10 V;
curve 7 = 2200 μF, 6,3 V.

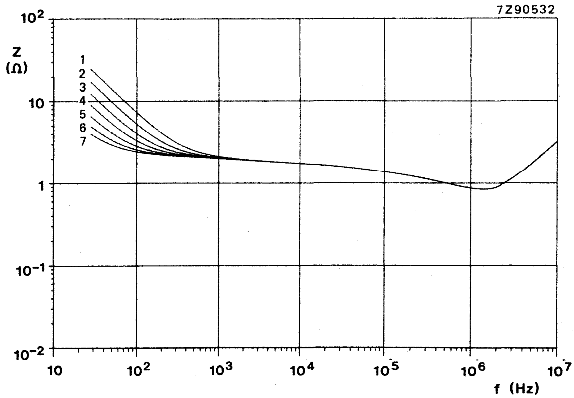
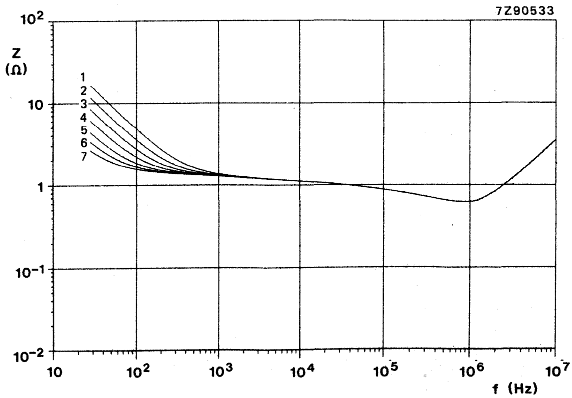


Fig. 56 Typical impedance as a function of frequency at $T_{amb} = -55$ °C, **case size 02.**
curve 1 = 330 μF, 63 V;
curve 2 = 470 μF, 63 V;
curve 3 = 680 μF, 40 V;
curve 4 = 1000 μF, 25 V;
curve 5 = 1500 μF, 16 V;
curve 6 = 2200 μF, 10 V;
curve 7 = 3300 μF, 6,3 V.



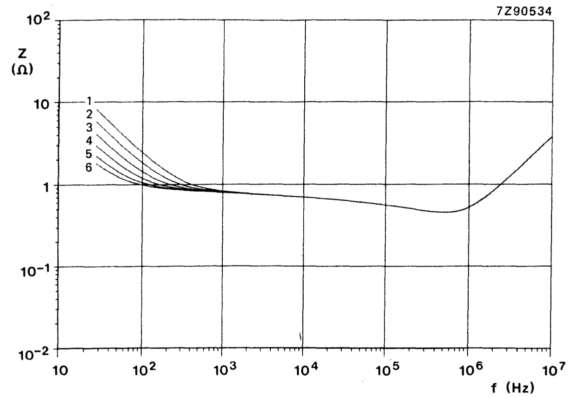


Fig. 57 Typical impedance as a function of frequency at T_{amb} = −55 °C, **case size 03.**

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;
curve 6 = 4700 μF, 6,3 V.

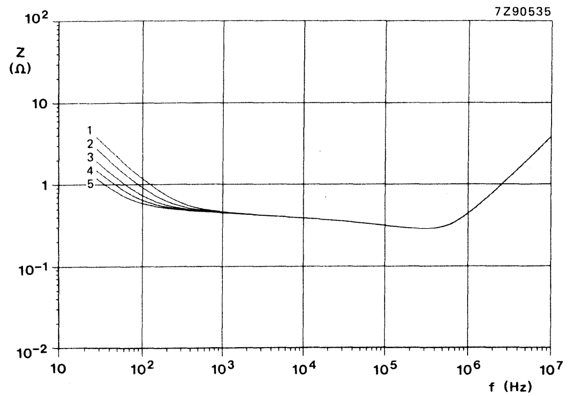


Fig. 58 Typical impedance as a function of frequency at T_{amb} = −55 °C, **case size 04.**

curve 1 = 1500 μF, 40 V;
curve 2 = 2200 μF, 25 V;
curve 3 = 3300 μF, 16 V;
curve 4 = 4700 μF, 10 V;
curve 5 = 6800 μF, 6,3 V.

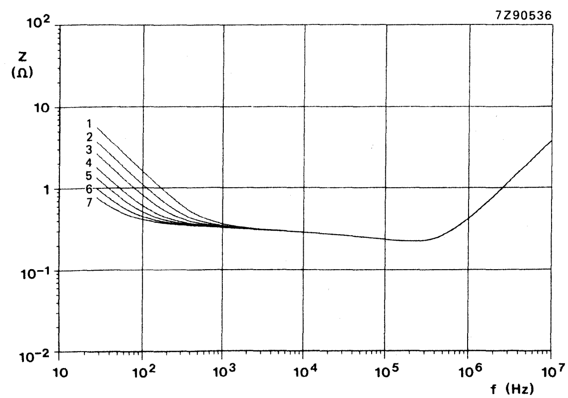


Fig. 59 Typical impedance as a function of frequency at T_{amb} = −55 °C, **case size 05.**

curve 1 = 1000 μF, 63 V;
curve 2 = 1500 μF, 63 V;
curve 3 = 2200 μF, 40 V;
curve 4 = 3300 μF, 25 and 40 V;
curve 5 = 4700 μF, 16 and 25 V;
curve 6 = 6800 μF, 10 and 16 V;
curve 7 = 10 000 μF, 6,3, 10 and 16 V.

Equivalent series inductance (ESL)

Case sizes 3 and 4	typ. 30 nH
Case size 5a	typ. 85 nH
Case size 5	typ. 50 nH
Case sizes 6 and 7	typ. 65 nH
Case sizes 00 and 01	typ. 50 nH
Case size 02	typ. 55 nH
Case sizes 03, 04 and 05	typ. 60 nH

OPERATIONAL DATA

Category temperature range: −55 to + 85 °C

Typical life time	T_{amb} = 85 °C	T_{amb} = 40 °C
case sizes 3 to 7	3000 h	70 000 h
case sizes 00 to 05	5000 h	100 000 h

Shelf life at 0 V and T_{amb} = 85 °C: 500 h

PACKING

All capacitors are supplied in boxes, except case sizes 3 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 4.

Table 4

case size	number of capacitors		
	style 1 per reel	style 1 per box	styles 2 and 3 per box
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

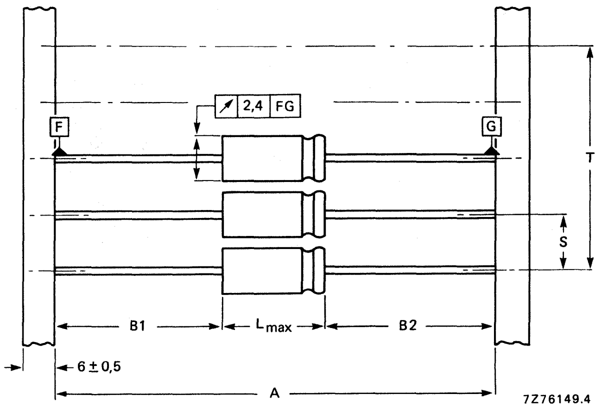


Fig. 60 Style 1 capacitors (case sizes 3 to 7) on bandoliers: the bandolier to which the negative capacitor terminals are connected is blue. See Table 5 for dimensions A, S, T and L_{max}.
$|B1 - B2|$ = max. 1,4 mm.

Table 5

Dimensions in mm

case size	A	S	T for number (n) of capacitors		L_{max}
			n < 50	50 < n < 100	
3	63,5 ± 1,5	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	10,5
5a	63,5 ± 1,5	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

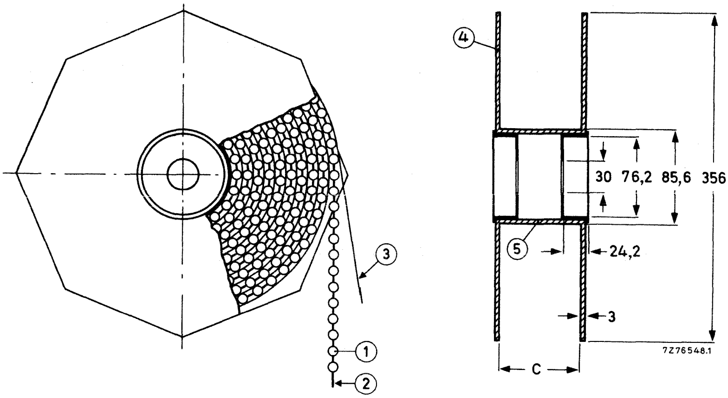


Fig. 61 Style 1 capacitors (case sizes 3 to 7) on bandoliers on reel; dimension C is 83,5 mm for case sizes 3 and 5a, and 88,5 mm for case sizes 4, 5, 6 and 7; the overall width of the reel is 94,5 mm and 99,5 mm respectively.

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

TESTS AND REQUIREMENTS

See Introduction, section 9, under aluminium electrolytic capacitors.

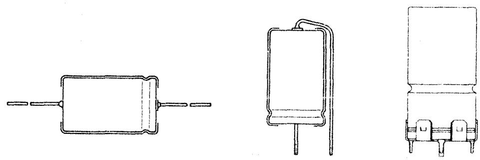
After *shelf life test, 500 h, 85 °C,* the capacitors meet the same requirements as after endurance test. The rated voltage shall be applied to the capacitors for minimum 30 min, at least 24 h and not more than 48 h before measurements.

Note: Capacitors 2222 014 are miniature and small types, long-life grade.

For miniature types of the 2222 021 series see page 99.

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
Endurance test at 85 °C	2000h
Shelf life at 0 V, 85 °C	500h
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

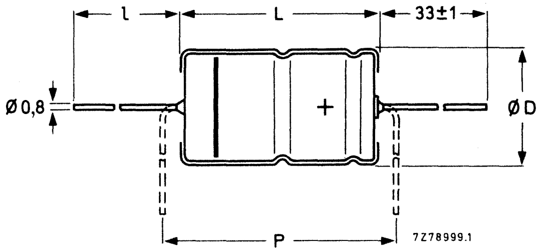


Fig. 1 Style 1; see Table 1a for dimensions D. L, l and P.

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

Table 1b

case size	style 2				
	d	D1	D2max	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

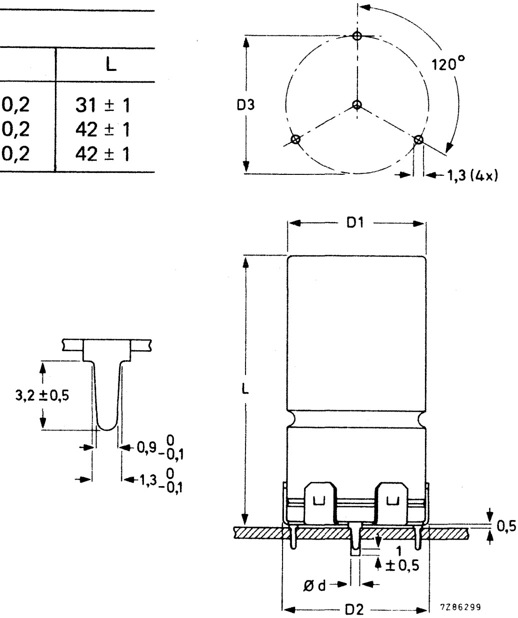


Fig. 2 Style 2; Table 1b for dimensions d, D1, D2, D3 and L.

Table 1c

case size	style 3			
	d	Dmax	Lmax	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

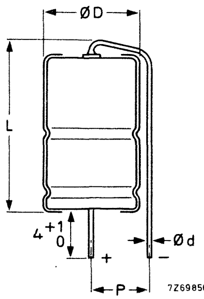


Fig. 3 Style 3; see Table 1c for dimensions d, D, L and P.

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

WARNING

Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled. Caution is necessary should the outer case be fractured.

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	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. ESR	max. impedance Ω		case size	catalogue number* 2222 021 followed by
V	µF	mA	µA		Ω	at 10 kHz	at 1 kHz		
10	1500	570	94	0,23	0,245		0,30	00	. 4152
	2200	740	136	0,25	0,177		0,20	01	. 4222
	3300	920	202	0,27	0,128		0,14	01	. 4332
	4700	1150	288	0,29	0,100		0,096	02	. 4472
	6800	1480	412	0,34	0,079		0,066	03	. 4682
	10000	1840	604	0,40	0,064		0,045	04	. 4103
	15000	2200	904	0,50	0,054		0,040	05	. 4153
16	1000	530	100	0,16	0,260	0,175		00	. 5102
	1500	680	148	0,19	0,205		0,267	01	. 5152
	2200	880	216	0,21	0,150		0,182	01	. 5222
	3300	1120	321	0,23	0,111		0,121	02	. 5332
	4700	1380	455	0,25	0,087		0,085	03	. 5472
	6800	1760	656	0,30	0,070		0,060	04	. 5682
	10000	2100	964	0,36	0,058		0,042	05	. 5103
25	680	480	106	0,14	0,323	0,175		00	. 6681
	1000	630	154	0,14	0,220	0,095		01	. 6102
	1500	780	229	0,17	0,179		0,20	01	. 6152
	2200	1020	334	0,19	0,132		0,136	02	. 6222
	3300	1240	499	0,21	0,099		0,091	03	. 6332
	4700	1650	709	0,23	0,079		0,064	04	. 6472
	6800	2000	1024	0,28	0,064		0,044	05	. 6682
40	470	440	117	0,12	0,404	0,175		00	. 7471
	680	580	167	0,12	0,279	0,095		01	. 7681
	1000	730	244	0,12	0,190	0,095		01	. 7102
	1500	815	364	0,15	0,159		0,160	02	. 7152
	2200	1170	532	0,17	0,118		0,110	03	. 7222
	3300	1500	796	0,19	0,090		0,073	04	. 7332
	4700	1815	1132	0,21	0,072		0,051	05	. 7472
63	220	350	88	0,08	0,614	0,20		00	. 8221
	330	480	129	0,08	0,409	0,14		01	. 8331
	470	570	182	0,08	0,287	0,10		01	. 8471
	680	770	261	0,08	0,199	0,080		02	. 8681
	1000	1035	382	0,08	0,135	0,065		03	. 8102
	1500	1330	571	0,11	0,122		0,143	04	. 8152
	2200	1740	836	0,13	0,099		0,098	05	. 8222

* 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).

Capacitance

Nominal capacitance at 100 Hz and T_{amb} = 25 °C	see Table 2
Tolerance on nominal capacitance at 100 Hz	± 20%

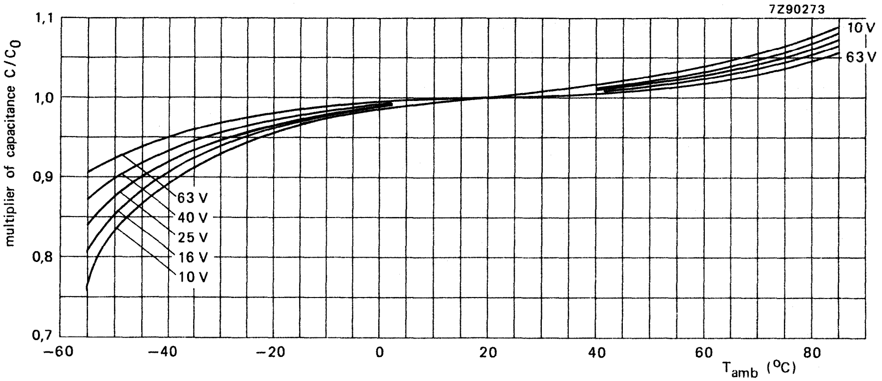


Fig. 4 Multiplier of capacitance as a function of ambient temperature; C_o = capacitance at 20 °C, 100 Hz.

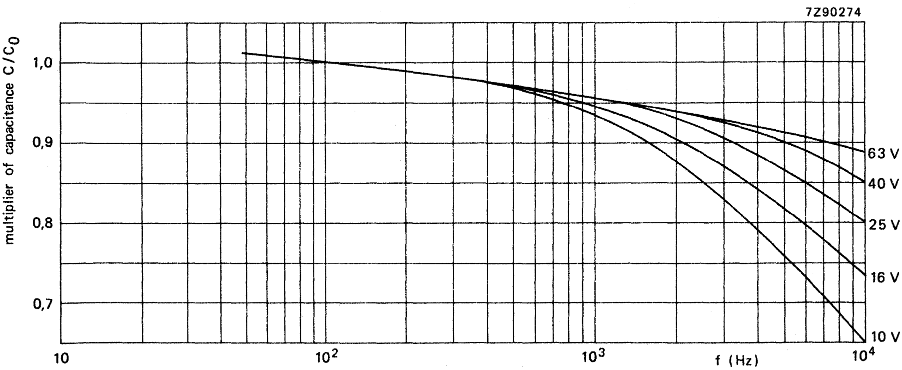


Fig. 5 Multiplier of capacitance as a function of frequency; C_o = capacitance at 20 °C; 100 Hz.

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 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 for short periods	2 V	

Ripple current**

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

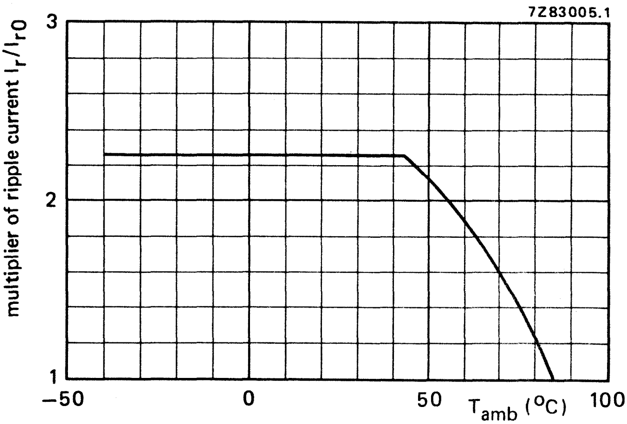


Fig. 6 Multiplier of ripple current as a function of ambient temperature; I_{r0} = ripple current at 85 °C, 100 Hz.

* 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.

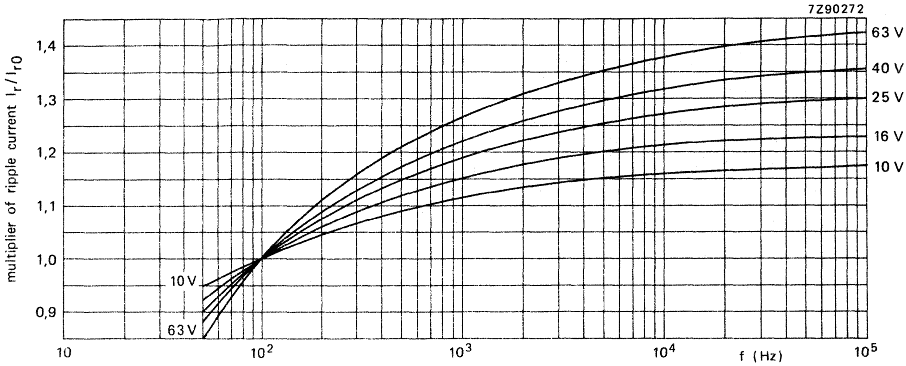


Fig. 7 Multiplier of ripple current as a function of frequency; I_{r0} = ripple current at 85 °C, 100 Hz.

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;
$\sqrt{r_n} = I_r/I_{r0}$	= 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-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.

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.

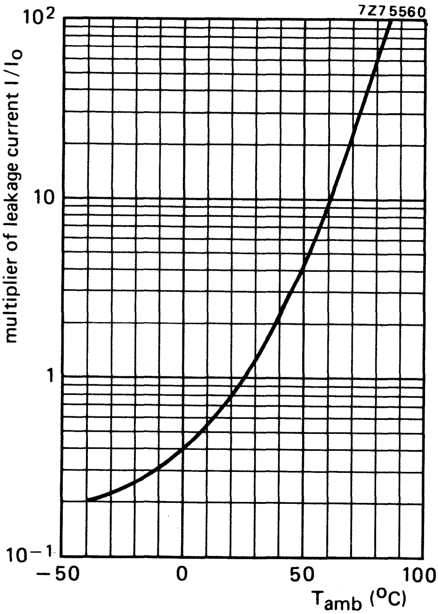


Fig. 8 Multiplier of leakage current as a function of ambient temperature; I_0 = leakage current during continuous operation at 25 °C and U_R.

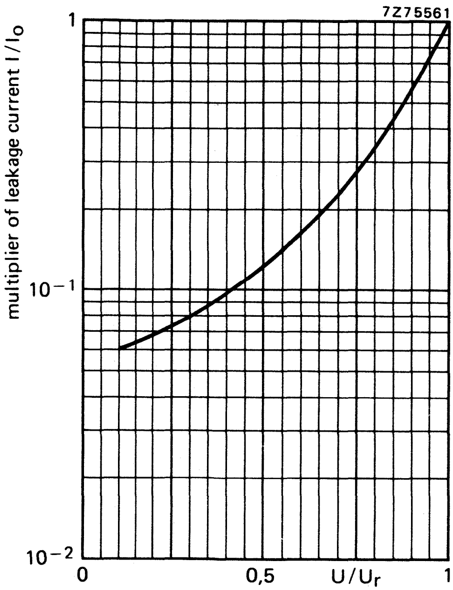


Fig. 9 Multiplier of leakage current as a function of U/U_R; I_0 = leakage current during continuous operation at 25 °C and U_R.

Equivalent series resistance (ESR)

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

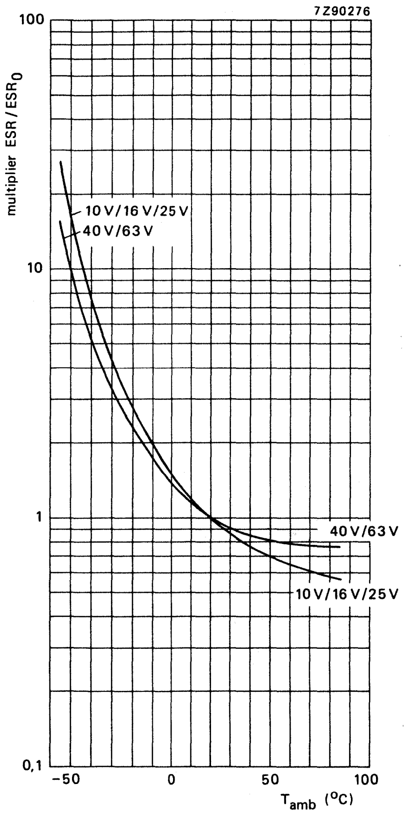


Fig. 10 Multiplier of ESR as a function of ambient temperature, *case sizes 00, 01 and 02;* ESR_0 = typical ESR at 20 °C, 100 Hz.

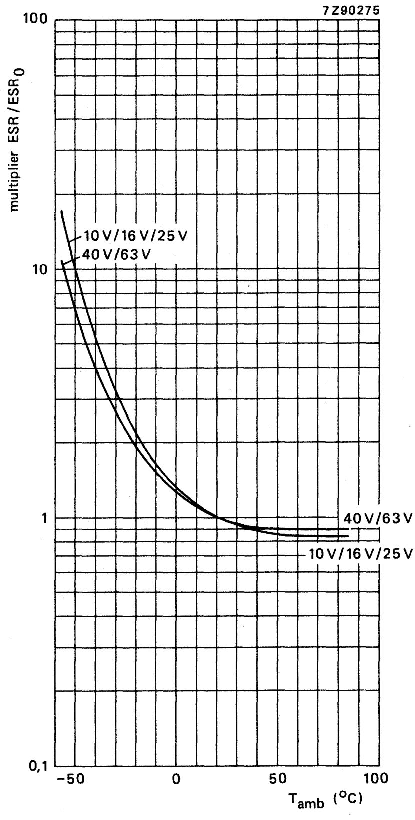


Fig. 11 Multiplier of ESR as a function of ambient temperature, *case sizes 03, 04 and 05;* ESR_0 = typical ESR at 20 °C, 100 Hz.

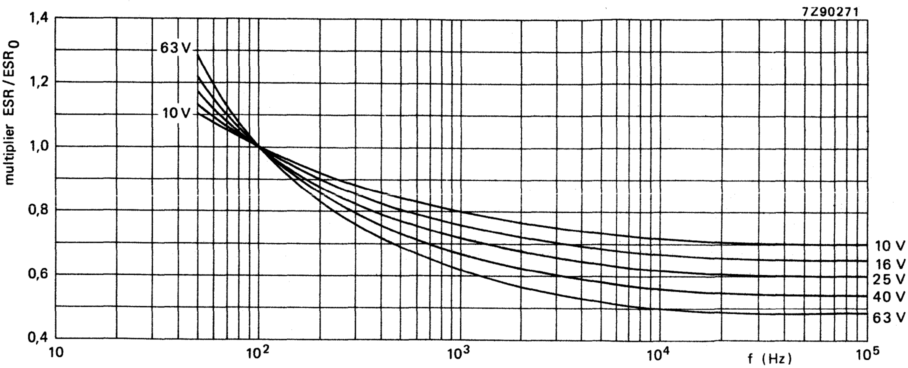


Fig. 12 Multiplier of ESR as a function of frequency; ESR_0 = typical ESR at 20 °C, 100 Hz.

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

Impedance

Maximum impedance at T_{amb} = 25 °C and 1 kHz or 10 kHz, measured by means of a four-terminal circuit (Thomson circuit) — see Table 2

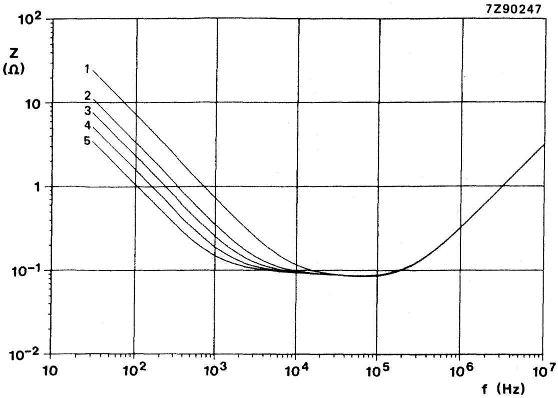


Fig. 13 Typical impedance as a function of frequency at T_{amb} = 20 °C, case size 00.

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

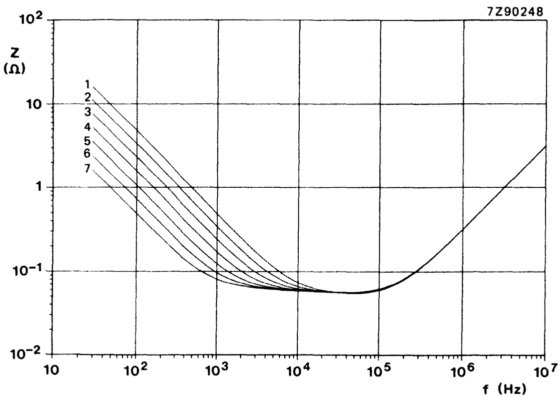


Fig. 14 Typical impedance as a function of frequency at T_{amb} = 20 °C, case size 01.

Curve 1 = 330 μF, 63 V;
curve 2 = 470 μF, 63 V;
curve 3 = 680 μF, 40 V;
curve 4 = 1000 μF, 25 V and 40 V;
curve 5 = 1500 μF, 16 V and 25 V;
curve 6 = 2200 μF, 10 V and 16 V;
curve 7 = 3300 μF, 10 V.

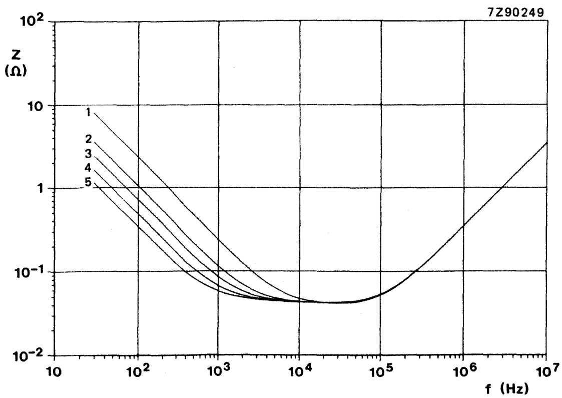


Fig. 15 Typical impedance as a function of frequency at T_{amb} = 20 °C, case size 02.

Curve 1 = 680 μF, 63 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.

Fig. 16 Typical impedance as a function of frequency at T_{amb} = 20 °C, case size 03.

Curve 1 = 1000 μF, 63 V;
curve 2 = 2200 μF, 40 V;
curve 3 = 3300 μF, 25 V;
curve 4 = 4700 μF, 16 V;
curve 5 = 6800 μF, 10 V.

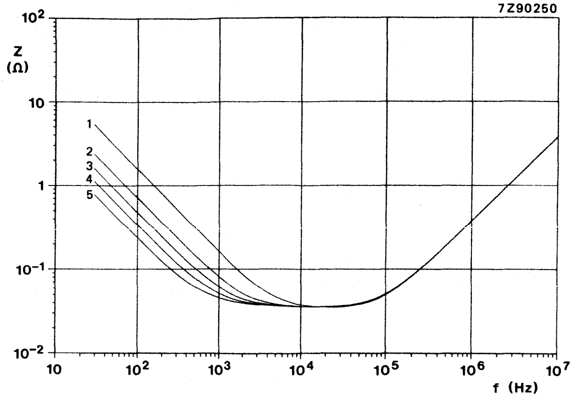


Fig. 17 Typical impedance as a function of frequency at T_{amb} = 20 °C, case size 04.

Curve 1 = 1500 μF, 63 V;
curve 2 = 3300 μF, 40 V;
curve 3 = 4700 μF, 25 V;
curve 4 = 6800 μF, 16 V;
curve 5 = 10 000 μF, 10 V.

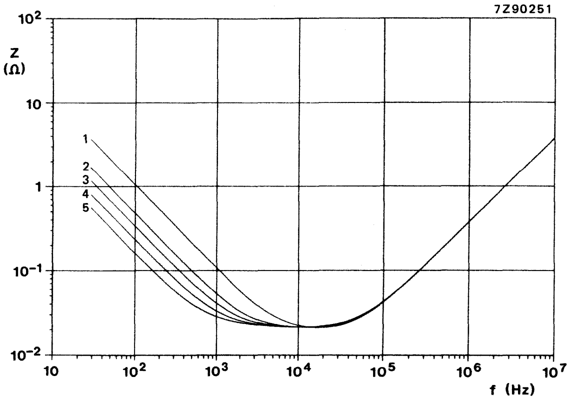
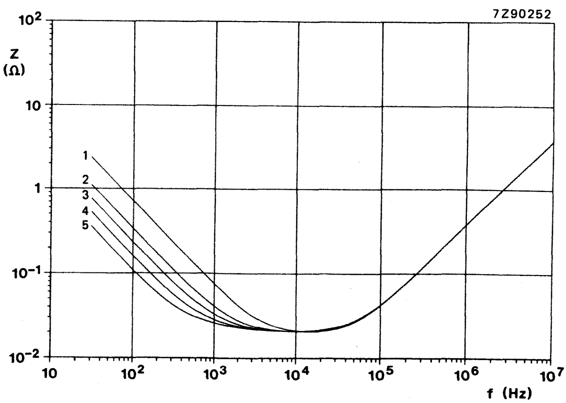


Fig. 18 Typical impedance as a function of frequency at T_{amb} = 20 °C, case size 05.

Curve 1 = 2200 μF, 63 V;
curve 2 = 4700 μF, 40 V;
curve 3 = 6800 μF, 25 V;
curve 4 = 10 000 μF, 16 V;
curve 5 = 15 000 μF, 10 V.



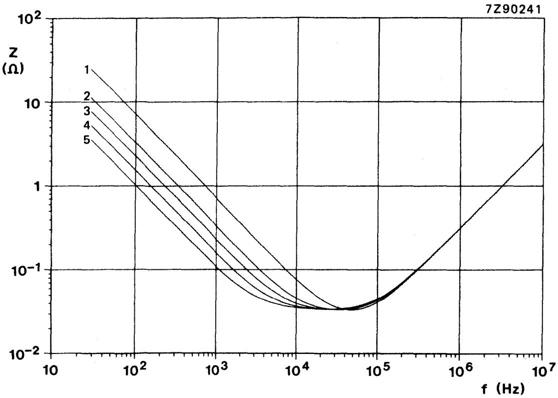


Fig. 19 Typical impedance as a function of frequency at T_{amb} = 85 °C, case size 00.
Curve 1 = 220 μF, 63 V;
curve 2 = 470 μF, 40 V;
curve 3 = 680 μF, 25 V;
curve 4 = 1000 μF, 16 V;
curve 5 = 1500 μF, 10 V.

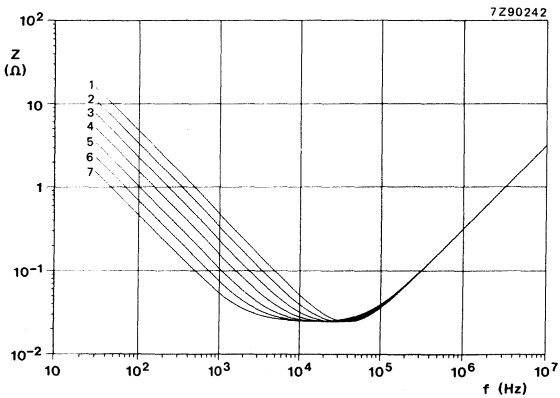


Fig. 20 Typical impedance as a function of frequency at T_{amb} = 85 °C, case size 01.
Curve 1 = 330 μF, 63 V;
curve 2 = 470 μF, 63 V;
curve 3 = 680 μF, 40 V;
curve 4 = 1000 μF, 25 V and 40 V;
curve 5 = 1500 μF, 16 V and 25 V;
curve 6 = 2200 μF, 10 V and 16 V;
curve 7 = 3300 μF, 10 V.

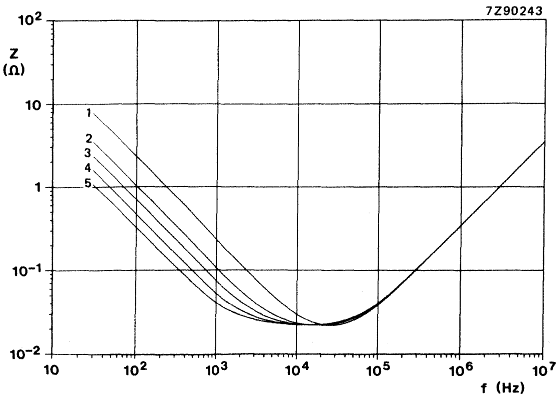


Fig. 21 Typical impedance as a function of frequency at T_{amb} = 85 °C, case size 02.
Curve 1 = 680 μF, 63 V;
curve 2 = 1500 μF, 40 V;
curve 3 = 2200 μF, 25 V;
curve 4 = 3300 μF, 16 V;
curve 5 = 4700 μF, 10 V.

Fig. 22 Typical impedance as a function of frequency at T_{amb} = 85 °C, case size 03.

Curve 1 = 1000 μF, 63 V;
curve 2 = 2200 μF, 40 V;
curve 3 = 3300 μF, 25 V;
curve 4 = 4700 μF, 16 V;
curve 5 = 6800 μF, 10 V.

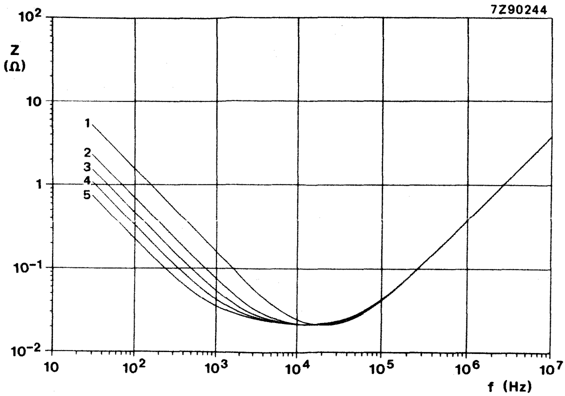


Fig. 23 Typical impedance as a function of frequency at T_{amb} = 85 °C, case size 04.

Curve 1 = 1500 μF, 63 V;
curve 2 = 3300 μF, 40 V;
curve 3 = 4700 μF, 25 V;
curve 4 = 6800 μF, 16 V;
curve 5 = 10 000 μF, 10 V.

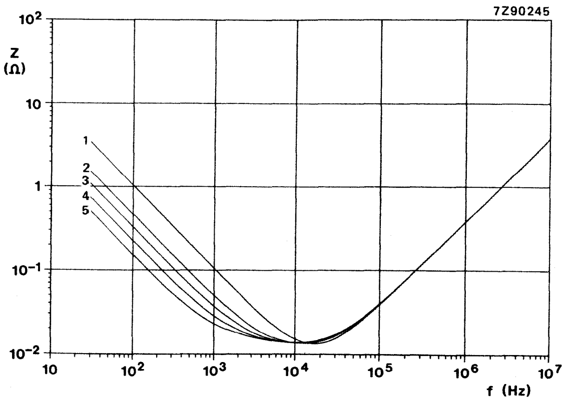
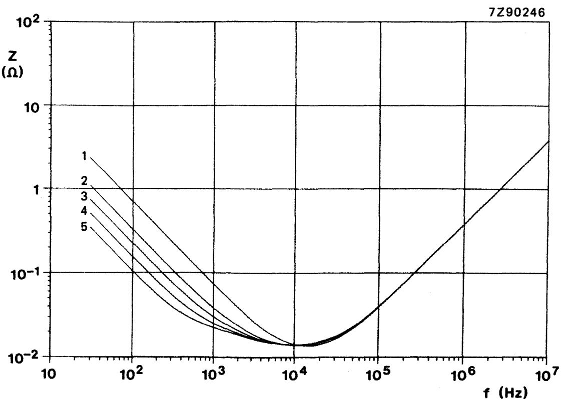


Fig. 24 Typical impedance as a function of frequency at T_{amb} = 85 °C, case size 05.

Curve 1 = 2200 μF, 63 V;
curve 2 = 4700 μF, 40 V;
curve 3 = 6800 μF, 25 V;
curve 4 = 10 000 μF, 16 V;
curve 5 = 15 000 μF, 10 V.



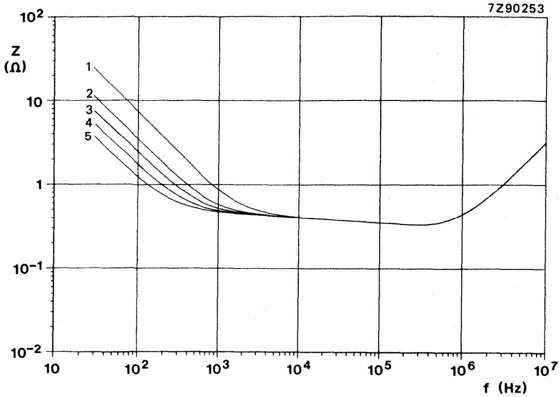


Fig. 25 Typical impedance as a function of frequency at T_{amb} = −25 °C, case size 00.
Curve 1 = 220 μF, 63 V;
curve 2 = 470 μF, 40 V;
curve 3 = 680 μF, 25 V;
curve 4 = 1000 μF, 16 V;
curve 5 = 1500 μF, 10 V.

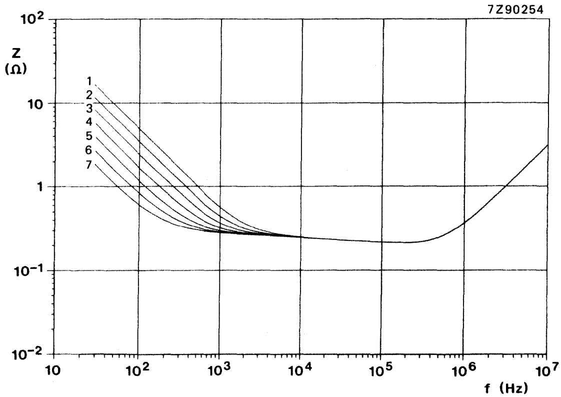


Fig. 26 Typical impedance as a function of frequency at T_{amb} = −25 °C, case size 01.
Curve 1 = 330 μF, 63 V;
curve 2 = 470 μF, 63 V;
curve 3 = 680 μF, 40 V;
curve 4 = 1000 μF, 25 V and 40 V;
curve 5 = 1500 μF, 16 V and 25 V;
curve 6 = 2200 μF, 10 V and 16 V;
curve 7 = 3300 μF, 10 V.

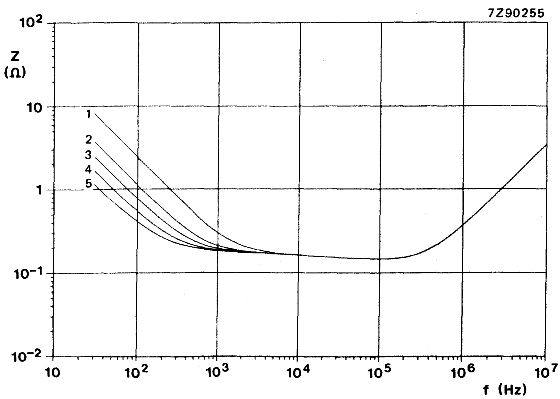


Fig. 27 Typical impedance as a function of frequency at T_{amb} = −25 °C, case size 02.
Curve 1 = 680 μF, 63 V;
curve 2 = 1500 μF, 40 V;
curve 3 = 2200 μF, 25 V;
curve 4 = 3300 μF, 16 V;
curve 5 = 4700 μF, 10 V.

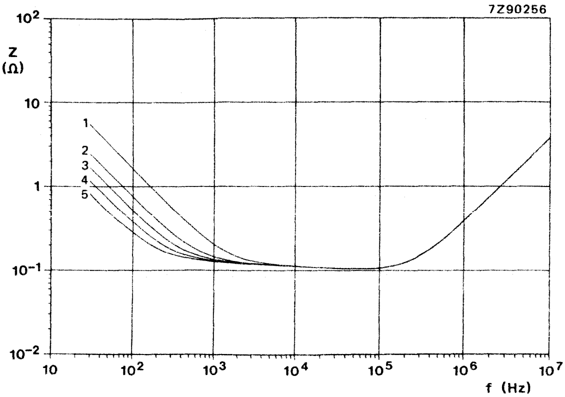


Fig. 28 Typical impedance as a function of frequency at T_{amb} = −25 °C, case size 03.

Curve 1 = 1000 μF, 63 V;
curve 2 = 2200 μF, 40 V;
curve 3 = 3300 μF, 25 V;
curve 4 = 4700 μF, 16 V;
curve 5 = 6800 μF, 10 V.

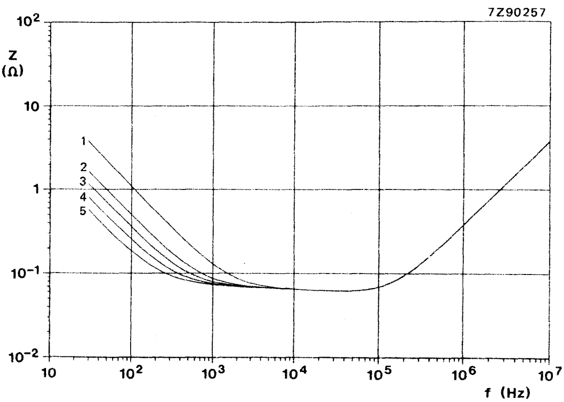


Fig. 29 Typical impedance as a function of frequency at T_{amb} = −25 °C, case size 04.

Curve 1 = 1500 μF, 63 V;
curve 2 = 3300 μF, 40 V;
curve 3 = 4700 μF, 25 V;
curve 4 = 6800 μF, 16 V;
curve 5 = 10 000 μF, 10 V.

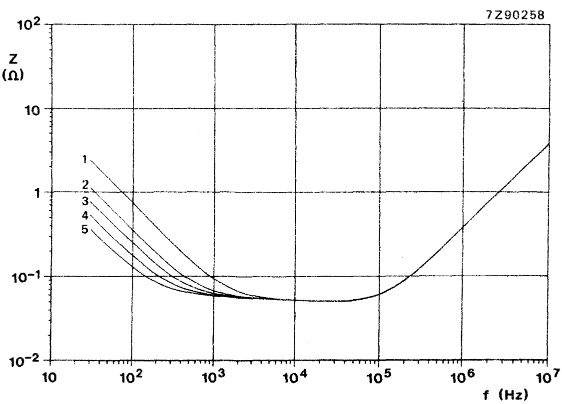


Fig. 30 Typical impedance as a function of frequency at T_{amb} = −25 °C, case size 05.

Curve 1 = 2200 μF, 63 V;
curve 2 = 4700 μF, 40 V;
curve 3 = 6800 μF, 25 V;
curve 4 = 10 000 μF, 16 V;
curve 5 = 15 000 μF, 10 V.

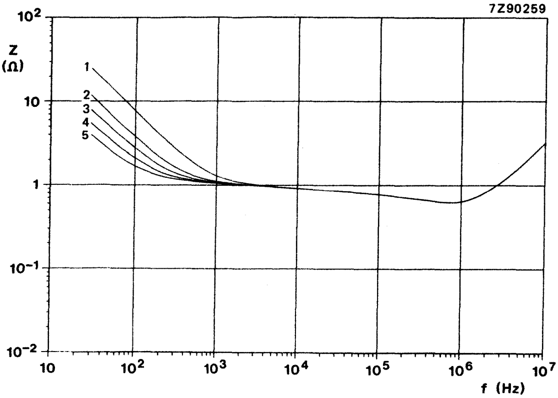


Fig. 31 Typical impedance as a function of frequency at T_{amb} = −40 °C, case size 00.
Curve 1 = 220 μF, 63 V;
curve 2 = 470 μF, 40 V;
curve 3 = 680 μF, 25 V;
curve 4 = 1000 μF, 16 V;
curve 5 = 1500 μF, 10 V.

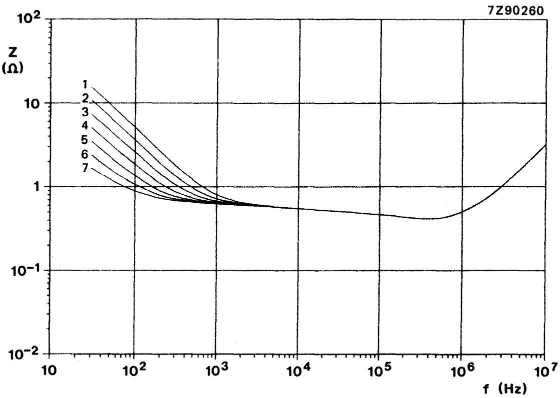


Fig. 32 Typical impedance as a function of frequency at T_{amb} = −40 °C, case size 01.
Curve 1 = 330 μF, 63 V;
curve 2 = 470 μF, 63 V;
curve 3 = 680 μF, 40 V;
curve 4 = 1000 μF, 25 V and 40 V;
curve 5 = 1500 μF, 16 V and 25 V;
curve 6 = 2200 μF, 10 V and 16 V;
curve 7 = 3300 μF, 10 V.

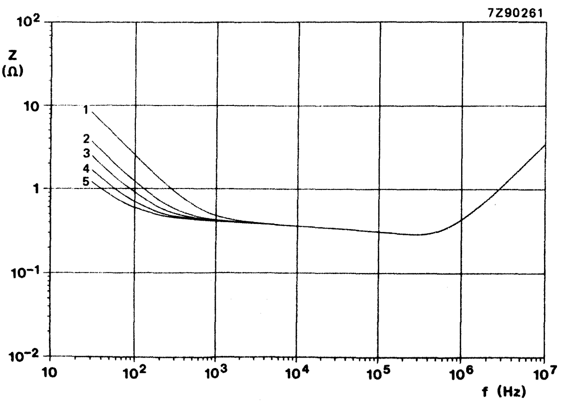


Fig. 33 Typical impedance as a function of frequency at T_{amb} = −40 °C, case size 02.
Curve 1 = 680 μF, 63 V;
curve 2 = 1500 μF, 40 V;
curve 3 = 2200 μF, 25 V;
curve 4 = 3300 μF, 16 V;
curve 5 = 4700 μF, 10 V.

Fig. 34 Typical impedance as a function of frequency at T_{amb} = −40 °C, case size 03.
Curve 1 = 1000 μF, 63 V;
curve 2 = 2200 μF, 40 V;
curve 3 = 3300 μF, 25 V;
curve 4 = 4700 μF, 16 V;
curve 5 = 6800 μF, 10 V.

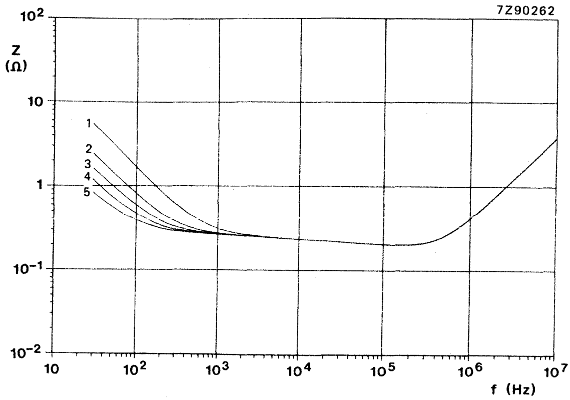


Fig. 35 Typical impedance as a function of frequency at T_{amb} = −40 °C, case size 04.
Curve 1 = 1500 μF, 63 V;
curve 2 = 3300 μF, 40 V;
curve 3 = 4700 μF, 25 V;
curve 4 = 6800 μF, 16 V;
curve 5 = 10 000 μF, 10 V.

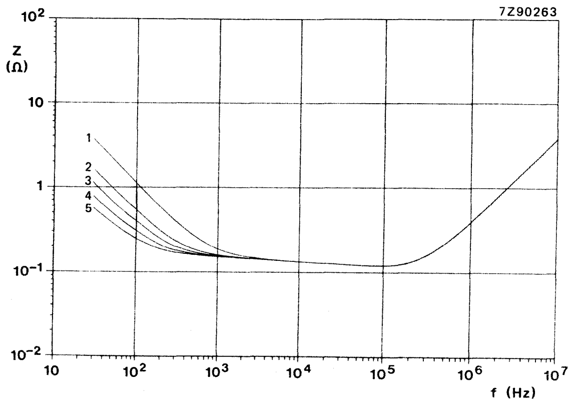
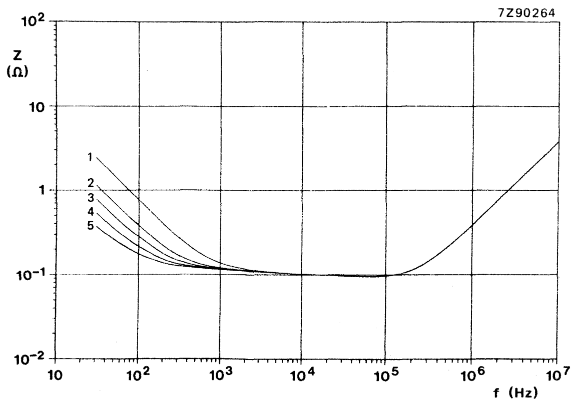


Fig. 36 Typical impedance as a function of frequency at T_{amb} = −40 °C, case size 05.
Curve 1 = 2200 μF, 63 V;
curve 2 = 4700 μF, 40 V;
curve 3 = 6800 μF, 25 V;
curve 4 = 10 000 μF, 16 V;
curve 5 = 15 000 μF, 10 V.



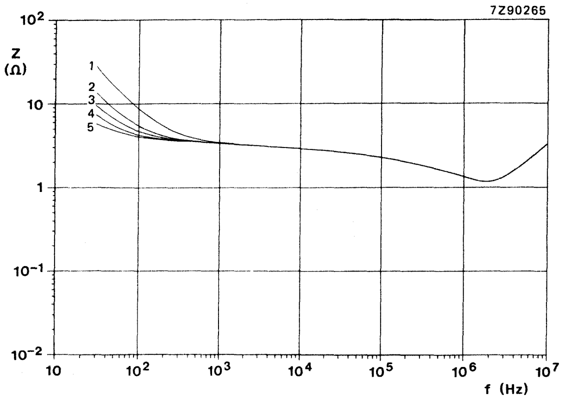


Fig. 37 Typical impedance as a function of frequency at T_{amb} = −55 °C, case size 00.

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

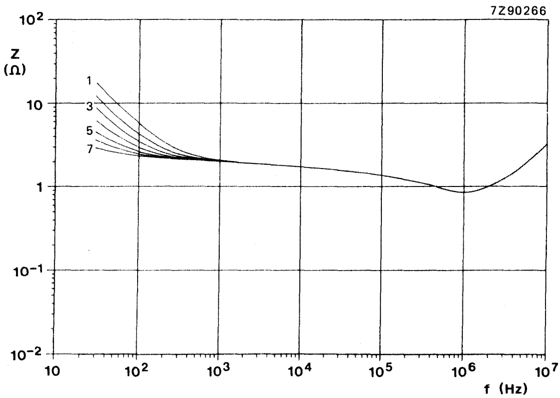


Fig. 38 Typical impedance as a function of frequency at T_{amb} = −55 °C, case size 01.

Curve 1 = 330 μF, 63 V;
curve 2 = 470 μF, 63 V;
curve 3 = 680 μF, 40 V;
curve 4 = 1000 μF, 25 V and 40 V;
curve 5 = 1500 μF, 16 V and 25 V;
curve 6 = 2200 μF, 10 V and 16 V;
curve 7 = 3300 μF, 10 V.

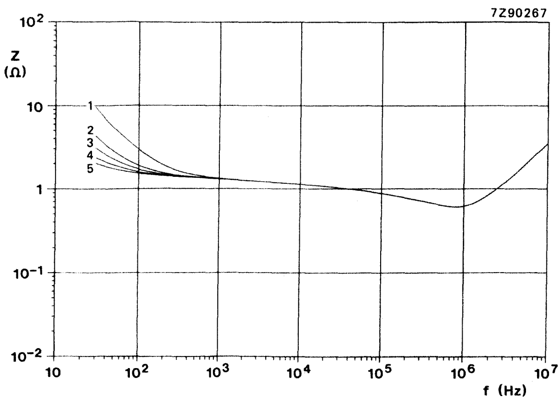


Fig. 39 Typical impedance as a a function of frequency at T_{amb} = −55 °C, case size 02.

Curve 1 = 680 μF, 63 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.

Fig. 40 Typical impedance as a function of frequency at T_{amb} = −55 °C, case size 03.
Curve 1 = 1000 μF, 63 V;
curve 2 = 2200 μF, 40 V;
curve 3 = 3300 μF, 25 V;
curve 4 = 4700 μF, 16 V;
curve 5 = 6800 μF, 10 V.

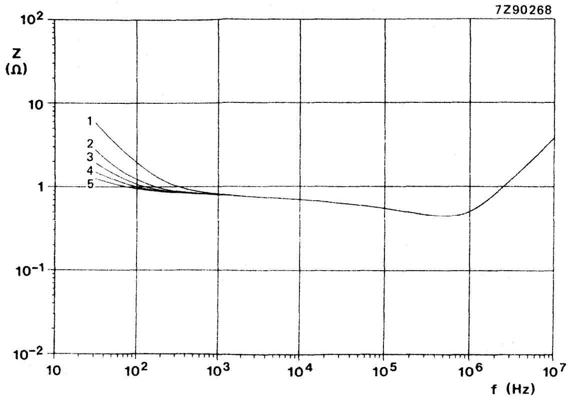


Fig. 41 Typical impedance as a function of frequency at T_{amb} = −55 °C, case size 04.
Curve 1 = 1500 μF, 63 V;
curve 2 = 3300 μF, 40 V;
curve 3 = 4700 μF, 25 V;
curve 4 = 6800 μF, 16 V;
curve 5 = 10 000 μF, 10 V.

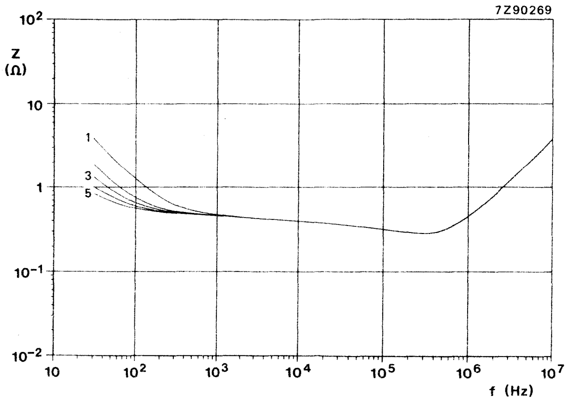
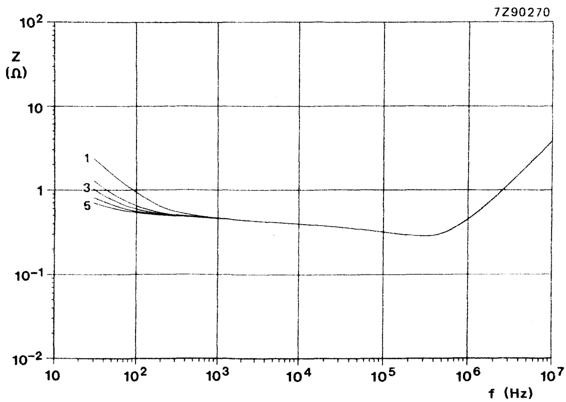


Fig. 42 Typical impedance as a function of frequency at T_{amb} = −55 °C, case size 05.
Curve 1 = 2200 μF, 63 V;
curve 2 = 4700 μF, 40 V;
curve 3 = 6800 μF, 25 V;
curve 4 = 10 000 μF, 16 V;
curve 5 = 15 000 μF, 10 V.



Equivalent series inductance (ESL)

Case sizes 00 and 01	typ. 50 nH
Case size 02	typ. 55 nH
Case sizes 03, 04 and 05	typ. 60 nH

OPERATIONAL DATA

Category temperature range for rated voltage	−55 to + 85 °C
Typical life time	
at T_{amb} = 85 °C	5000 h
→ at T_{amb} = 40 °C	< 100 000 h
Shelf life at 0 V and T_{amb} = 85 °C	500 h

PACKING

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

TESTS AND REQUIREMENTS

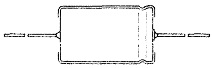
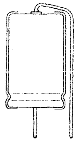
See introduction, section 9, under aluminium electrolytic capacitors.

→ After *shelf life test, 500h, 85 °C,* the capacitors meet the same requirements as after endurance test. The rated voltage shall be applied to the capacitors for minimum 30 min., at least 24 h and not more than 48 h before measurements.

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

For small types of the 2222 021 series see page 77.

ALUMINIUM ELECTROLYTIC CAPACITORS

- Miniature type
- Axial leads and single ended
- Very high CU-product per unit volume
- General applications

QUICK REFERENCE DATA

Nominal capacitance range (E6 series):	0,22 to 1500 μF
Tolerance on nominal capacitance	± 20%
Rated voltage range, U_R (R5 series):	10 to 100 V
Category temperature range:	−55 to + 85 °C
Endurance test at 85 °C:	1000 h *
Shelf life at 0 V, 85 °C:	500 h
Basic specifications:	
IEC 384-4, G.P. grade	
DIN 41332, type II	
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	100
0,22					2	
0,33					2	
0,47					2	
0,68					2	
1					2	2
1,5					2	
2,2					2	2
3,3					2	
4,7					2	2
6,8					2	2
10					2	3
15					2	4/5a
22				2	3	4/5a
33					3	4
47			2	3	4/5a	5
68		2			4/5a	6
100	2		3	4/5a	5	7
150		3	4/5a	5	6	
220	3	5a	4	6	7	
330	5a	4	5	7		
470	4	5	6			
680	5	6	7			
1000	6	7				
1500	7					

case size	nominal dimensions (mm)
2	Ø 4,5 x 10
3	Ø 6 x 10
5a	Ø 8 x 11
4	Ø 6,5 x 18
5	Ø 8 x 18
6	Ø 10 x 18
7	Ø 10 x 25

* 2000 h under consideration.

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. The bandoliered version is extremely suitable for automatic insertion and for cutting and forming equipment.

DESCRIPTION

The capacitors have etched and oxidized 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 2 styles, both with soldered-copper leads.

Style 1: axial leads; supplied on bandoliers.
Style 3: single ended.

MECHANICAL DATA

Dimensions in mm

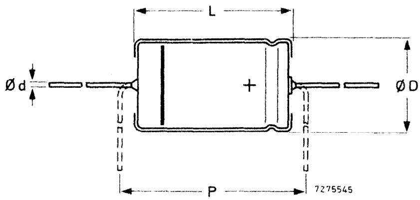


Fig. 1 Style 1; see Table 1a for dimensions d, D, L and P.

Table 1a

case size	style 1						mass approx. g
	d	D_{nom}	L_{nom}	D_{max}	L_{max}	P_{min}	
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

Table 1b

case size	style 3				mass approx. g
	d	D_{max}	L_{max}	P	
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

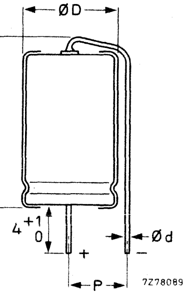


Fig. 2 Style 3; see Table 1b for dimensions d, D, L and P.

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 IEC 62;
- band to identify the negative terminal;
- + signs to identify the positive terminal (not for case sizes 2, 3 and 5a).

Mounting

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

Table 1c

lead diameter	required hole diameter
0,6 mm	0,8 + 0,1 mm
0,8 mm	1,0 + 0,1 mm

Minimum atmospheric pressure 8,5 kPa

WARNING

Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled; caution is necessary should the outer case be fractured.

DEVELOPMENT SAMPLE DATA

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 1 min. µA	max. tan δ	max. ESR Ω	max. impedance at 10 kHz Ω	case size	catalogue number* 2222 021 followed by
10	100	65	10	0,20	3,2	2,0	2	. 4101
	220	110	17	0,20	1,5	0,91	3	. 4221
	330	165	24	0,20	1,0	0,61	5a	. 4331
	470	210	32	0,20	0,68	0,43	4	. 4471
	680	285	45	0,20	0,47	0,29	5	. 4681
	1000	400	64	0,20	0,32	0,20	6	. 4102
	1500	530	94	0,23	0,25	0,18	7	**
16	68	60	11	0,16	3,8	2,4	2	. 5689
	150	100	18	0,16	1,7	1,1	3	. 5151
	220	150	25	0,16	1,2	0,73	5a	. 5221
	330	200	36	0,16	0,77	0,48	4	. 5331
	470	265	49	0,16	0,55	0,34	5	. 5471
	680	365	69	0,16	0,38	0,24	6	. 5681
	1000	510	100	0,16	0,26	0,16	7	**
25	47	50	11	0,14	4,8	2,6	2	. 6479
	100	90	19	0,14	2,3	1,2	3	. 6101
	150	135	27	0,14	1,5	0,80	5a	**
	150	145	27	0,14	1,5	0,80	4	. 6151
	220	170	37	0,14	1,0	0,55	4	. 6221
	330	240	54	0,14	0,68	0,36	5	. 6331
	470	325	75	0,14	0,48	0,26	6	. 6471
	680	450	106	0,14	0,33	0,18	7	**
40	22	40	9	0,11	8,0	3,2	2	. 7229
	47	70	15	0,11	3,8	1,5	3	. 7479
	100	120	28	0,11	1,8	0,70	5a	**
	100	130	28	0,11	1,8	0,70	4	. 7101
	150	180	40	0,11	1,1	0,47	5	. 7151
	220	250	57	0,11	0,8	0,32	6	. 7221
	330	350	83	0,11	0,53	0,21	7	. 7331

* Replace dot in catalogue number by:
2 for style 1 on bandoliers on reel (preferred for case sizes 2, 3 and 4);
3 for style 1 on bandoliers in box (preferred for case sizes 5a, 5, 6 and 7);
8 for style 3.

** See Table 3.

U_R V	nom. cap. μF	max. r.m.s. ripple current at at T_{amb} = 85 °C mA	max. leakage current at U_R after 1 min. μA	max. tan δ	max. ESR Ω	max. impedance at 10 kHz Ω	case size	catalogue number* 2222 021 followed by
63	0,22	5	4,1	0,09	650	250	2	.8227
	0,33	5	4,1	0,09	440	170	2	.8337
	0,47	8	4,2	0,09	310	120	2	.8477
	0,68	10	4,3	0,09	210	81	2	.8687
	1	12	4,4	0,09	150	55	2	.8108
	1,5	12	4,6	0,09	100	37	2	.8158
	2,2	21	4,8	0,09	65	25	2	.8228
	3,3	25	5,2	0,09	44	17	2	.8338
	4,7	31	5,8	0,09	31	12	2	.8478
	6,8	31	6,6	0,09	21	8,1	2	.8688
	10	35	7,8	0,08	13	5,5	2	.8109
	15	40	9,5	0,08	8,5	3,7	2	.8159
	22	55	12	0,08	5,8	2,5	3	.8229
	33	65	16	0,08	3,9	1,7	3	.8339
	47	100	22	0,08	2,7	1,2	5a	**
	47	105	22	0,08	2,7	1,2	4	.8479
	68	120	30	0,08	1,9	0,81	5a	**
	68	125	30	0,08	1,9	0,81	4	.8689
	100	175	42	0,08	1,3	0,55	5	.8101
	150	245	61	0,08	0,85	0,37	6	.8151
	220	350	88	0,08	0,60	0,25	7	**
100	1	14	4,6	0,08	130	90	2	.9108
	2,2	20	5,3	0,08	58	41	2	.9228
	4,7	21	7	0,08	27	19	2	.9478
	6,8	25	8	0,08	19	13	2	.9688
	10	45	10	0,08	13	9	3	.9109
	15	55	13	0,08	8,5	6	5a	**
	15	60	13	0,08	8,5	6	4	.9159
	22	67	17	0,08	5,8	4,1	5a	**
	22	72	17	0,08	5,8	4,1	4	.9229
	33	90	24	0,08	3,9	2,7	4	.9339
	47	120	32	0,08	2,7	1,9	5	.9479
	68	165	45	0,08	1,9	1,3	6	.9689
	100	230	64	0,08	1,3	0,9	7	**

DEVELOPMENT SAMPLE DATA

* Replace dot in catalogue number by:
2 for style 1 on bandoliers on reel (preferred for case sizes 2, 3 and 4);
3 for style 1 on bandoliers in box (preferred for case sizes 5a, 5, 6 and 7);
8 for style 3.

** See Table 3.

Table 3

U_R V	nom. cap. µF	case size	catalogue number style 1 on reel	style 1 in box	style 3
10	1500	7	2222 021 90524	2222 021 90525	2222 021 90526
16	1000	7	90517	90518	90519
25	150	5a	90534	90535	90536
	680	7	90527	90528	90529
40	100	5a	90537	90538	90539
63	47	5a	90541	90542	90543
	68	5a	90544	90545	90546
	220	7	90511	90512	90513
100	15	5a	90547	90548	90549
	22	5a	90551	90552	90553
	100	7	90531	90532	90533

Capacitance

Nominal capacitance at 100 Hz and T_{amb} = 20 °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 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

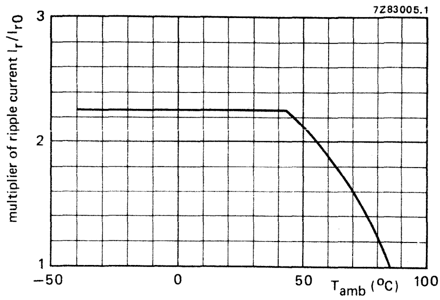


Fig. 3 Multiplier of ripple current as a function of ambient temperature;
I_{r0} = ripple current at 85 °C, 100 Hz.

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.

Leakage current

Maximum leakage current 1 min after application
of U_R, at T_{amb} = 20 °C — see Table 2 (0,006 CU + 4 μA)

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.

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

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

Equivalent series inductance (ESL)

Case size 2	typ. 17 nH
Case sizes 3 and 4	typ. 30 nH
Case size 5a	typ. 85 nH
Case size 5	typ. 50 nH
Case sizes 6 and 7	typ. 65 nH

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

Impedance (Z)

Maximum impedance at T_{amb} = 20 °C and 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 4

Table 4

T_{amb}	$z = Z \times C_{nom}$ (Ω µF) at U_R; at 10 kHz					
	10 V	16 V	25 V	40 V	63 V	100 V
+20 °C	⩽ 200	⩽ 160	⩽ 120	⩽ 70	⩽ 55	⩽ 90
−25 °C	⩽ 1200	⩽ 750	⩽ 560	⩽ 300	⩽ 180	⩽ 600
−40 °C	⩽ 3200	⩽ 2000	⩽ 1500	⩽ 900	⩽ 500	⩽ 1600
−55 °C	typ. 9000	typ. 6500	typ. 5000	typ. 3000	typ. 1500	typ. 5000

OPERATIONAL DATA

Category temperature range	−55 to + 85 °C
Typical life time	
at T_{amb} = 40 °C	50 000 h
at T_{amb} = 85 °C	2000 h
Shelf life at 0 V and T_{amb} = 85 °C	500 h

PACKING

Capacitors of style 3 are supplied in boxes; capacitors of style 1 are supplied on bandoliers in boxes or on reels. The number of capacitors per box or per reel is shown in Table 5.

DEVELOPMENT SAMPLE DATA

Table 5

case size	number of capacitors		
	style 1 per reel	style 1 per box	style 3 per box
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

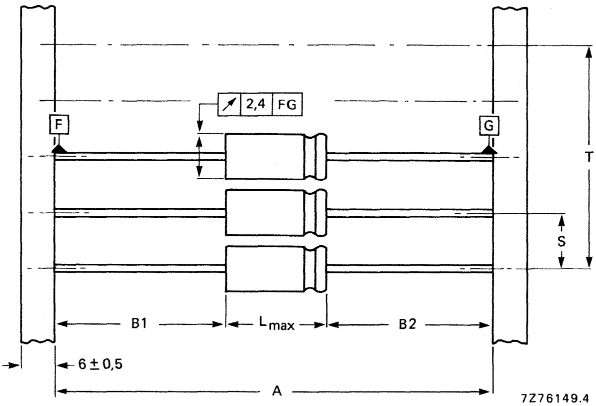


Fig. 4 Style 1 capacitors on bandoliers; the bandolier to which the negative capacitor terminals are connected is blue. See Table 6 for dimensions A, S, T and L.
$|B1-B2|$ = max. 1,4 mm.

Table 6

Dimensions in mm

case size	A	S	T for number (n) of capacitors		L_{max}
			n < 50	50 < n < 100	
2	63,5 ± 1,5	5 ± 0,4	5 (n-1) ± 2	5 (n-1) ± 4	10,5
3	63,5 ± 1,5	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	10,5
5a	63,5 ± 1,5	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

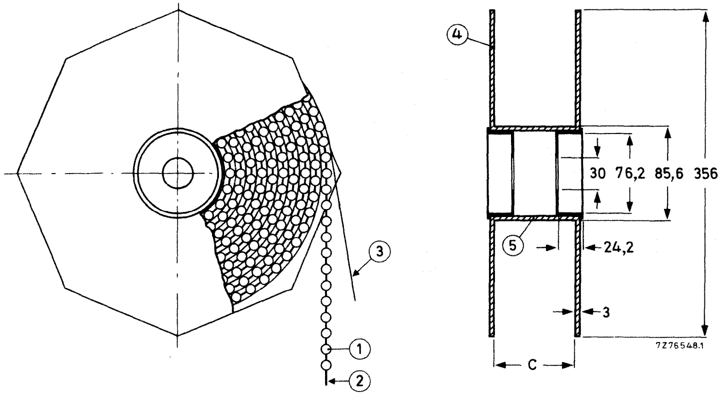


Fig. 5 Style 1 capacitors on bandoliers on reel; dimension C is 83,5 mm for case sizes 2,3 and 5a and 88,5 mm for case sizes 4, 5, 6 and 7; the overall width of the reel is 94,5 mm and 99,5 mm respectively.

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.

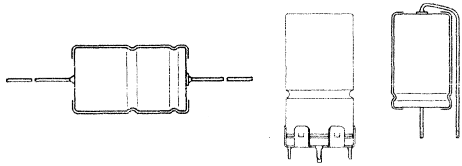
After *shelf life test, 500 h, 85 °C,* the capacitors meet the same requirements as after endurance test, except for leakage current: ⩽ 200% of specified value. The rated voltage shall be applied to the capacitors for minimum 30 min., at least 24 h and not more than 48 h before measurements.

Note:

Capacitors 2222 021 are miniature types, general-purpose 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 111 to 153								2222 041; 042; 043 see pages 197 to 215			

Miniature types

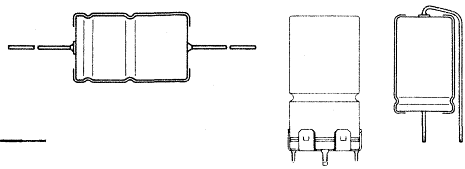
case size	nominal dimensions mm	series number
1	Ø 3,3 x 10	030
2	Ø 4,5 x 10	
3	Ø 6 x 10	
5a	Ø 8 x 11	
4	Ø 6,5 x 18	031 041
5	Ø 8 x 18	
6	Ø 10 x 18	
7	Ø 10 x 25	

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	033 043
05	Ø 21 x 40	

ALUMINIUM ELECTROLYTIC CAPACITORS

- **Miniature and small types**
- **Axial leads and 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:	
case sizes 1 to 7	−55 to +85 °C
case sizes 00 to 05	−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
Shelf life at 0 V; 85 °C:	500 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, case sizes 1 to 7:	55/085/56
case sizes 00 to 05:	40/085/56
DIN 40040, case sizes 1 to 7:	FPF
case sizes 00 to 05:	GPF

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

* Not applicable to case size 1, which is general-purpose grade.

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 and oxidized 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 3 styles, all with soldered-copper leads.

Style 1: axial leads; all case sizes; 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 02.

MECHANICAL DATA

Dimensions in mm

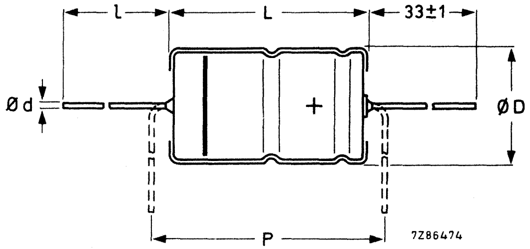


Fig. 1 Style 1; see Table 1a for dimensions d, D, L, l and P.

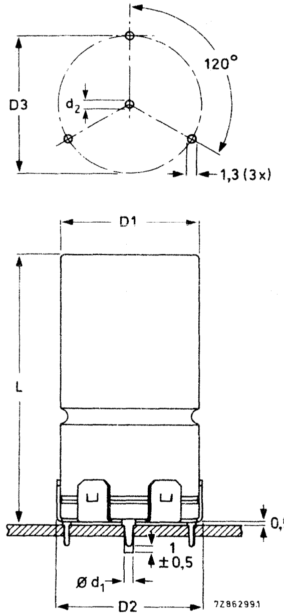
Table 1a

case size	d	l	style 1					mass approx. g
			D_{nom}	L_{nom}	D_{max}	L_{max}	P_{min}	
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.
	d_1	d_2	D1	$D2_{max}$	D3	L	g
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



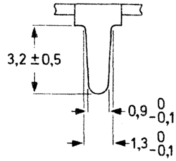


Fig. 2 Style 2; see Table 1b for dimensions d_1, d_2, D1, D2, D3 and L.

Table 1c

case size	d	style 3			mass approx.
		D_{max}	L_{max}	P	g
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

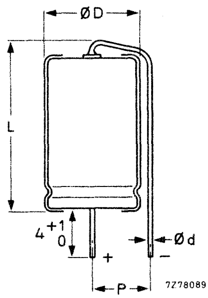


Fig. 3 Style 3 see Table 1c for dimensions d, D, L and P.

Marking

The capacitors are marked with:
- nominal capacitance;
- tolerance on nominal capacitance (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 1d.

→ Table 1d

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

Minimum atmospheric pressure 8,5 kPa

→ WARNING

Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled. Caution is necessary should the outer case be fractured.

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	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
V	μF	mA	μA		Ω	at 10 kHz	at 1 kHz		
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

* 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, case sizes 03 to 05;
8 for style 3, case sizes 1 to 02.

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
V	μF	mA	μA		Ω	at 10 kHz	at 1 kHz		
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

* 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, case sizes 03 to 05;
→ 8 for style 3, case sizes 1 to 02.

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

* See footnote on the opposite page.

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
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, case sizes 03 to 05;
→ 8 for style 3, case sizes 1 to 02.

Capacitance

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

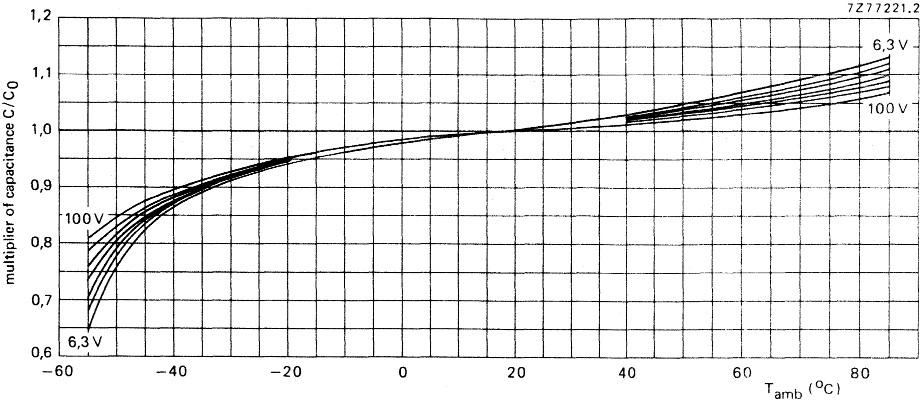


Fig. 4 Multiplier of capacitance as a function of ambient temperature; **case sizes 1 to 7**; C_0 = capacitance at 20 °C, 100 Hz.

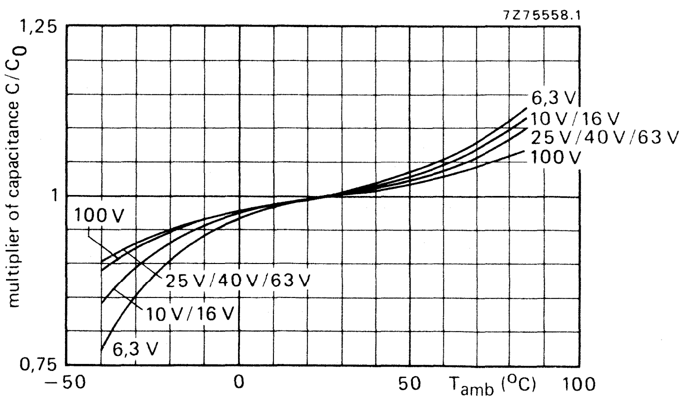


Fig. 5 Multiplier of capacitance as a function of ambient temperature; **case sizes 00 to 05**; C_0 = capacitance at 25 °C, 100 Hz.

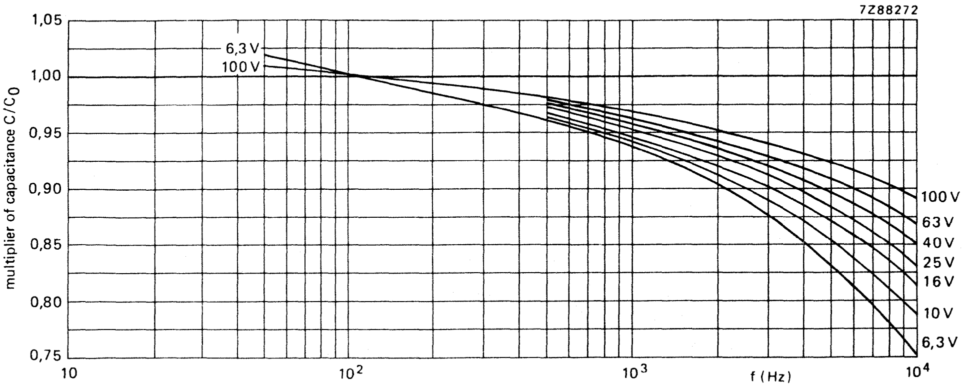


Fig. 6 Multiplier of capacitance as a function of frequency; **case sizes 1 to 7;** C_0 = capacitance at 20 °C, 100 Hz.

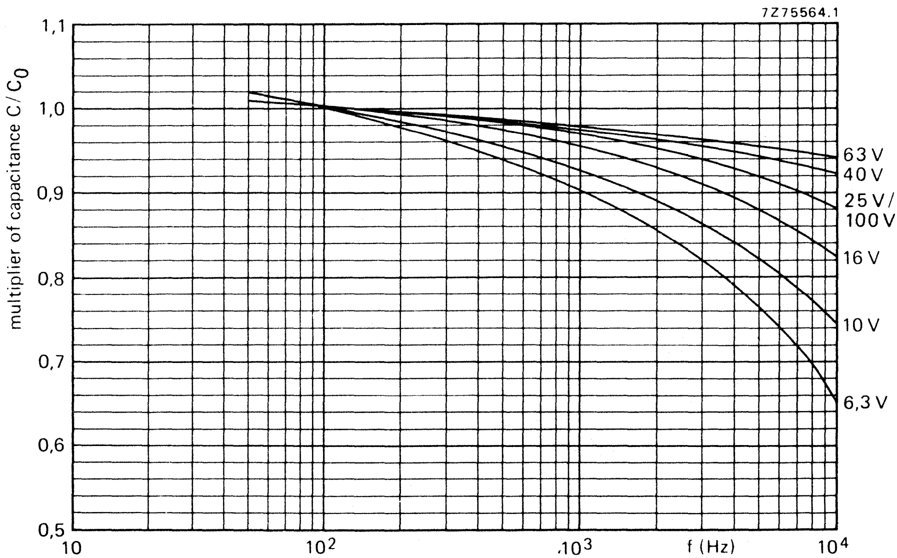


Fig. 7 Multiplier of capacitance as a function of frequency; **case sizes 00 to 05;** C_0 = capacitance at 25 °C, 100 Hz.

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 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	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

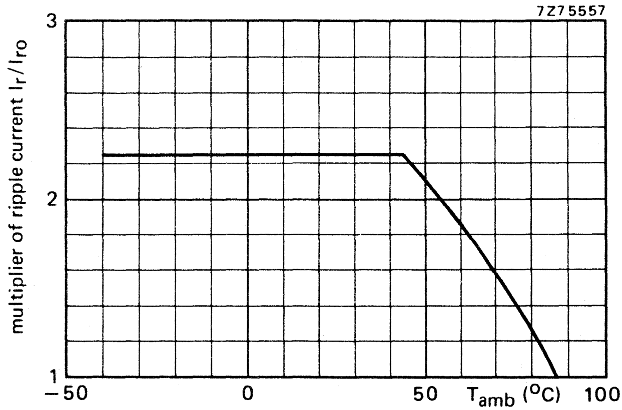


Fig. 8 Multiplier of ripple current as a function of ambient temperature; I_{r0} = ripple current at 85 °C, 100 Hz.

* 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.

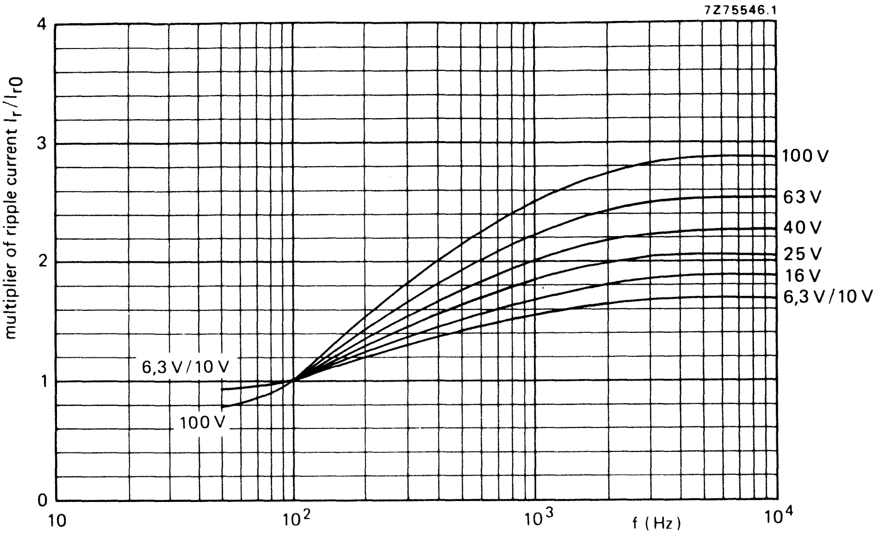


Fig. 9 Multiplier of ripple current as a function of frequency, **case sizes 1 to 7;** I_{r0} = ripple current at 85 °C, 100 Hz.

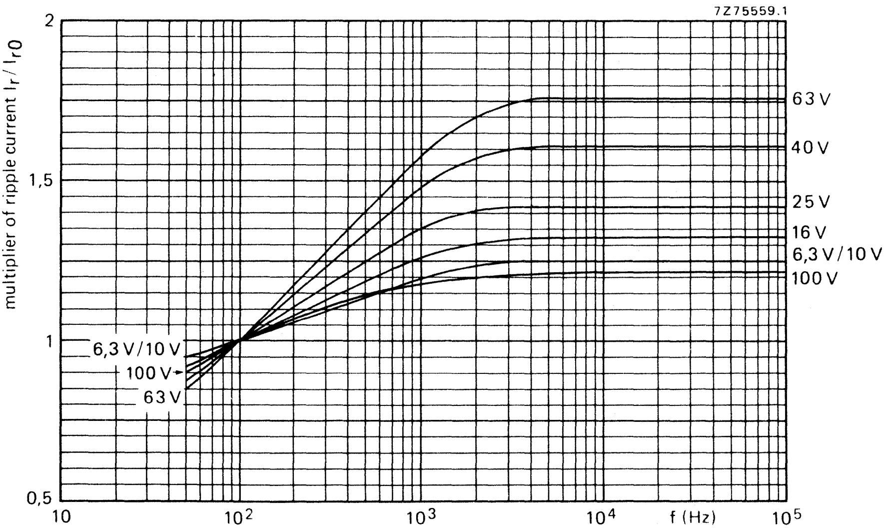


Fig. 10 Multiplier of ripple current as a function of frequency, **case sizes 00 to 03;** I_{r0} = ripple current at 85 °C, 100 Hz.

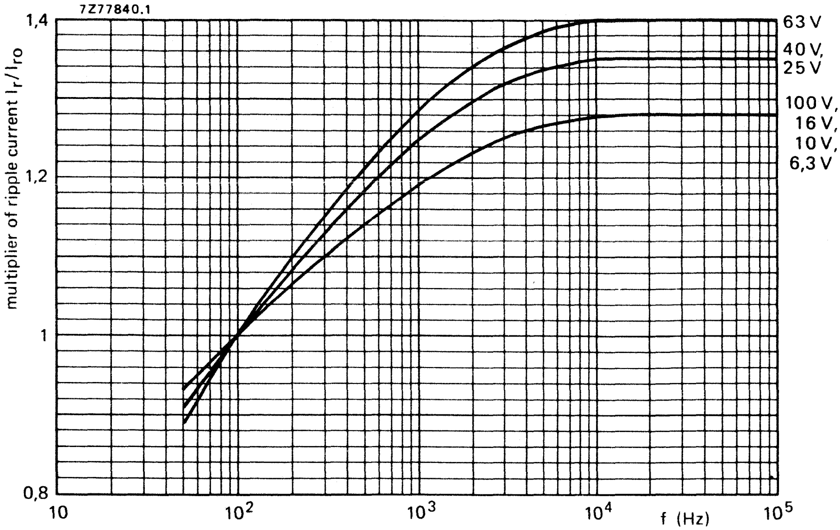


Fig. 11 Multiplier of ripple current as a function of frequency, **case sizes 04 and 05;** I_{r0} = ripple current at 85 °C, 100 Hz.

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

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

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

I_n = ripple current at a certain frequency;

$\sqrt{r_n} = I_r/I_{r0}$ = 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 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.

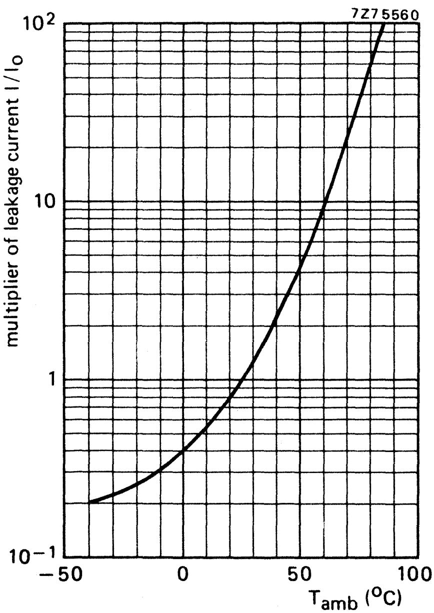


Fig. 12 Multiplier of leakage current as a function of ambient temperature, **case sizes 00 to 05;** I_o = leakage current during continuous operation at 25 °C and U_R.

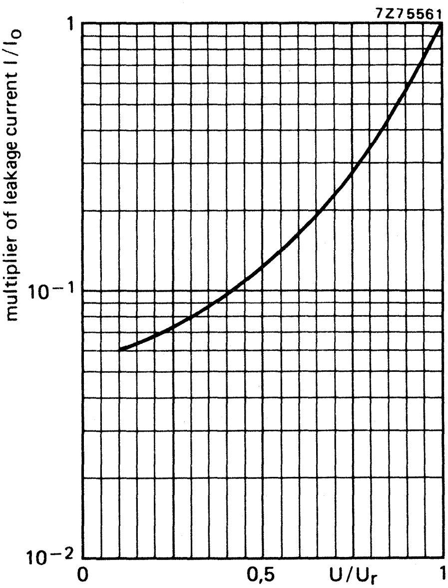


Fig. 13 Multiplier of leakage current as a function of U/U_R, **case sizes 00 to 05;** I_o = leakage current during continuous operation at 25 °C and U_R.

Tan δ (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

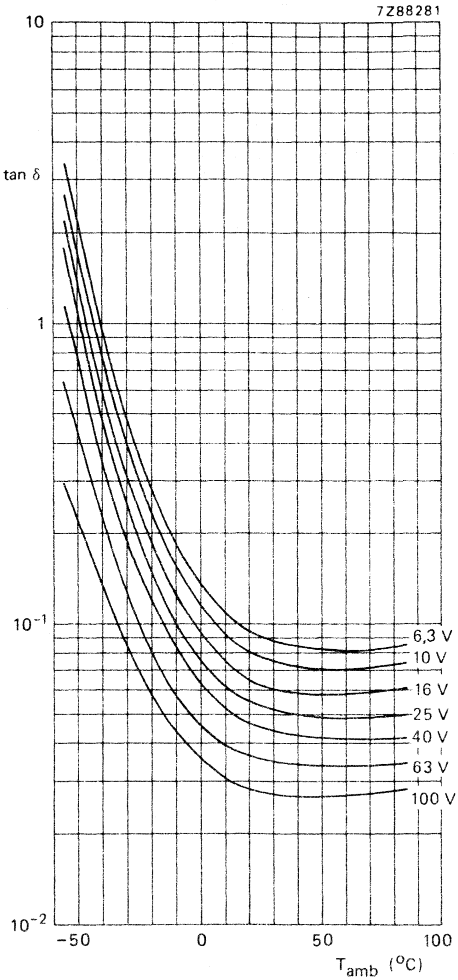


Fig. 14 Typical tan δ as a function of ambient temperature at 100 Hz; **case sizes 1 to 7.**

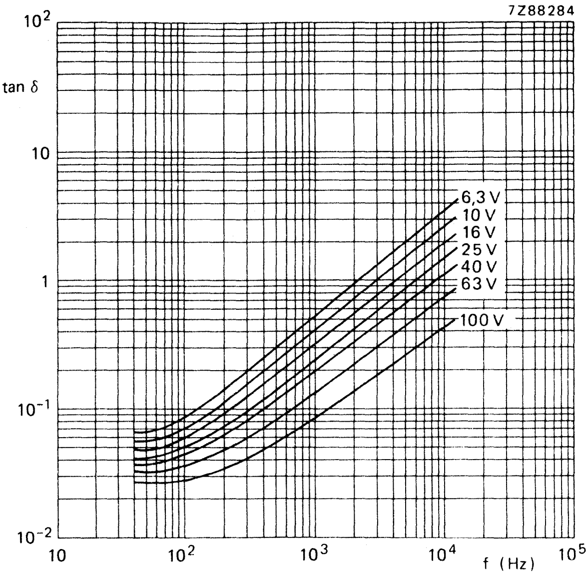


Fig. 15 Typical tan δ as a function of frequency at 25 °C, **case sizes 1 to 7.**

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

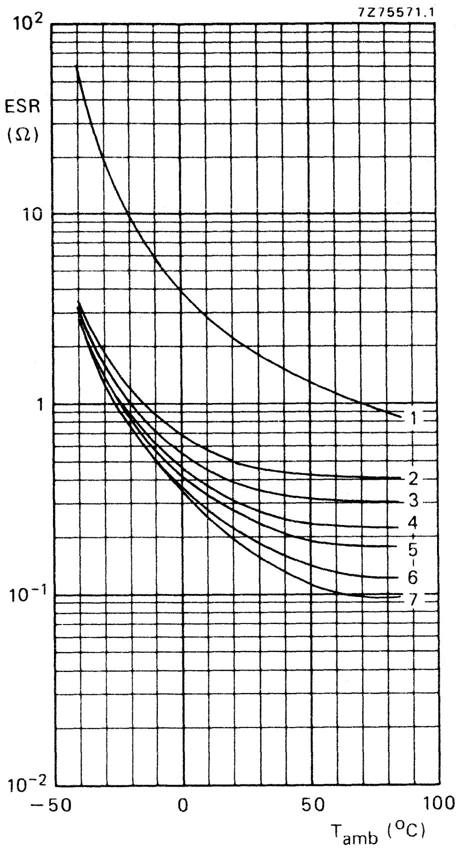


Fig. 16 Typical ESR as a function of ambient temperature at 100 Hz.

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.

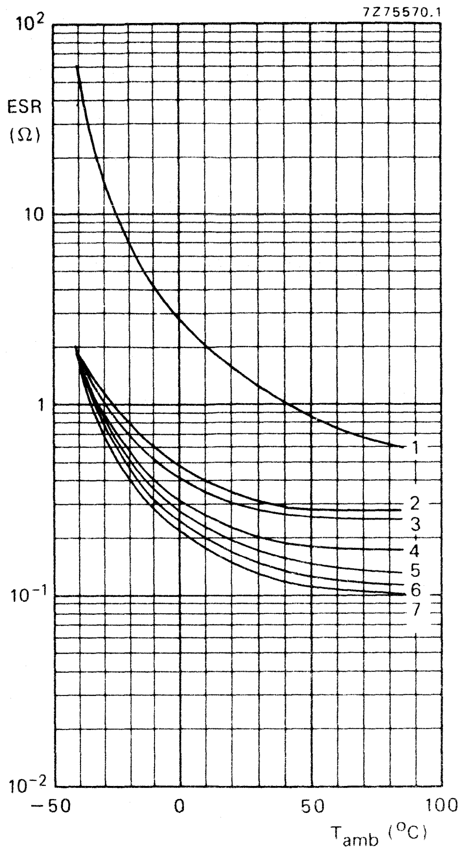


Fig. 17 Typical ESR as a function of ambient temperature at 100 Hz.

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.

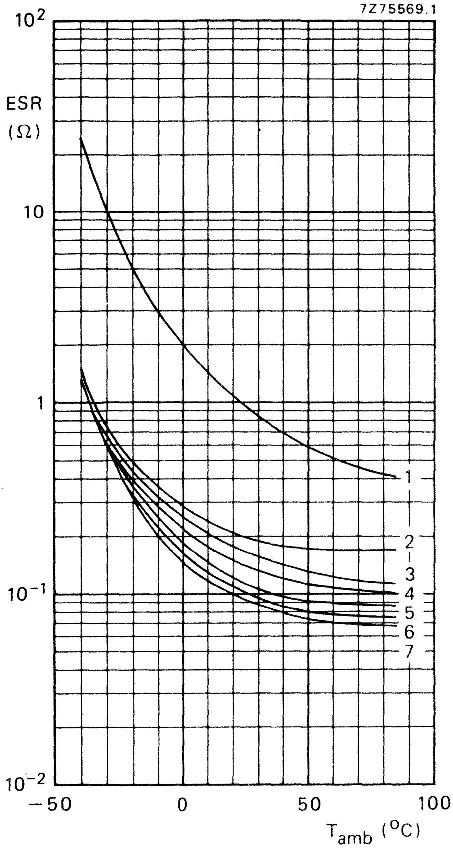


Fig. 18 Typical ESR as a function of ambient temperature at 100 Hz.

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.

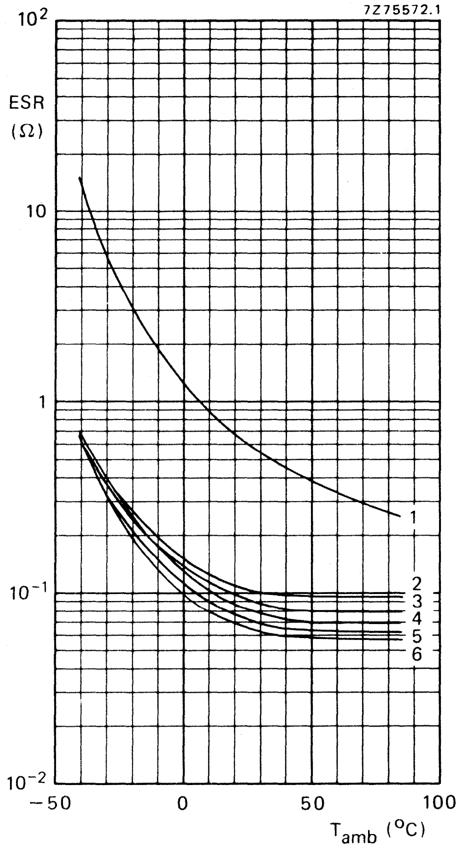


Fig. 19 Typical ESR as a function of ambient temperature at 100 Hz.

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.

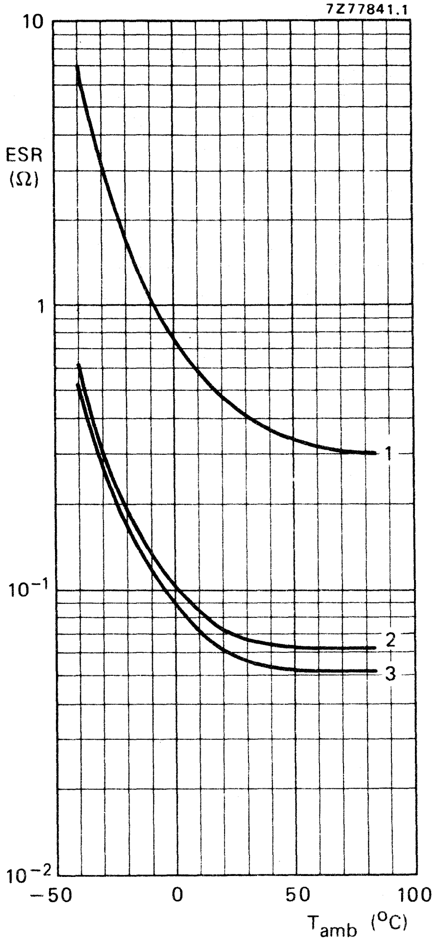


Fig. 20 Typical ESR as a function of ambient temperature at 100 Hz.

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.

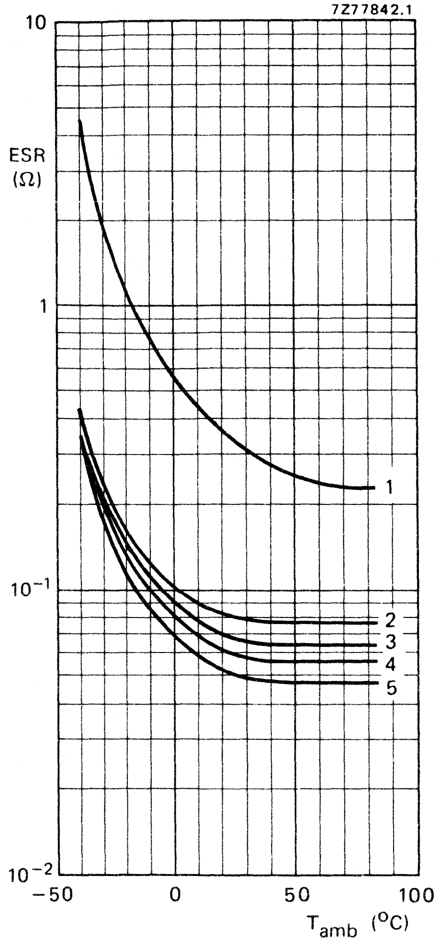


Fig. 21 Typical ESR as a function of ambient temperature at 100 Hz.

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.

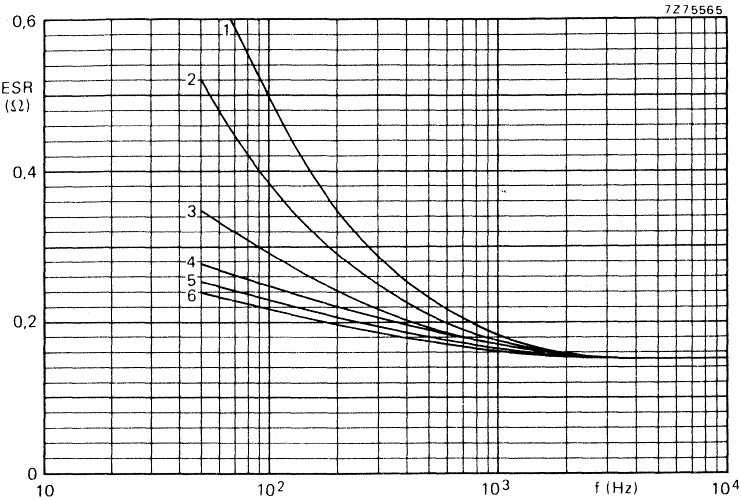


Fig. 22 Typical ESR as a function of frequency at 25 °C. 6,3 to 63 V versions, **case size 00:**
curve 1 = 150 μF, 63 V; curve 2 = 220 μF, 40 V; curve 3 = 470 μF, 25 V; curve 4 = 680 μF, 16 V; curve 5 = 1000 μF, 10 V; curve 6 = 1500 μF, 6,3 V.

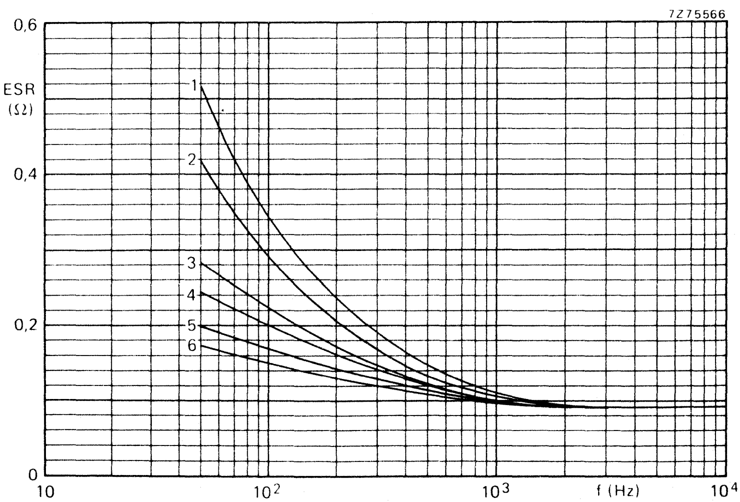


Fig. 23 Typical ESR as a function of frequency at 25 °C. 6,3 to 63 V versions, **case size 01:**
curve 1 = 220 μF, 63 V; curve 2 = 330 μF, 40 V; curve 3 = 470 μF, 40 V; curve 4 = 680 μF, 25 V; curve 5 = 1000 μF, 16 V; curve 6 = 1500 μF, 10 V; and 2200 μF, 6,3 V.

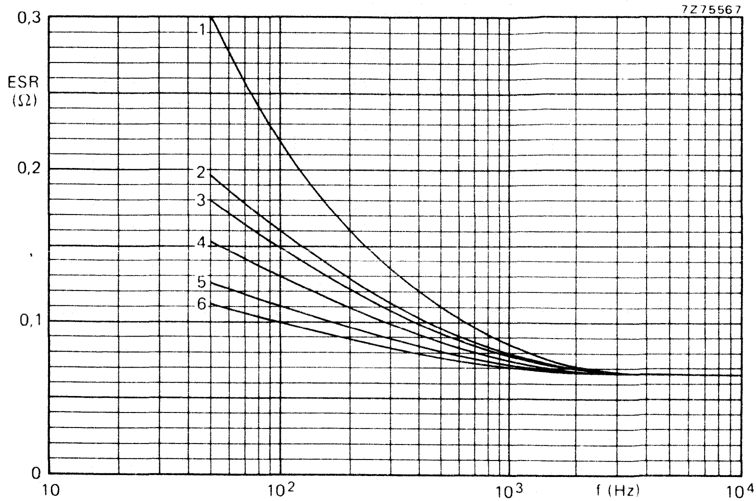


Fig. 24 Typical ESR as a function of frequency at 25 °C. 6,3 to 63 V versions, **case size 02:**

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.

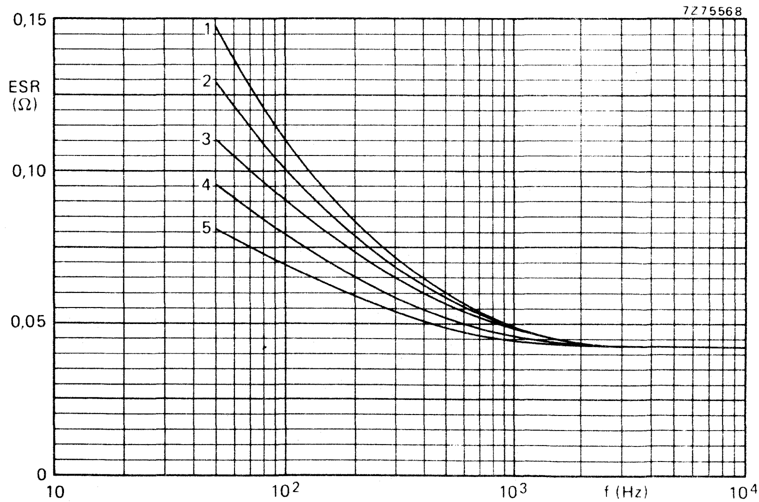


Fig. 25 Typical ESR as a function of frequency at 25 °C. 6,3 to 63 V versions, **case size 03:**

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.

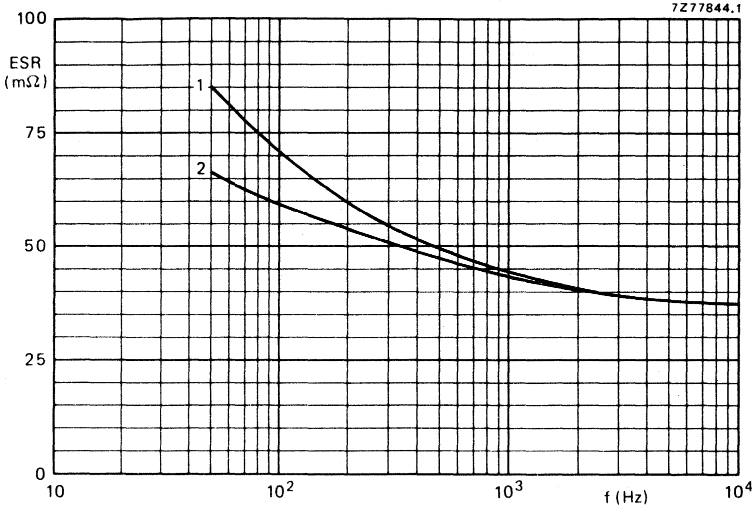


Fig. 26 Typical ESR as a function of frequency at 25 °C. **Case size 04:** curve 1 = 1500 μF, 40 V and 2200 μF, 25 V; curve 2 = 3300 μF, 16 V, 4700 μF, 10 V and 6800 μF, 6,3 V.

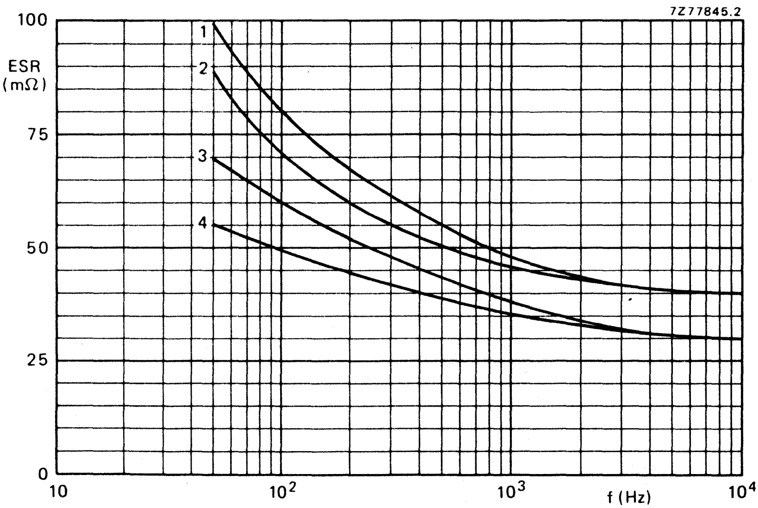


Fig. 27 Typical ESR as a function of frequency at 25 °C. **Case size 05:** curve 1 = 1000 μF, 63 V; curve 2 = 1500 μF, 63 V; curve 3 = 2200 μF, 40 V and 3300 μF, 25 V; curve 4 = 4700 μF, 16 V, 6800 μF, 10 V, 10 000 μF and 15 000 μF, 6,3 V.

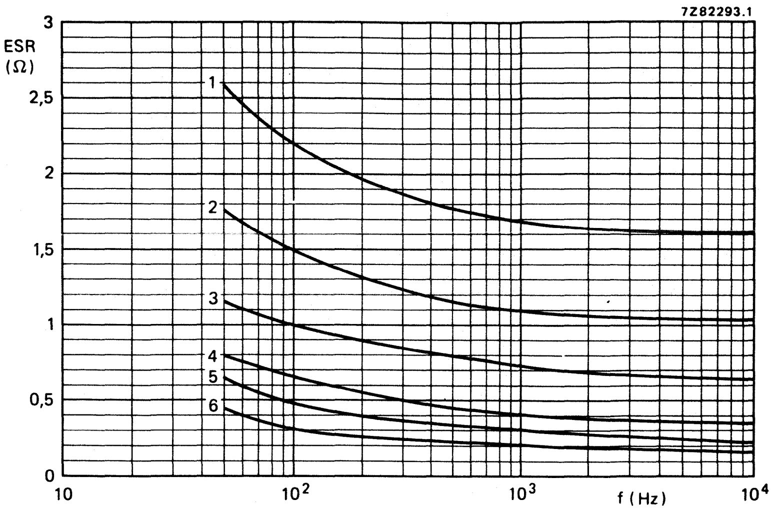


Fig. 28 Typical ESR as a function of frequency at 25 °C; 100 V version:
curve 1 = 68 μF, case size 00;
curve 2 = 100 μF, case size 01;
curve 3 = 150 μF, case size 02;
curve 4 = 220 μF, case size 03;
curve 5 = 330 μF, case size 04;
curve 6 = 470 μf and 680 μF, case size 05.

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
−55 °C*	typ. 6500	typ. 5000	typ. 3300	typ. 2400	typ. 1500	typ. 850	typ. 500

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	⩽ –

* For case sizes 1 to 7 only.

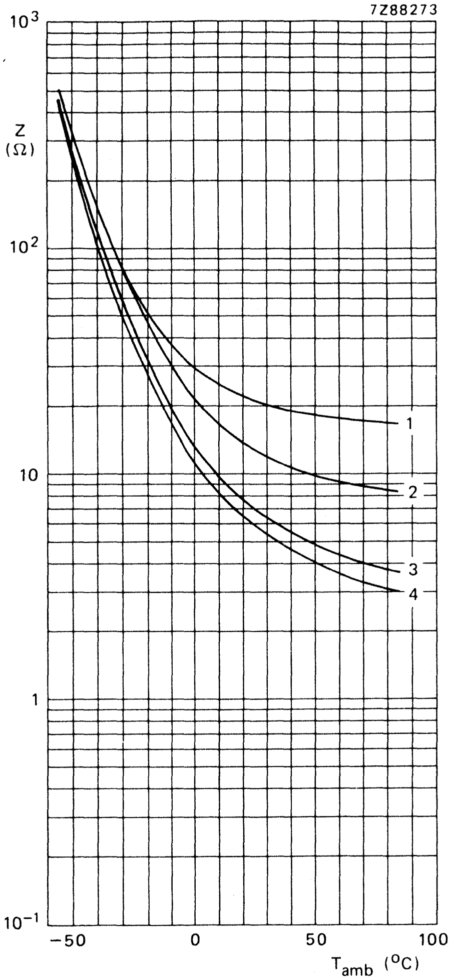


Fig. 29 Typical impedance as a function of ambient temperature at 10 kHz; **case size 1:**

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.

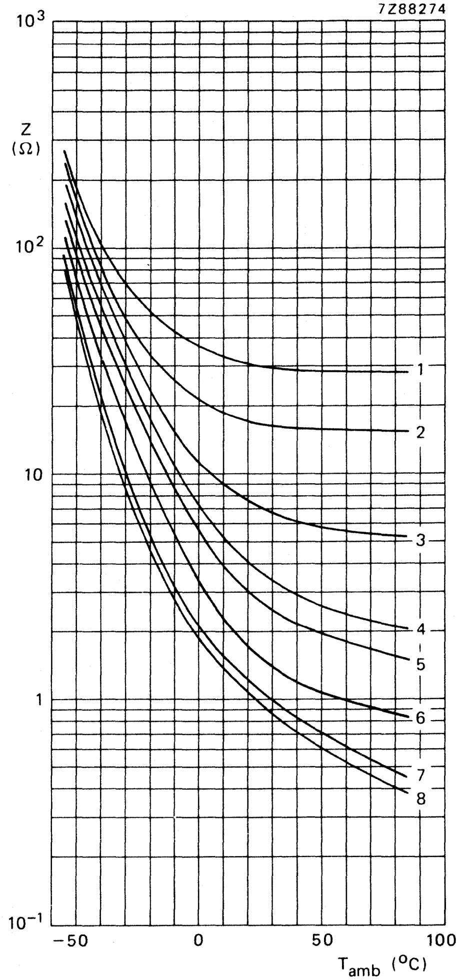


Fig. 30 Typical impedance as a function of ambient temperature at 10 kHz; **case size 2:**

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.

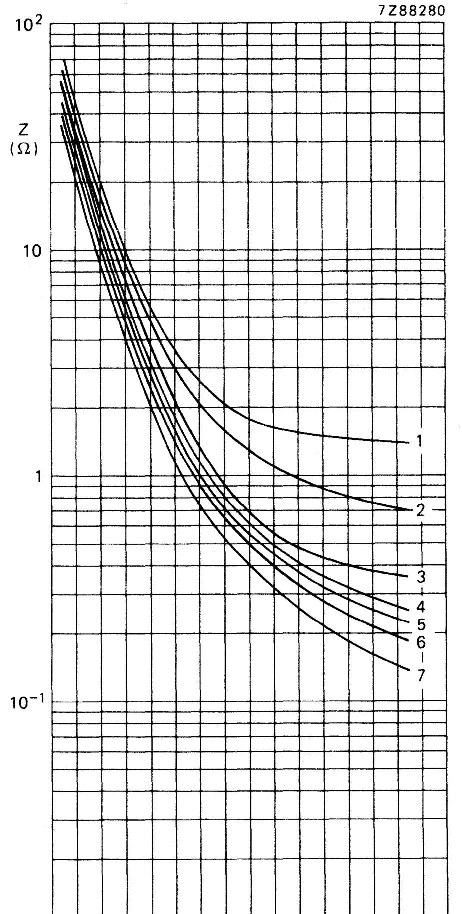


Fig. 31 Typical impedance as a function of ambient temperature at 10 kHz; **case size 3:**

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.

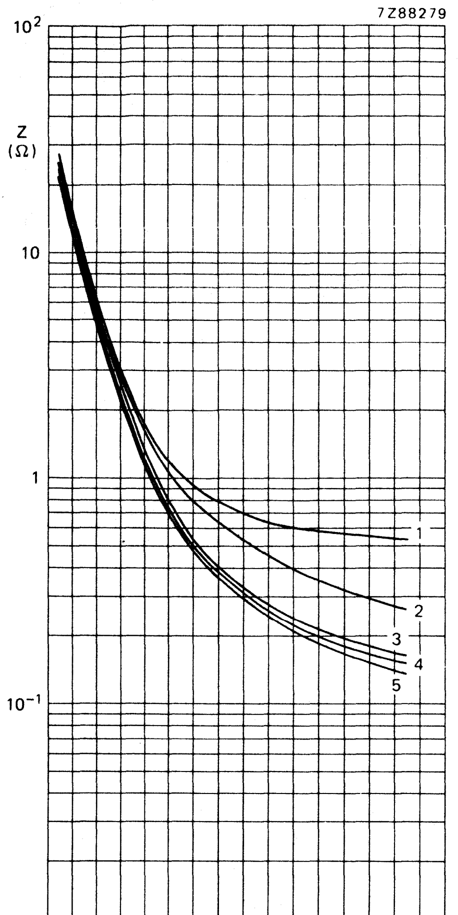


Fig. 32 Typical impedance as a function of ambient temperature at 10 kHz; **case size 5a:**

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.

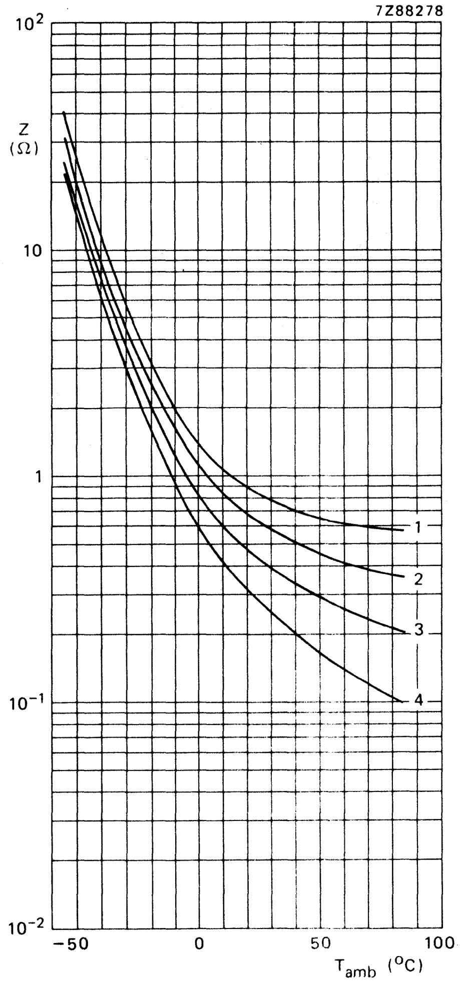


Fig. 33 Typical impedance as a function of ambient temperature at 10 kHz; **case size 4**:

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

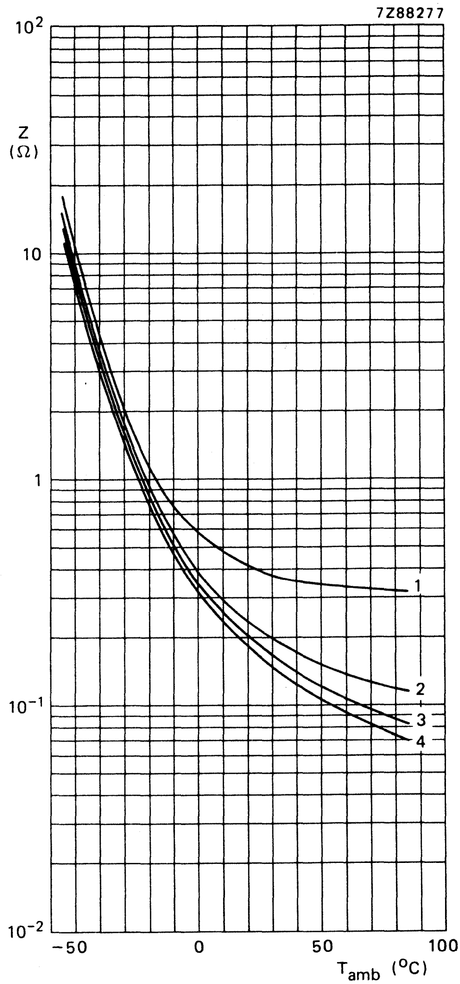


Fig. 34 Typical impedance as a function of ambient temperature at 10 kHz; **case size 5**:

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.

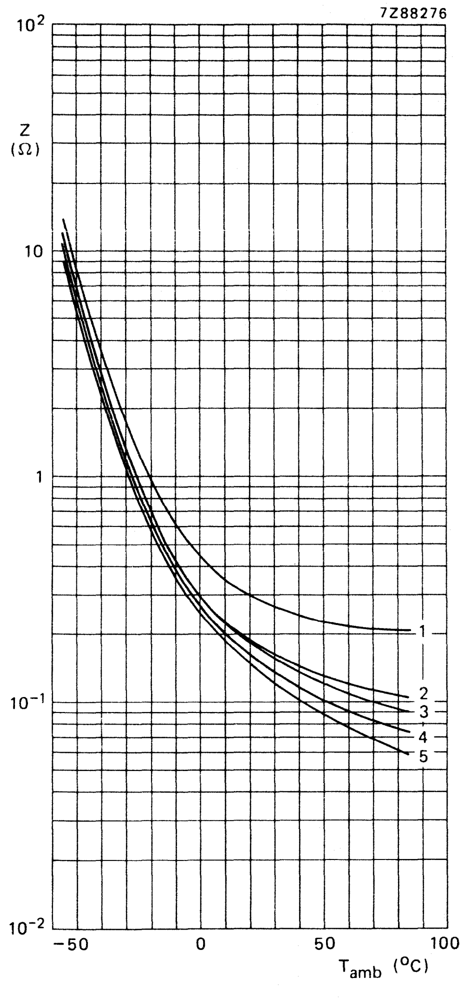


Fig. 35 Typical impedance as a function of ambient temperature at 10 kHz; **case size 6:**

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.

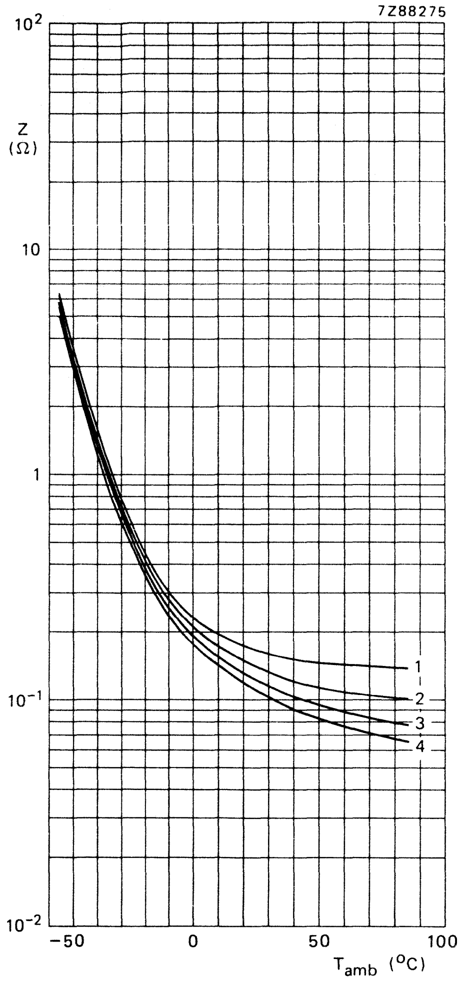


Fig. 36 Typical impedance as a function of ambient temperature at 10 kHz; **case size 7:**

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.

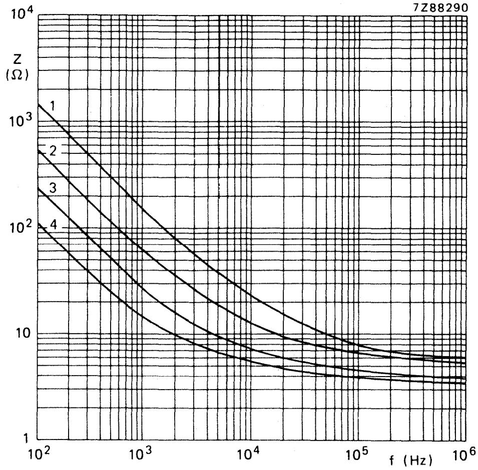


Fig. 37 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 1:**
curve 1 = 1 μF, 63 V;
curve 2 = 2,2 μF, 40 V;
curve 3 = 4,7 μF, 16 V;
curve 4 = 10 μF, 6,3 V.

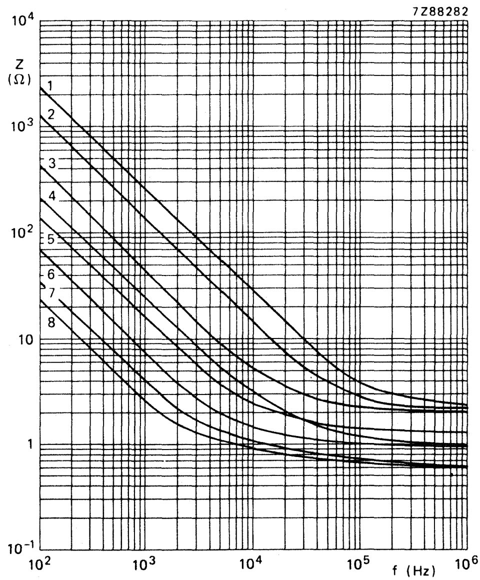


Fig. 38 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 2:**
curve 1 = 0,47 μF, 63 V;
curve 2 = 1 μF, 63 V/100 V;
curve 3 = 3,3 μF, 63 V/100 V;
curve 4 = 6,8 μF, 63 V;
curve 5 = 10 μF, 25 V;
curve 6 = 22 μF, 25 V;
curve 7 = 47 μF, 10 V;
curve 8 = 68 μF, 6,3 V.

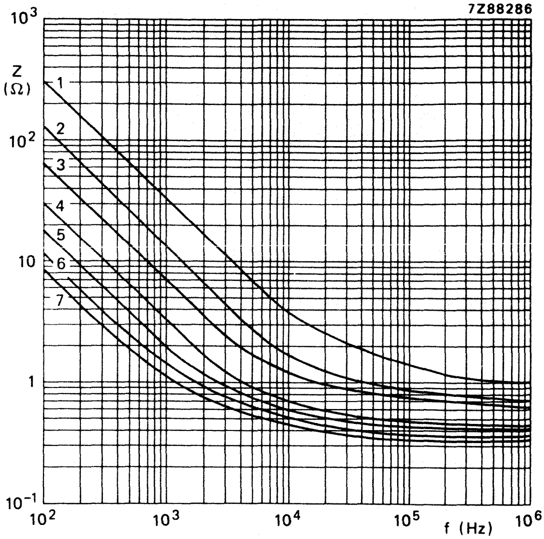


Fig. 39 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 3:**
curve 1 = 4,7 μF, 100 V;
curve 2 = 10 μF, 63 V;
curve 3 = 22 μF, 40 V;
curve 4 = 47 μF, 25 V;
curve 5 = 68 μF, 16 V;
curve 6 = 100 μF, 10 V;
curve 7 = 150 μF, 6,3 V.

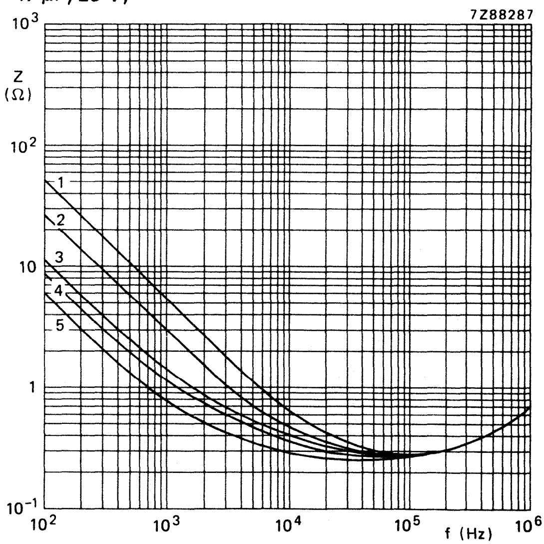


Fig. 40 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 5a:**
curve 1 = 22 μF, 63 V;
curve 2 = 47 μF, 40 V;
curve 3 = 100 μF, 25 V;
curve 4 = 150 μF, 16 V;
curve 5 = 220 μF, 10 V.

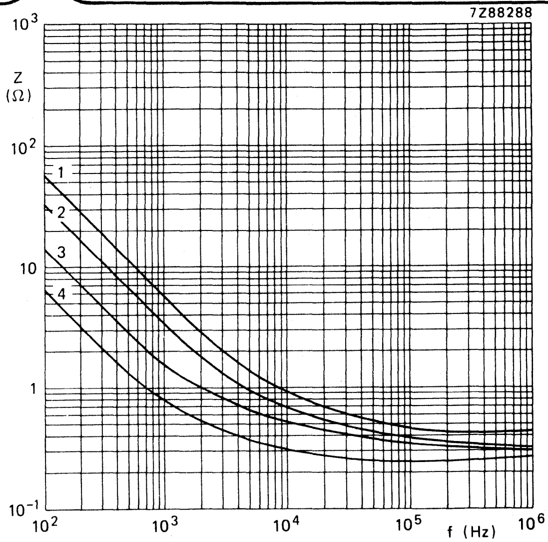


Fig. 41 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 4:**
curve 1 = 22 μF, 63 V;
curve 2 = 47 μF, 40 V;
curve 3 = 100 μF, 25 V;
curve 4 = 220 μF, 10 V.

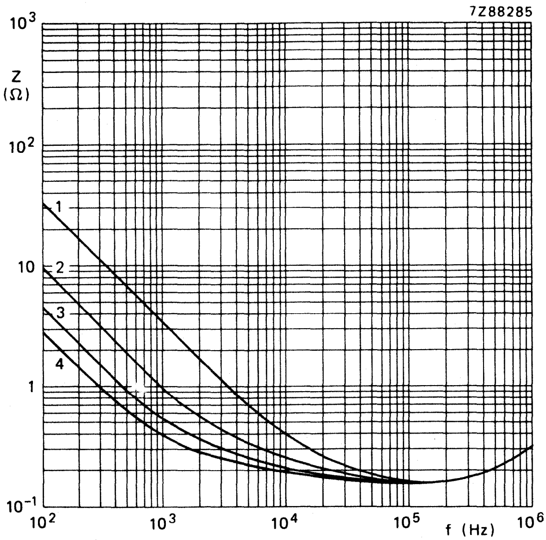


Fig. 42 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 5:**
curve 1 = 47 μF, 63 V;
curve 2 = 150 μF, 25 V;
curve 3 = 330 μF, 10 V;
curve 4 = 470 μF, 6,3 V.

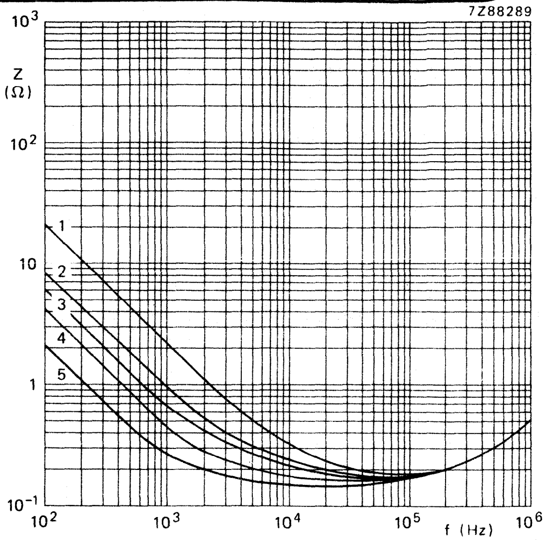


Fig. 43 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 6:**
curve 1 = 68 μF, 63 V;
curve 2 = 150 μF, 40 V;
curve 3 = 220 μF, 25 V;
curve 4 = 330 μF, 16 V;
curve 5 = 680 μF, 6,3 V.

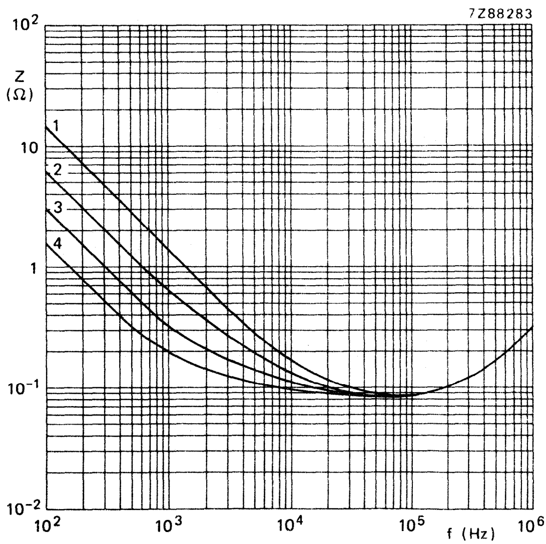


Fig. 44 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 7:**
curve 1 = 100 μF, 63 V;
curve 2 = 220 μF, 40 V;
curve 3 = 470 μF, 16 V;
curve 4 = 1000 μF, 6,3 V.

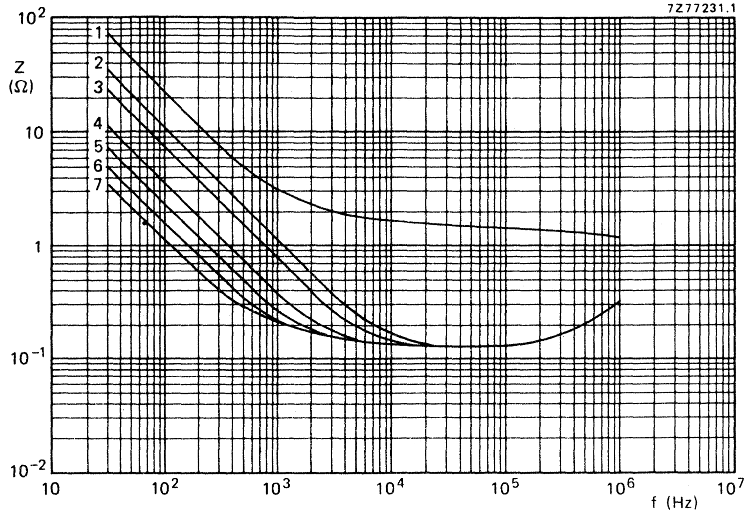


Fig. 45 Typical impedance as a function of frequency at 20 °C. **Case size 00:**
curve 1 = 68 μF, 100 V; curve 2 = 150 μF, 63 V; curve 3 = 220 μF, 40 V; curve 4 = 470 μF, 25 V; curve 5 = 680 μF, 16 V; curve 6 = 1000 μF, 10 V; curve 7 = 1500 μF, 6,3 V.

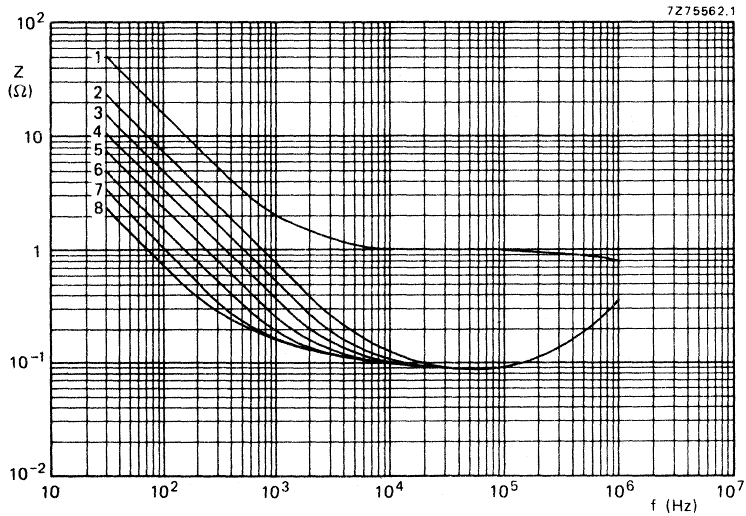


Fig. 46 Typical impedance as a function of frequency at 20 °C. **Case size 01:**
curve 1 = 100 μF, 100 V; curve 2 = 220 μF, 63 V; curve 3 = 330 μF, 40 V; curve 4 = 470 μF, 40 V; curve 5 = 680 μF, 25 V; curve 6 = 1000 μF, 16 V; curve 7 = 1500 μF, 10 V; curve 8 = 2200 μF, 6,3 V.

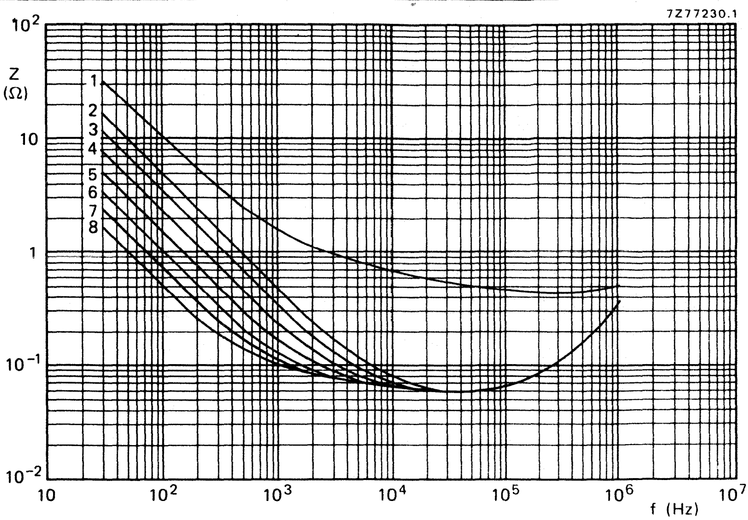


Fig. 47 Typical impedance as a function of frequency at 20 °C. **Case size 02:**
curve 1 = 150 μF, 100 V;
curve 2 = 330 μF, 63 V;
curve 3 = 470 μF, 63 V;
curve 4 = 680 μF, 40 V;
curve 5 = 1000 μF, 25 V;
curve 6 = 1500 μF, 16 V;
curve 7 = 2200 μF, 10 V;
curve 8 = 3300 μF, 6,3 V.

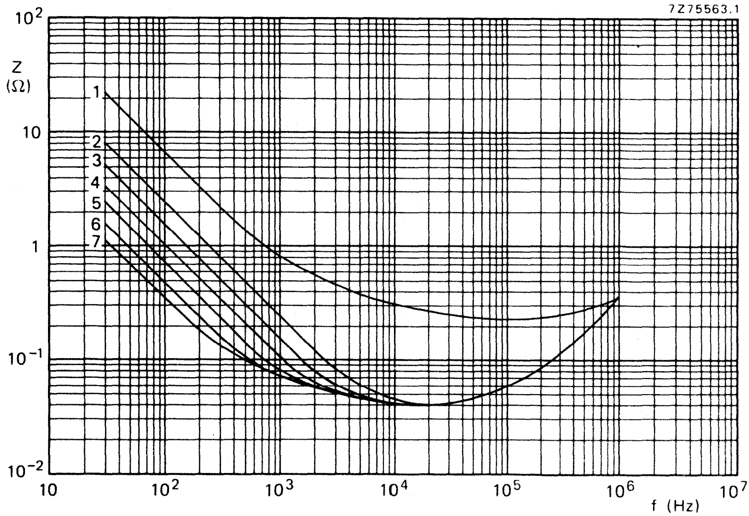


Fig. 48 Typical impedance as a function of frequency at 20 °C. **Case size 03:**
curve 1 = 220 μF, 100 V;
curve 2 = 680 μF, 63 V;
curve 3 = 1000 μF, 40 V;
curve 4 = 1500 μF, 25 V;
curve 5 = 2200 μF, 16 V;
curve 6 = 3300 μF, 10 V;
curve 7 = 4700 μF, 6,3 V.

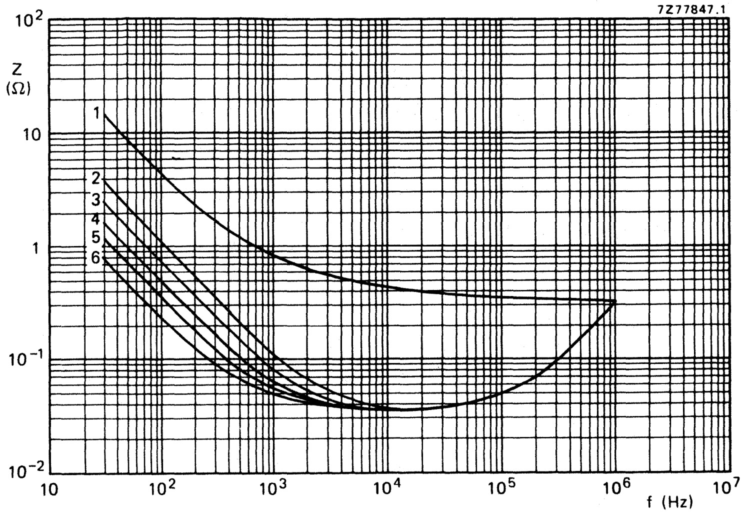


Fig. 49 Typical impedance as a function of frequency at 20 °C. **Case size 04:**
curve 1 = 330 μF, 100 V;
curve 2 = 1500 μF, 40 V;
curve 3 = 2200 μF, 25 V;
curve 4 = 3300 μF, 16 V;
curve 5 = 4700 μF, 10 V;
curve 6 = 6800 μF, 6,3 V.

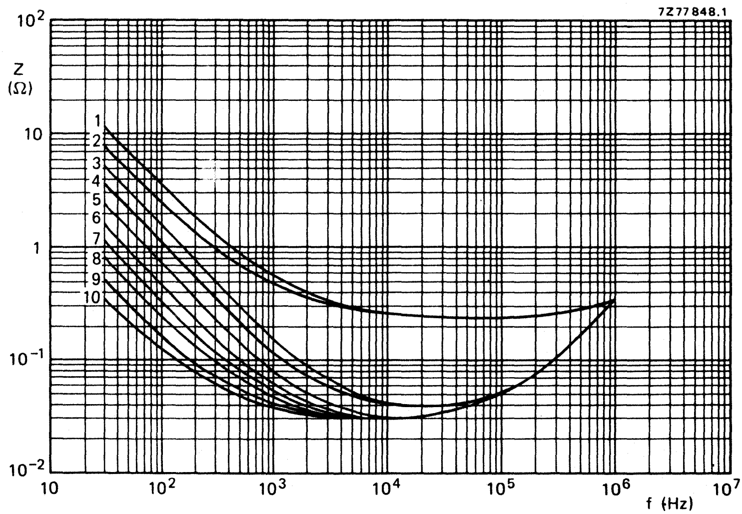


Fig. 50 Typical impedance as a function of frequency at 20 °C. **Case size 05:**
curve 1 = 470 μF, 100 V;
curve 2 = 680 μF, 100 V;
curve 3 = 1000 μF, 63 V;
curve 4 = 1500 μF, 63 V;
curve 5 = 2200 μF, 40 V;
curve 6 = 3300 μF, 25 V;
curve 7 = 4700 μF, 16 V;
curve 8 = 6800 μF, 10 V;
curve 9 = 10 000 μF, 6,3 V;
curve 10 = 15 000 μF, 6,3 V.

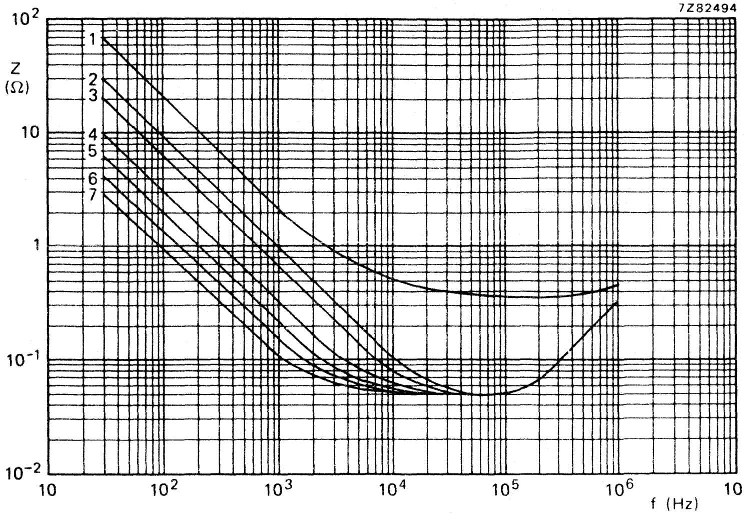


Fig. 51 Typical impedance as a function of frequency at 85 °C. **Case size 00:**
curve 1 = 68 μF, 100 V;
curve 2 = 150 μF, 63 V;
curve 3 = 220 μF, 40 V;
curve 4 = 470 μF, 25 V;
curve 5 = 680 μF, 16 V;
curve 6 = 1000 μF, 10 V;
curve 7 = 1500 μF, 6,3 V.

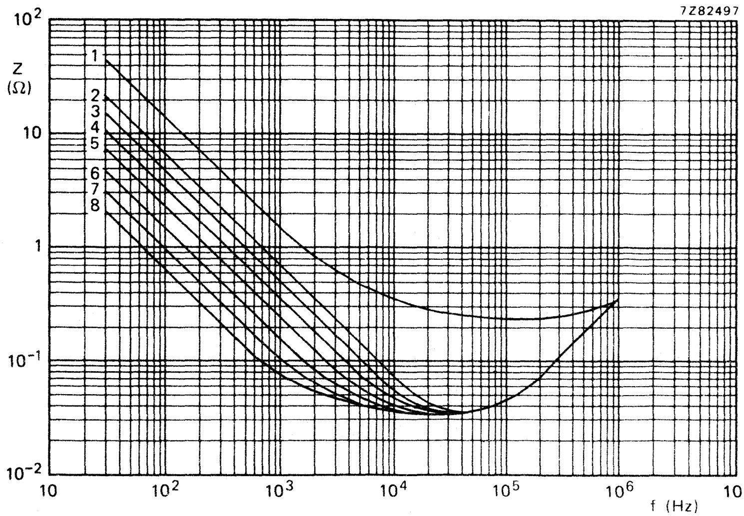


Fig. 52 Typical impedance as a function of frequency at 85 °C. **Case size 01:**
curve 1 = 100 μF, 100 V;
curve 2 = 220 μF, 63 V;
curve 3 = 330 μF, 40 V;
curve 4 = 470 μF, 40 V;
curve 5 = 680 μF, 25 V;
curve 6 = 1000 μF, 16 V;
curve 7 = 1500 μF, 10 V;
curve 8 = 2200 μF, 6,3 V.

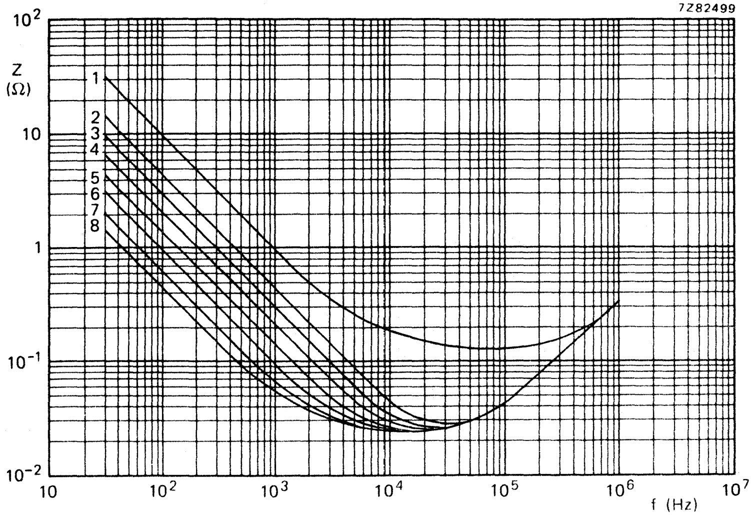


Fig. 53 Typical impedance as a function of frequency at 85 °C. **Case size 02:**
curve 1 = 150 μF, 100 V; curve 2 = 330 μF, 63 V; curve 3 = 470 μF, 63 V; curve 4 = 680 μF, 40 V; curve 5 = 1000 μF, 25 V; curve 6 = 1500 μF, 16 V; curve 7 = 2200 μF, 10 V; curve 8 = 3300 μF, 6,3 V.

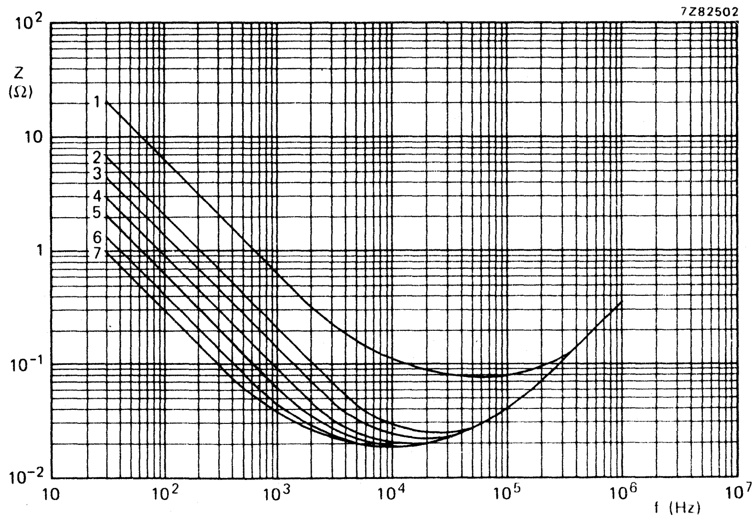


Fig. 54 Typical impedance as a function of frequency at 85 °C. **Case size 03:**
curve 1 = 220 μF, 100 V; curve 2 = 680 μF, 63 V; curve 3 = 1000 μF, 40 V; curve 4 = 1500 μF, 25 V; curve 5 = 2200 μF, 16 V; curve 6 = 3300 μF, 10 V; curve 7 = 4700 μF, 6,3 V.

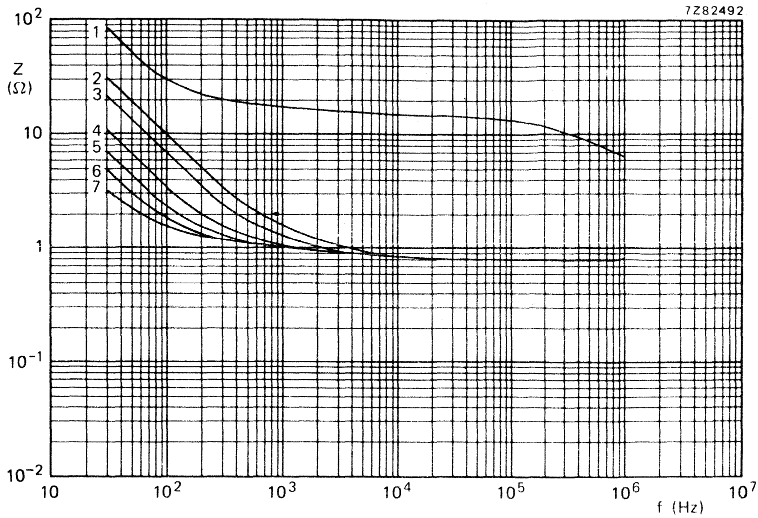


Fig. 55 Typical impedance as a function of frequency at −25 °C. **Case size 00:**
curve 1 = 68 μF, 100 V;
curve 2 = 150 μF, 63 V;
curve 3 = 220 μF, 40 V;
curve 4 = 470 μF, 25 V;
curve 5 = 680 μF, 16 V;
curve 6 = 1000 μF, 10 V;
curve 7 = 1500 μF, 6,3 V.

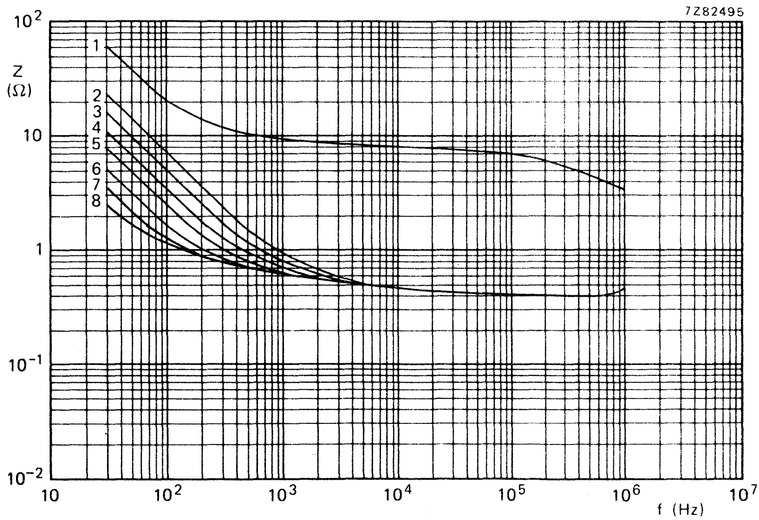


Fig. 56 Typical impedance as a function of frequency at −25 °C. **Case size 01:**
curve 1 = 100 μF, 100 V;
curve 2 = 220 μF, 63 V;
curve 3 = 330 μF, 40 V;
curve 4 = 470 μF, 40 V;
curve 5 = 680 μF, 25 V;
curve 6 = 1000 μF, 16 V;
curve 7 = 1500 μF, 10 V;
curve 8 = 2200 μF, 6,3 V.

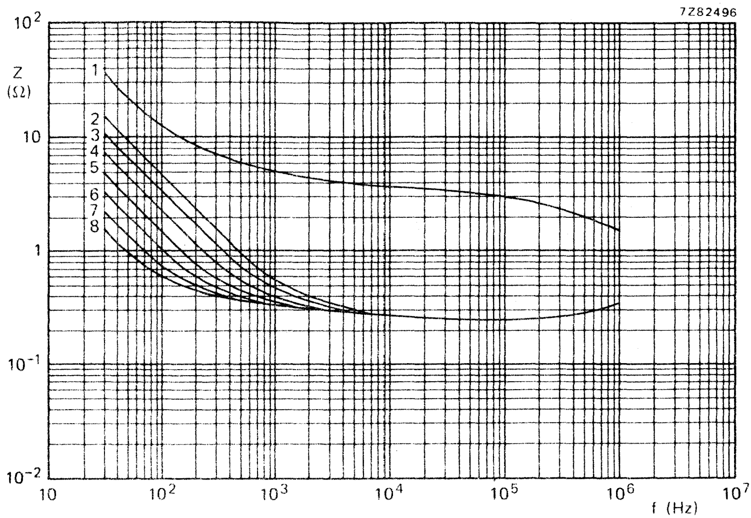


Fig. 57 Typical impedance as a function of frequency at −25 °C. **Case size 02:**
curve 1 = 150 μF, 100 V;
curve 2 = 330 μF, 63 V;
curve 3 = 470 μF, 63 V;
curve 4 = 680 μF, 40 V;
curve 5 = 1000 μF, 25 V;
curve 6 = 1500 μF, 16 V;
curve 7 = 2200 μF, 10 V;
curve 8 = 3300 μF, 6,3 V.

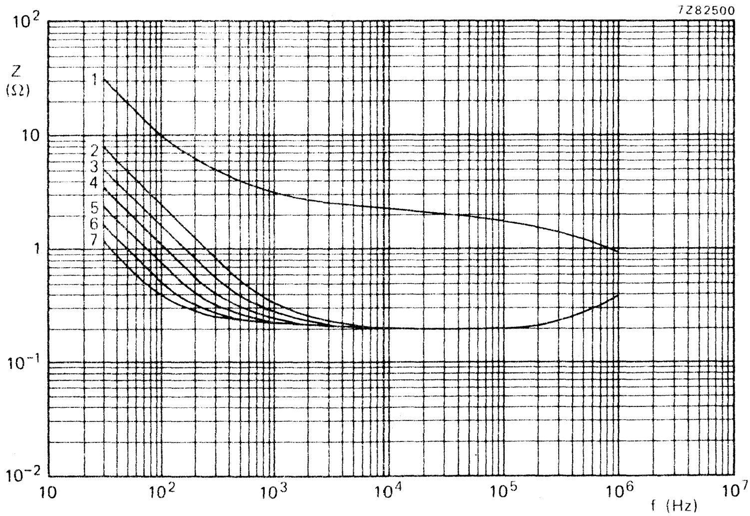


Fig. 58 Typical impedance as a function of frequency at −25 °C. **Case size 03:**
curve 1 = 220 μF, 100 V;
curve 2 = 680 μF, 63 V;
curve 3 = 1000 μF, 40 V;
curve 4 = 1500 μF, 25 V;
curve 5 = 2200 μF, 16 V;
curve 6 = 3300 μF, 10 V;
curve 7 = 4700 μF, 6,3 V.

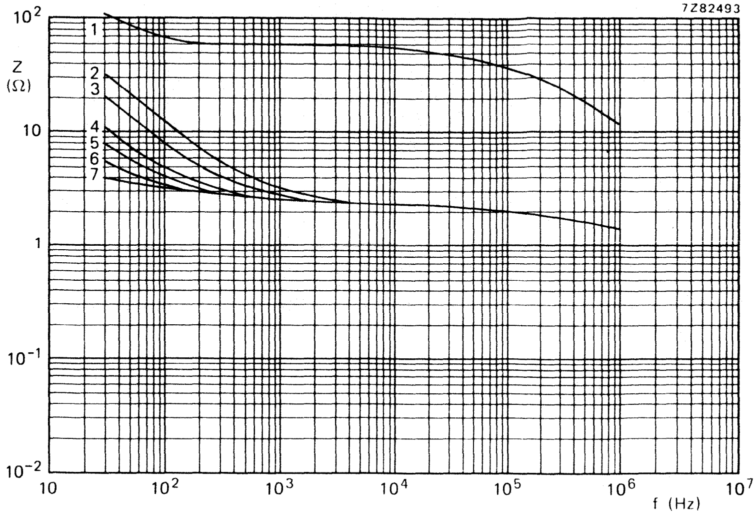


Fig. 59 Typical impedance as a function of frequency at −40 °C. **Case size 00:**
curve 1 = 68 μF, 100 V;
curve 2 = 150 μF, 63 V;
curve 3 = 220 μF, 40 V;
curve 4 = 470 μF, 25 V;
curve 5 = 680 μF, 16 V;
curve 6 = 1000 μF, 10 V;
curve 7 = 1500 μF, 6,3 V.

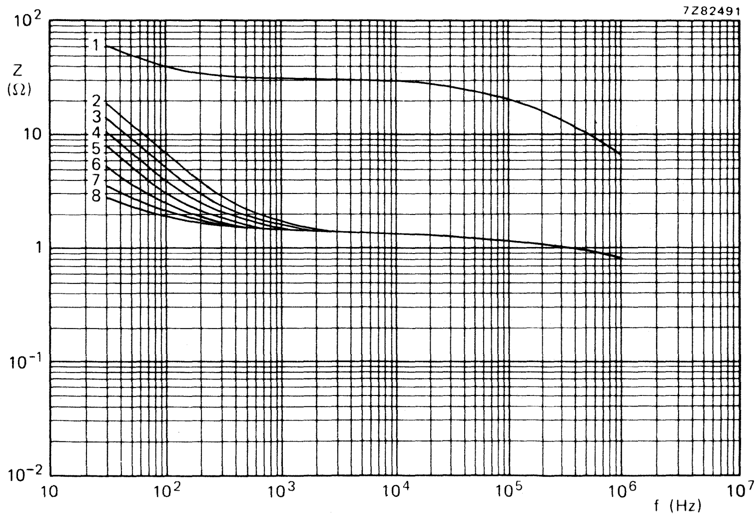


Fig. 60 Typical impedance as a function of frequency at −40 °C. **Case size 01:**
curve 1 = 100 μF, 100 V;
curve 2 = 220 μF, 63 V;
curve 3 = 330 μF, 40 V;
curve 4 = 470 μF, 40 V;
curve 5 = 680 μF, 25 V;
curve 6 = 1000 μF, 16 V;
curve 7 = 1500 μF, 10 V;
curve 8 = 2200 μF, 6,3 V.

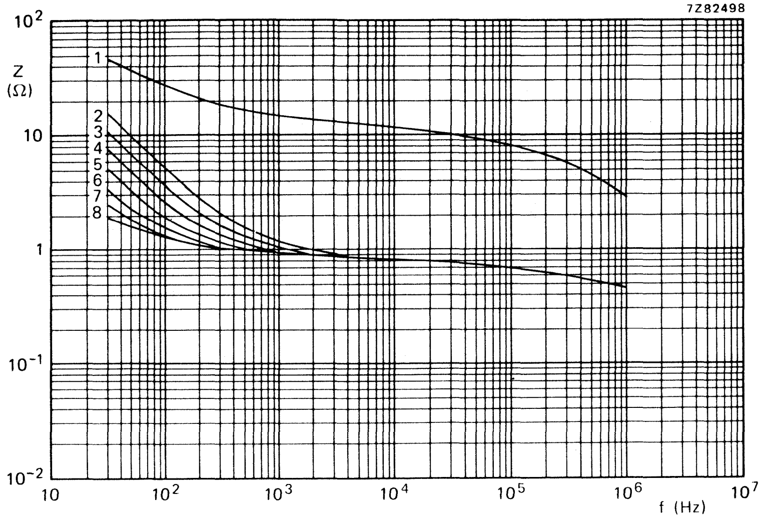


Fig. 61 Typical impedance as a function of frequency at −40 °C. **Case size 02:**
curve 1 = 150 μF, 100 V;
curve 2 = 330 μF, 63 V;
curve 3 = 470 μF, 63 V;
curve 4 = 680 μF, 40 V;
curve 5 = 1000 μF, 25 V;
curve 6 = 1500 μF, 16 V;
curve 7 = 2200 μF, 10 V;
curve 8 = 3300 μF, 6,3 V.

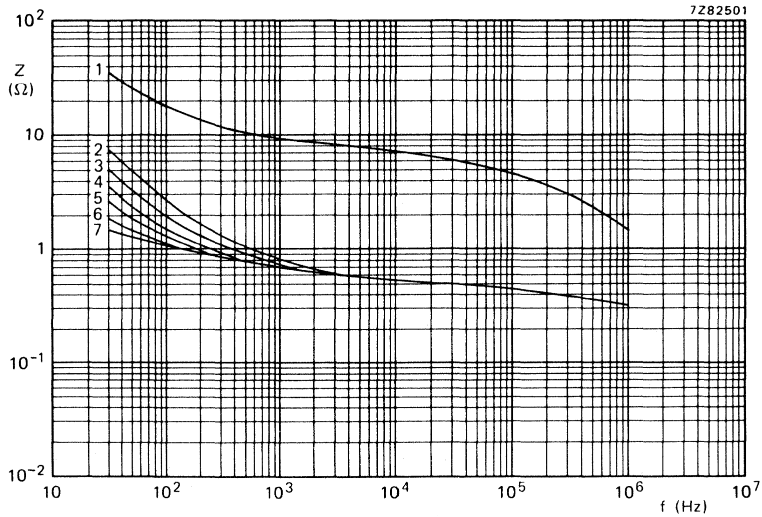


Fig. 62 Typical impedance as a function of frequency at −40 °C. **Case size 03:**
curve 1 = 220 μF, 100 V;
curve 2 = 680 μF, 63 V;
curve 3 = 1000 μF, 40 V;
curve 4 = 1500 μF, 25 V;
curve 5 = 2200 μF, 16 V;
curve 6 = 3300 μF, 10 V;
curve 7 = 4700 μF, 6,3 V.

Equivalent series inductance (ESL)

Case size 1	typ. 15 nH
Case size 2	typ. 17 nH
Case sizes 3 and 4	typ. 30 nH
Case size 5a	typ. 85 nH
Case size 5	typ. 50 nH
Case sizes 6 and 7	typ. 65 nH
Case sizes 00 and 01	typ. 50 nH
Case size 02	typ. 55 nH
Case sizes 03, 04 and 05	typ. 60 nH

OPERATIONAL DATA

Category temperature range

case sizes 1 to 7	−55 to +85 °C
case sizes 00 to 05	−40 to +85 °C

Typical life time	T_{amb} = 85 °C	T_{amb} = 40 °C
case size 1	1500 h	35 000 h
case sizes 2 to 7	3000 h	70 000 h
case sizes 00 to 05	10 000 h	> 200 000 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 on bandoliers per reel	style 1 on bandoliers per box	style 1 per box	style 2 per box	style 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	

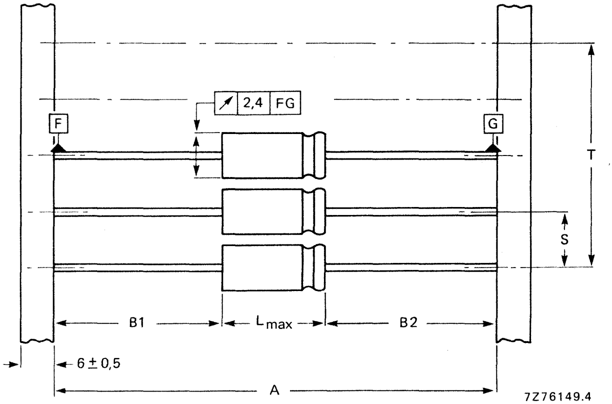


Fig. 63 Style 1 capacitors (case sizes 1 to 7) on bandoliers: the bandolier to which the negative capacitor terminals are connected is blue. See Table 6 for dimensions A, S, T and L.
|B1 − B2| = max. 1,4 mm.

Table 6

Dimensions in mm

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

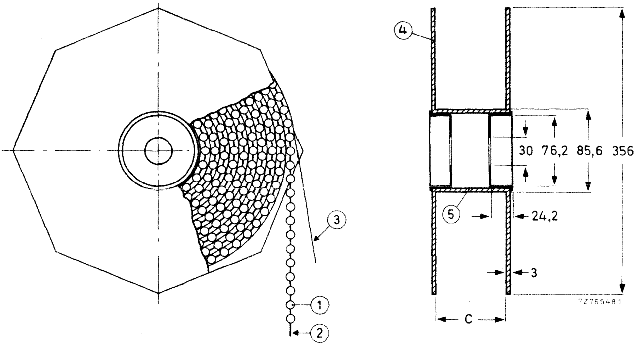


Fig. 64 Style 1 capacitors (case sizes 1 to 7) on bandoliers on reel; dimension C is 83,5 mm for case sizes 1, 2, 3 and 5a, and 88,5 mm for case sizes 4, 5, 6 and 7; the overall width of the reel is 94,5 mm and 99,5 mm respectively.

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 (1000 h for case size 1), 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.

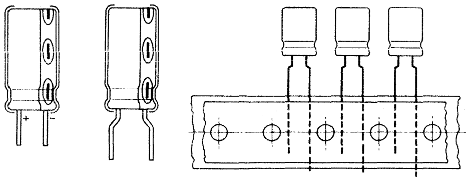
After *shelf life test, 500 h, 85 °C,* the capacitors meet the same requirements as after endurance test. The rated voltage shall be applied to the capacitors for minimum 30 min, at least 24 h and not more than 48 h before measurements.

Note:

Capacitors 2222 030, case size 1 are miniature types, general-purpose grade.
Capacitors 2222 030 and 2222 031, case sizes 2 to 7, 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 applications**



QUICK REFERENCE DATA

Nominal capacitance range (E6 series):	0,10 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 at 85 °C:	1000 h
Shelf life at 0 V, 85 °C:	500 h
Basic specifications: IEC 384-4, G.P. grade DIN 41332/DIN 41259	
Climatic category:	
IEC 68:	40/085/56
DIN 40040:	GPF

* ± 10% to special order.

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

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
0,10								11	
0,15								11	
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	20					
3300	19		20						
4700	20								

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. The taped versions are suitable for automatic insertion and for cutting and forming equipment.

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.

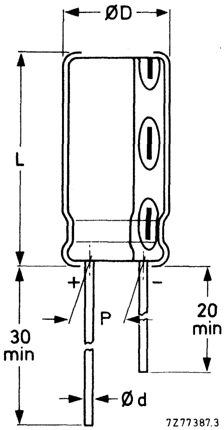


Fig. 1 Style 1; see Table 1 for dimensions d, D, L and P.

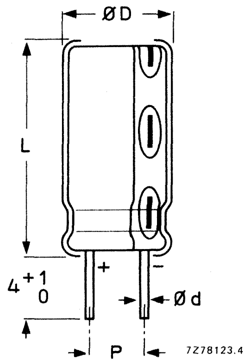


Fig. 2 Style 2; non preferred, see Table 1 for dimensions d, D, L and P.

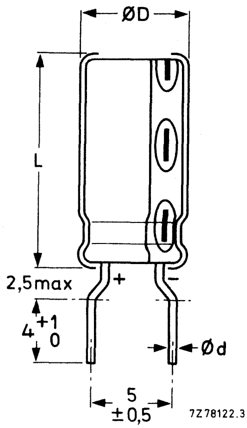
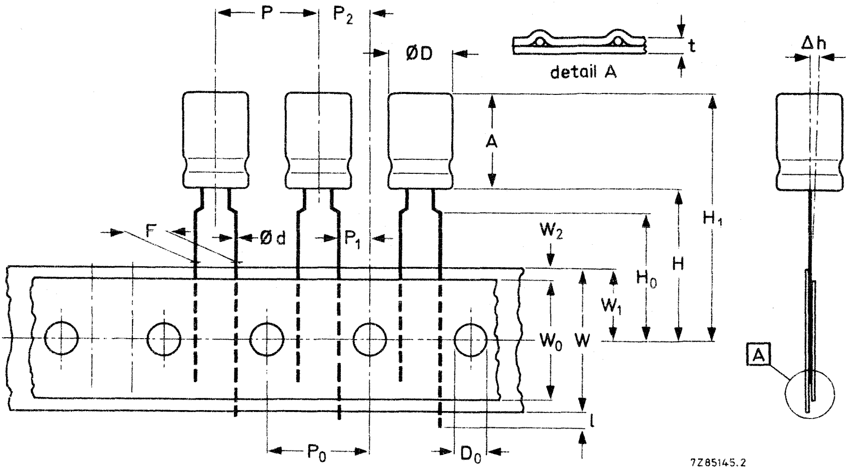


Fig. 3 Style 3, case sizes 11, 12 and 13; non preferred, see Table 1 for dimensions d, D and L.

Table 1

case size	dimensions					mass g
	d	D_{max}	L_{max}	P		
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
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.



→ direction of tape transport

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

Table 2

	symbol	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	32,0	32,0	32,0	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

→ WARNING

Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled. Caution is necessary should the outer case be fractured.

ELECTRICAL DATA

Unless otherwise specified all electrical values in Table 3 apply at an ambient temperature of 20 to 25 ^{o}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 (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 (Ω) at T_{amb} = 20 °C at 1 kHz	max. impedance (Ω) at T_{amb} = 20 °C at 10 kHz	case size	catalogue number 2222 035 followed by style 1	style 2	style 3	on reel style 4	in ammopack style 5
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	0,13	17	53152	63152			
	2200	800	280	0,24	0,16	0,09	18	53222	63222			
	3300	850	419	0,24	0,11	0,06	19	53332	63332			
	4700	960	595	0,24	0,07	0,04	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	0,11	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	0,08	19	55152	65152			
	2200	1000	707	0,16	0,11	0,05	19	55222	65222			
	3300	1200	1059	0,16	0,08	0,04	20	55332	65332			

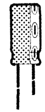
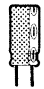
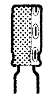
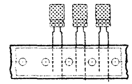
Table 3 (continued)

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. tan δ	max. impedance (Ω) at T_{amb} = 20 °C at 1 kHz	at 10 kHz	case size	catalogue number 2222 035 followed by 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	0,06	20	56152	66152			
	2200	1200	1103	0,14	0,10	0,04	20	56222	66222			
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	0,10	3,5	3	0,08		550	11	58107	88107	68107	28107	38107
	0,15	4,5	3	0,08		367	11	58157	88157	68157	28157	38157
	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} = 20 °C	see Table 3
Tolerance on nominal capacitance at 100 Hz	−20 to +20%

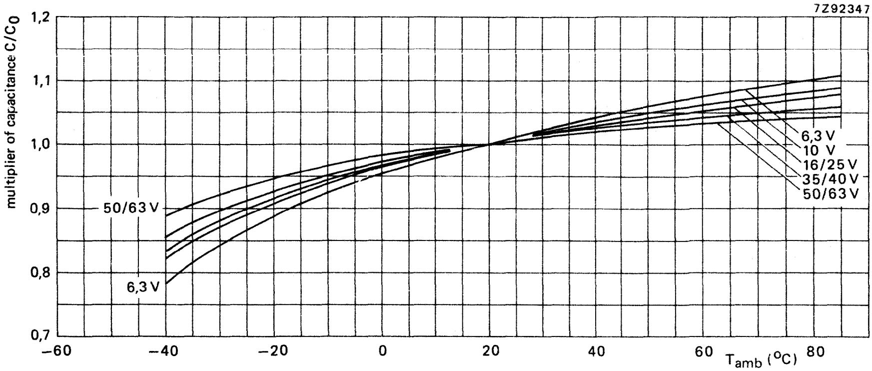


Fig. 5 Typical multiplier of capacitance as a function of ambient temperature; C_0 = capacitance at 20 °C, 100 Hz.

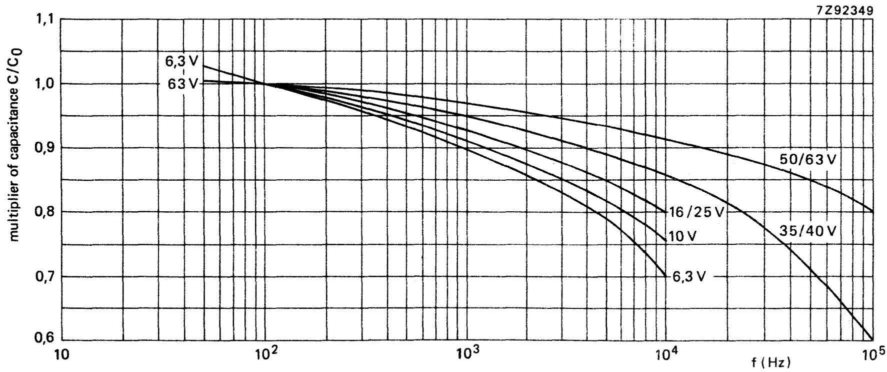


Fig. 6 Typical multiplier of capacitance as a function of frequency; C_0 = capacitance at 20 °C, 100 Hz.

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 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	1,15 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

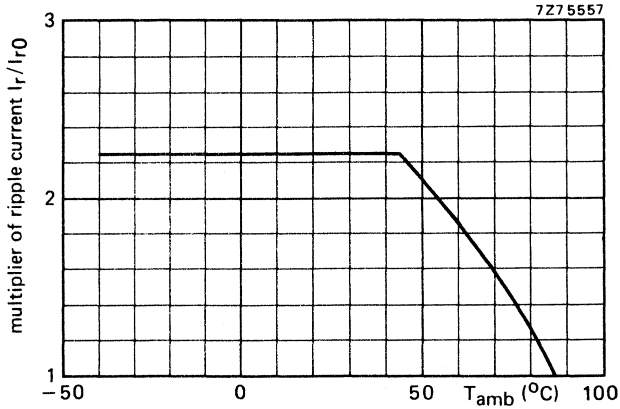


Fig. 7 Typical multiplier of ripple current as a function of ambient temperature; I_{r0} = ripple current at 85 °C, 100 Hz.

* 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.

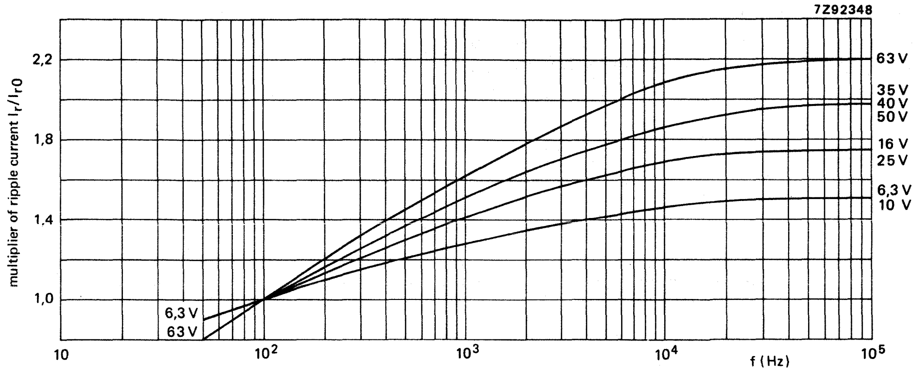


Fig. 8 Typical multiplier of ripple current as a function of frequency; I_{r0} = ripple current at 85 °C; 100 Hz.

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;
$\sqrt{r_n} = I_r/I_{r0}$ = 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-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} = 20 °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	⩽ 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

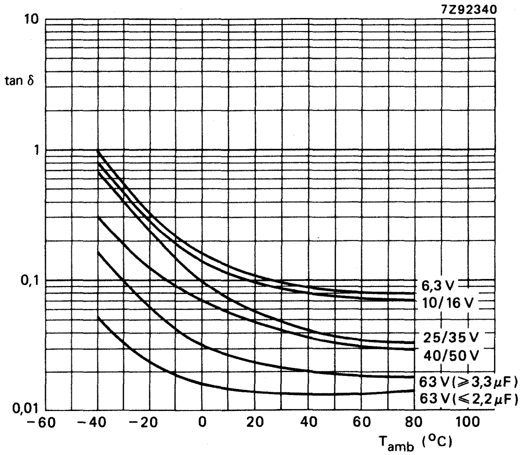


Fig. 9 Typical tan δ at 100 Hz as a function of ambient temperature.

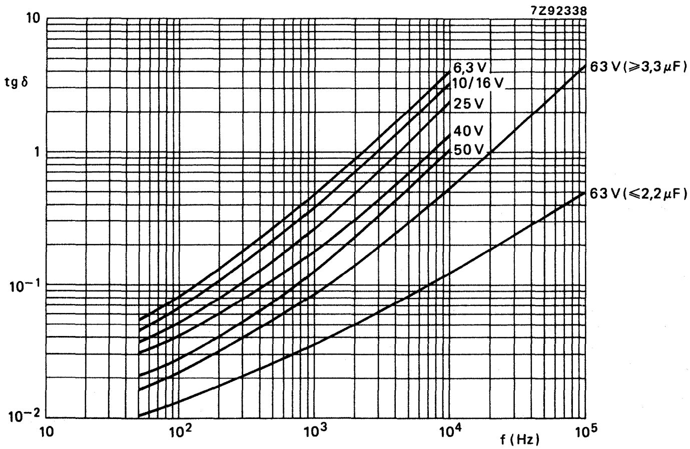


Fig. 10 Typical tan δ as a function of frequency at T_{amb} = 20 °C.

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 and 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

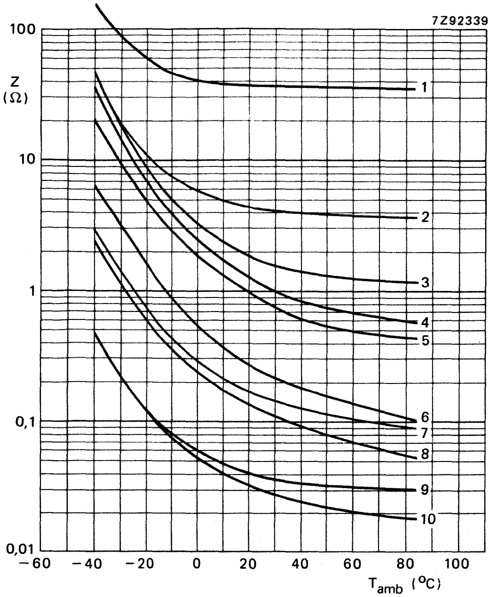
Maximum ratio between impedances at T_{amb} = –25 °C and + 20 °C, and at T_{amb} = –40 °C and + 20 °C, at 100 Hz measured by means of a four-terminal circuit (Thomson circuit) — see Table 5

Table 4

	T_{amb}	z = Z x C_{nom} (Ω μF) 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 μF, measured at 1 kHz	+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	700
C_{nom} ≤ 1000 μF, measured at 10 kHz	+20 °C	200	160	120	90	75	70	60	55	45
	–25 °C	1200	750	560	400	330	300	220	180	130
	–40 °C	3200	2000	1500	1100	950	900	700	500	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
$\frac{Z \text{ at } -25\,°C}{Z \text{ at } +20\,°C}$	4	3	2	2	2	2	2	2	2
$\frac{Z \text{ at } -40\,°C}{Z \text{ at } +20\,°C}$	7	5	5	4	4	4	4	4	4



Curve 1 = 0,47 μF; 63 V;
curve 2 = 4,7 μF; 63 V;
curve 3 = 15 μF; 40 V;
curve 4 = 47 μF; 10 V;
curve 5 = 47 μF; 25 V;
curve 6 = 330 μF; 6,3 V;
curve 7 = 150 μF; 6,3 V;
curve 8 = 680 μF; 6,3 V;
curve 9 = 680 μF; 50 V;
curve 10 = 4700 μF; 6,3 V.

Fig. 11 Typical impedance at 10 kHz as a function of ambient temperature.

Curve 1 = 0,47 μF; 6,3 V;
curve 2 = 4,7 μF; 63 V;
curve 3 = 15 μF; 40 V;
curve 4 = 47 μF; 10 V;
curve 5 = 47 μF; 25 V;
curve 6 = 47 μF; 63 V;
curve 7 = 330 μF; 6,3 V.

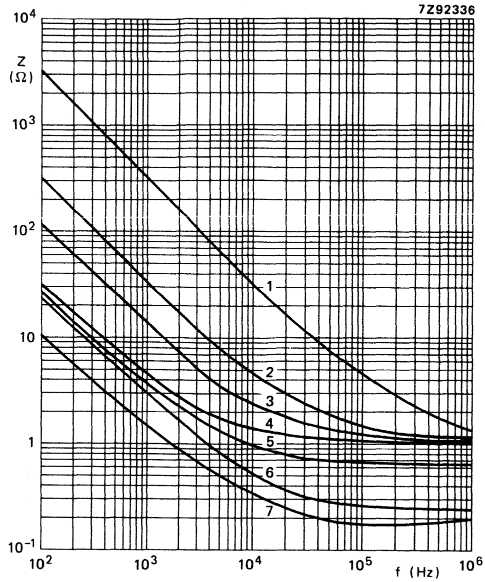


Fig. 12 Typical impedance as a function of frequency at T_{amb} = 20 °C.

Curve 1 = 150 μF; 63 V;
curve 2 = 680 μF; 6,3 V;
curve 3 = 680 μF; 50 V;
curve 4 = 4700 μF; 6,3 V.

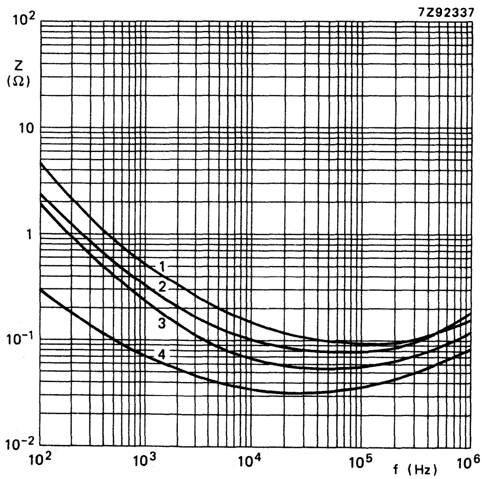


Fig. 13 Typical impedance as a function of frequency at T_{amb} = 20 °C.

OPERATIONAL DATA

Category temperature range — −40 to + 85 °C

→ Typical life time
- at T_{amb} = 40 °C — 50 000 h
- at T_{amb} = 85 °C — 2000 h
- at T_{amb} = 95 °C — 1000 h
- at T_{amb} = 105 °C — 500 h

→ Shelf life at 0 V and T_{amb} = 85 °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			

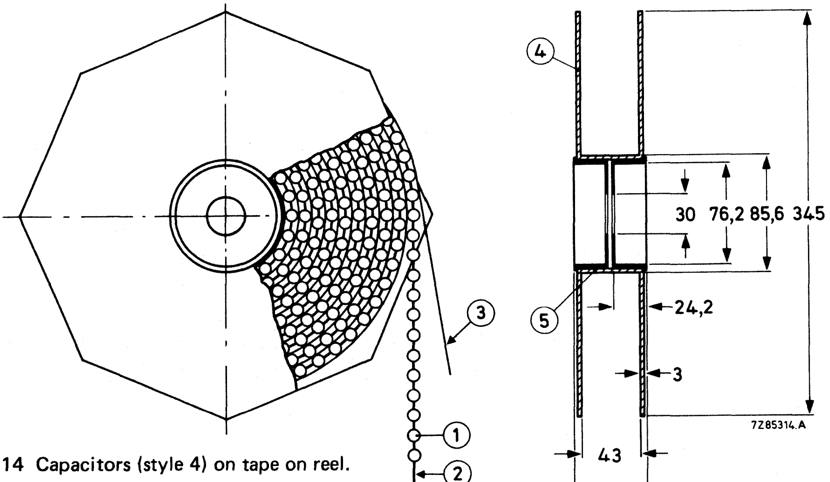


Fig. 14 Capacitors (style 4) on tape on reel.

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

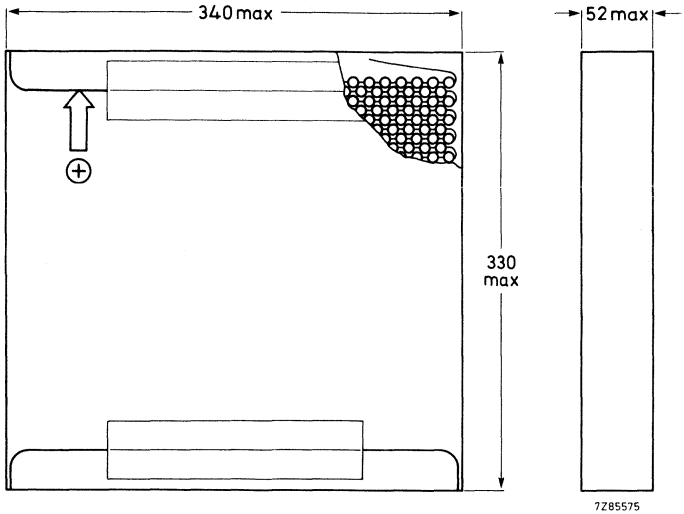


Fig. 15 Capacitors (style 5) on tape in ammunition pack.

TESTS AND REQUIREMENTS

See Introduction, section 9, under aluminium electrolytic capacitors.

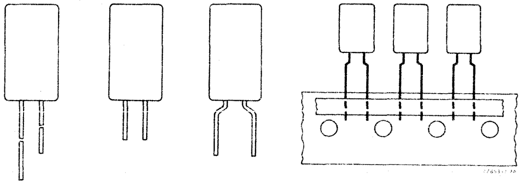
After *shelf life test, 500 h, 85 ^{o}C,* the capacitors meet the same requirements as after endurance test, except for leakage current of the 100 V range: $\leqslant$ 200% of specified value. The rated voltage shall be applied to the capacitors for minimum 30 min, at least 24 h and not more than 48 h before measurements.

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

For low-leakage version, see 2222 013; for high-temperature version, see 2222 116.

ALUMINIUM ELECTROLYTIC CAPACITORS

- **Miniature type**
- **Single ended**
- **Long life**
- **General and industrial applications**



QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	0,15 to 470 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 at 85 °C	2000 h
Shelf life at 0 V, 85 °C	500 h
Basic specification	IEC384-4, long-life grade DIN41332/DIN41259
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
0,15								11
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			11
33			11				11	13
47		11			11		13	13
68		11		11		13		13
100	11		11	13			13	
150		11	13		13			
220		13	13	13				
330	13		13					
470		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 extremely high CV product to volume ratio 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 timing and delay circuits. The taped versions are suitable for automatic insertion and for cutting and forming equipment.

DESCRIPTION

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

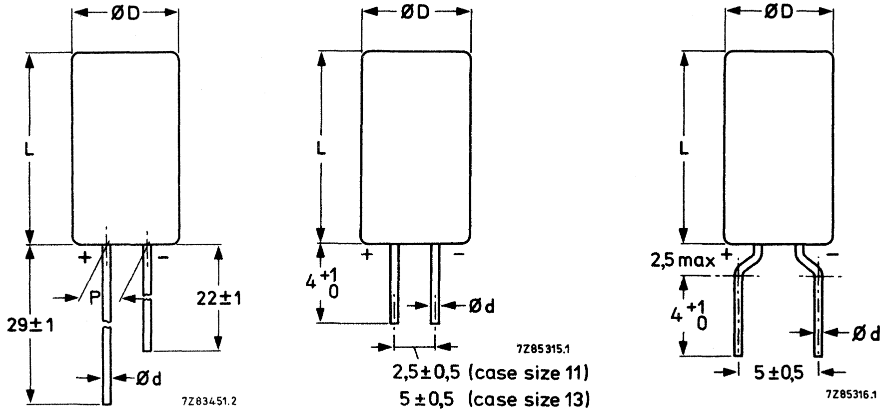


Fig. 1 Style 1; see Table 1 for dimensions d, D, L and P.

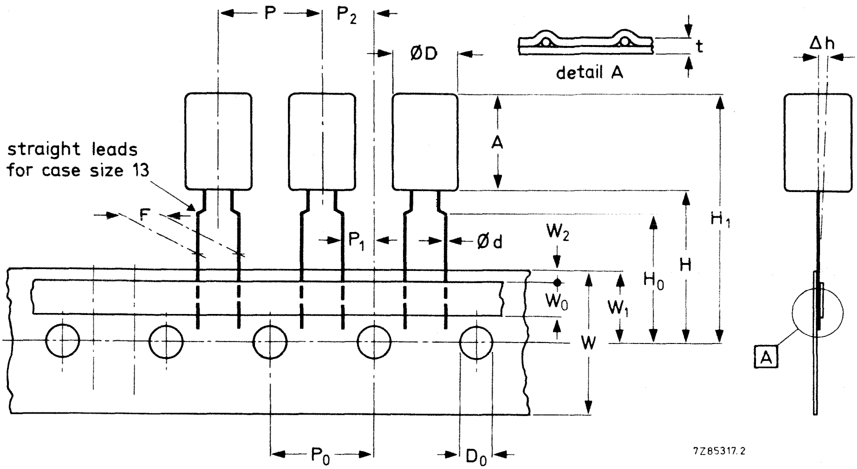
Fig. 2 Style 2; non preferred, see Table 1 for dimensions d, D and L.

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	6,0	6,0	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	32,0	32,0	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.

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

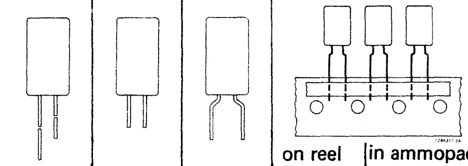
WARNING

Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled. Caution is necessary should the outer case be fractured.

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%.

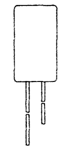
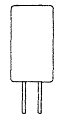
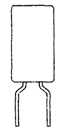
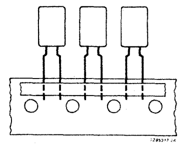
Table 3



U_R 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	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	11	53101	83101	63101	23101	33101
	330	320	16	0,20	13	53331	63331		23331	33331
10	47	100	6	0,16	11	54479	84479	64479	24479	34479
	68	120	7	0,16	11	54689	84689	64689	24689	34689
	150	95	12	0,20	11	54151	84151	64151	24151	34151
	220	250	17	0,16	13	54221	64221		24221	34221
	470	230	31	0,20	13	54471	64471		24471	34471
16	33	90	7	0,14	11	55339	85339	65339	25339	35339
	100	90	13	0,16	11	55101	85101	65101	25101	35101
	150	270	18	0,14	13	55151	65151		25151	35151
	220	230	24	0,14	13	55221	65221		25221	35221
	330	210	35	0,16	13	55331	65331		25331	35331
25	68	80	13	0,14	11	56689	86689	66689	26689	36689
	100	230	18	0,12	13	56101	66101		26101	36101
	220	180	36	0,14	13	56221	66221		26221	36221
35	22	90	8	0,10	11	90001	90002	90003	90016	90027
	47	70	13	0,12	11	90094	90095	90096	90097	90098
	150	160	35	0,12	13	90099	90101		90102	90103
40	15	70	7	0,10	11	57159	87159	67159	27159	37159
	68	200	20	0,10	13	57689	67689		27689	37689
50	10	60	6	0,08	11	90004	90005	90006	90017	90028
	33	65	13	0,10	11	90104	90105	90106	90107	90108
	47	180	18	0,08	13	90011	90012		90019	90031
	100	150	33	0,10	13	90109	90111		90112	90113

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

Table 3 (continued)

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. tan δ	case size*	catalogue number 2222 036 followed by				
						 style 1	 style 2	 style 3	 on reel style 4	in ammopack style 5
63	0,15	5	4	0,08	11	58157	88157	68157	28157	38157
	0,22	5,5	4	0,06	11	58227	88227	68227	28227	38227
	0,33	7	4	0,06	11	58337	88337	68337	28337	38337
	0,47	8	4	0,06	11	58477	88477	68477	28477	38477
	0,68	10	4	0,06	11	58687	88687	68687	28687	38687
	1,0	12	4	0,06	11	58108	88108	68108	28108	38108
	1,5	16	4	0,06	11	58158	88158	68158	28158	38158
	2,2	22	4	0,06	11	58228	88228	68228	28228	38228
	3,3	32	5	0,06	11	58338	88338	68338	28338	38338
	4,7	40	5	0,06	11	58478	88478	68478	28478	38478
	6,8	55	6	0,06	11	58688	88688	68688	28668	38688
	10	70	7	0,06	11	58109	88109	68109	28109	38109
	22	55	11	0,08	11	58229	88229	68229	28229	38229
	33	160	16	0,06	13	58339	68339		28339	38339
	47	150	21	0,07	13	58479	68479		28479	38479
	68	140	29	0,08	13	58689	68689		28689	39689

* 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%

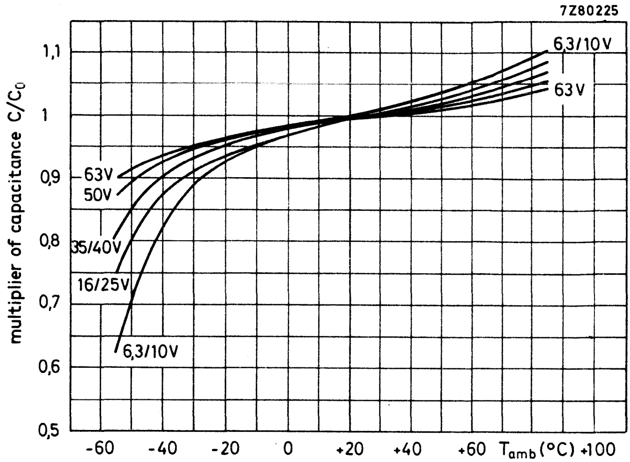


Fig. 5 Typical multiplier of capacitance as a function of ambient temperature; C_0 = capacitance at 20 °C, 100 Hz.

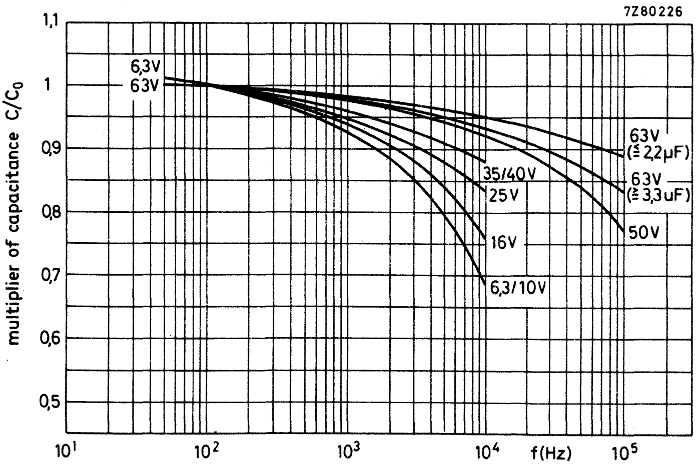


Fig. 6 Typical multiplier of capacitance as a function of frequency; C_0 = capacitance at 20 °C, 100 Hz.

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 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 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

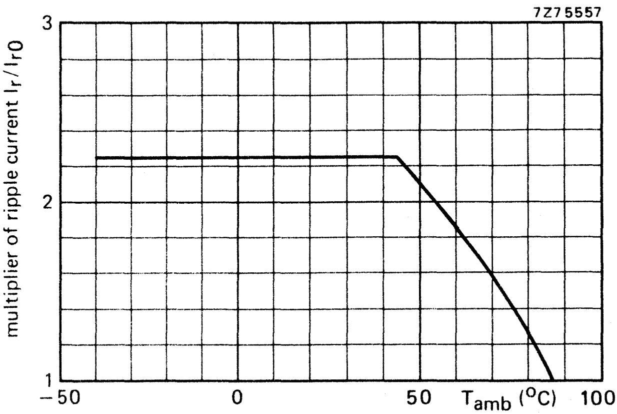


Fig. 7 Typical multiplier of ripple current as a function of ambient temperature; I_{r0} = ripple current at 85 °C, 100 Hz.

* 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.

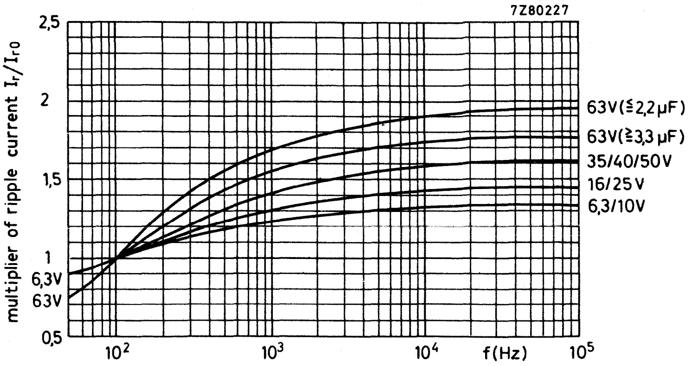


Fig. 8 Typical multiplier of ripple current as a function of frequency;
I_{r0} = ripple current at 85 °C, 100 Hz.

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

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} = 20 °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

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 a four-terminal circuit (Thomson circuit) — see Table 3

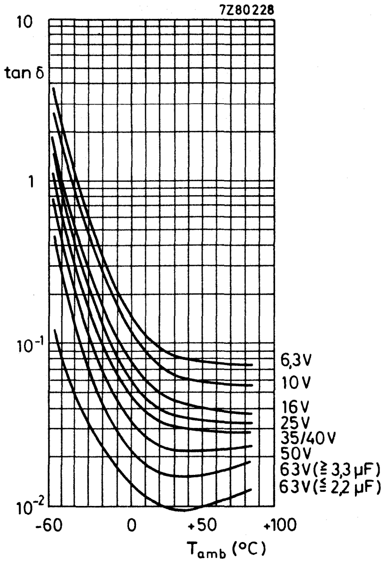


Fig. 9 Typical tan δ at 100 Hz as a function of ambient temperature.

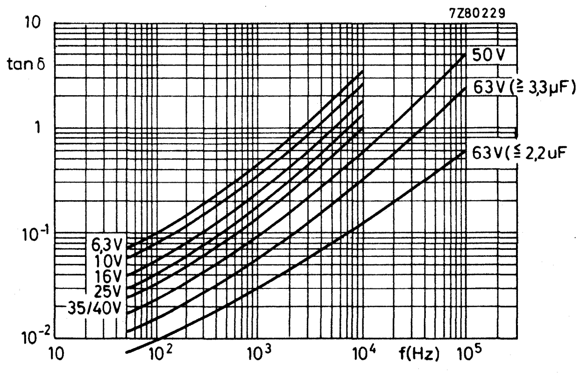


Fig. 10 Typical tan δ as a function of frequency at T_{amb} = 20 °C.

Equivalent series resistance (ESR)

ESR = $\tan \delta / \omega C$
Maximum $\tan \delta$ and C at 100 Hz and T_{amb} = 25 °C — see Table 3

Equivalent series inductance (ESL)

Case size 11	typ. 13 nH
Case size 13	typ. 16 nH

Impedance (Z)

Maximum impedance at T_{amb} = 20 °C, −25 °C and −40 °C and 10 kHz, measured by a four-terminal circuit (Thomson circuit) — see Table 4

Maximum ratio between impedances at T_{amb} = −25 °C and +20 °C, at T_{amb} = −40 °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 4

Table 4

U_R V	nom. cap. µF	case size*	max. impedance at 10 kHz T_{amb} = 20 °C Ω	T_{amb} = −25 °C Ω	T_{amb} = −40 °C Ω	maximum impedance ratio at U_R and 100 Hz $\frac{Z \text{ at } -25\,^oC}{Z \text{ at } +20\,^oC}$	$\frac{Z \text{ at } -40\,^oC}{Z \text{ at } +20\,^oC}$	$\frac{Z \text{ at } -55\,^oC}{Z \text{ at } +20\,^oC}$
6,3	100	11	1,7	9,0	25,0	2	3	7
	330	13	0,52	2,7	7,6	2	3	7
10	47	11	2,8	11,9	31,9	2	3	5
	68	11	1,9	8,2	22,1	2	3	5
	150	11	1,3	8,0	21,3	2	3	8
	220	13	0,59	2,6	6,8	2	3	5
	470	13	0,43	2,6	6,8	2	3	8
16	33	11	2,7	12,1	33,1	1,5	2	5
	100	11	1,6	7,5	20,0	1,5	2	6
	150	13	0,60	2,7	7,3	1,5	2	5
→	220	13	0,55	2,5	6,8	1,5	2	5
	330	13	0,48	2,3	6,1	1,5	2	6
25	68	11	1,8	8,2	22,1	1,5	2	5
	100	13	0,70	3,0	9,0	1,5	2	4
	220	13	0,55	2,6	6,8	1,5	2	5
35	22	11	2,7	11,4	34,1	1,5	2	4
	47	11	1,9	8,5	23,4	1,5	2	4
	150	13	0,60	2,7	7,3	1,5	2	4
40	15	11	3,7	14,7	46,7	1,5	2	3
	68	13	0,81	3,2	10,3	1,5	2	3
50	10	11	4,5	16,0	58,0	1,5	2	3
	33	11	2,1	9,1	27,3	1,5	2	3
	47	13	0,96	3,4	12,3	1,5	2	3
	100	13	0,70	3,0	9,0	1,5	2	3
→ 63	0,15	11	267	867	2670	1,3	1,5	2
	0,22	11	182	591	1818	1,3	1,5	2
	0,33	11	121	394	1212	1,3	1,5	2
	0,47	11	85,1	277	851	1,3	1,5	2
	0,68	11	58,1	191	588	1,3	1,5	2
	1,0	11	40	130	400	1,3	1,5	2
	1,5	11	26,7	86,7	267	1,3	1,5	2
	2,2	11	18,2	59,1	182	1,3	1,5	2
	3,3	11	12,1	39,4	121	1,5	2	3
	4,7	11	8,5	27,2	85,1	1,5	2	3
	6,8	11	5,9	19,1	58,8	1,5	2	3
	10	11	4,0	13,0	40,0	1,5	2	3
	22	11	2,7	10,0	31,8	1,5	2	3
	33	13	1,2	3,9	12,1	1,5	2	3
→	47	13	1,0	3,5	11,2	1,5	2	3
	68	13	0,88	3,2	10,3	1,5	2	3

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

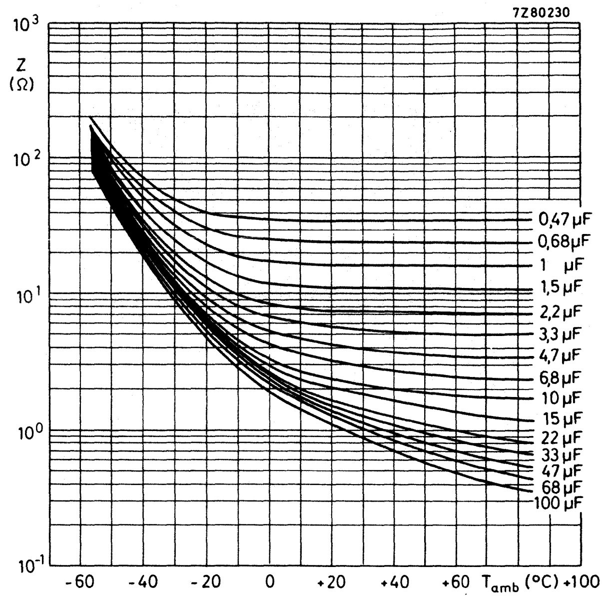


Fig. 11 Typical impedance at 10 kHz as a function of ambient temperature, case size 11.

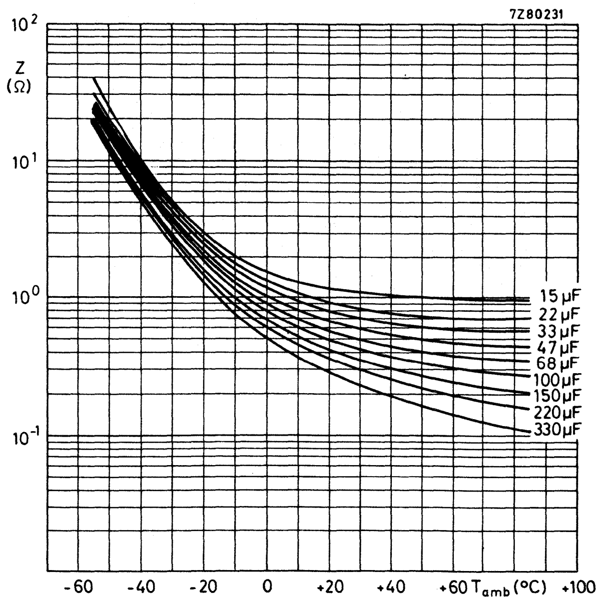


Fig. 12 Typical impedance at 10 kHz as a function of ambient temperature, case size 13.

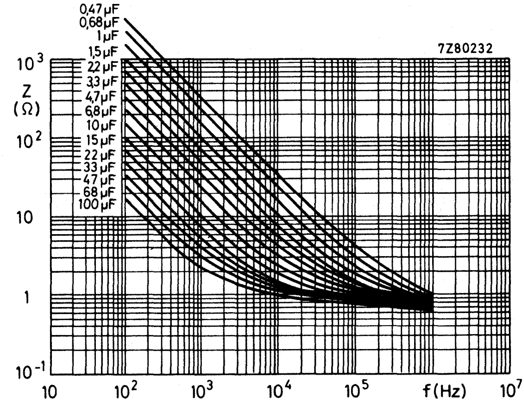


Fig. 13 Typical impedance as a function of frequency at T_{amb} = 20 °C, case size 11.

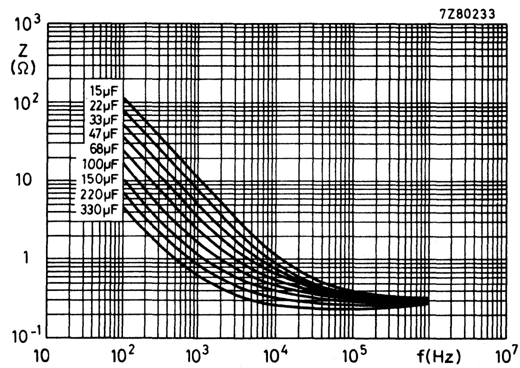


Fig. 14 Typical impedance as a function of frequency at T_{amb} = 20 °C, case size 13.

OPERATIONAL DATA

Category temperature range	−55 to +85 °C
Typical life time	
at T_{amb} = 40 °C	70 000 h
at T_{amb} = 85 °C	3000 h
at T_{amb} = 95 °C	1500 h
at T_{amb} = 105 °C	750 h
Shelf life at 0 V and T_{amb} = 85 °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 5.

Table 5

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

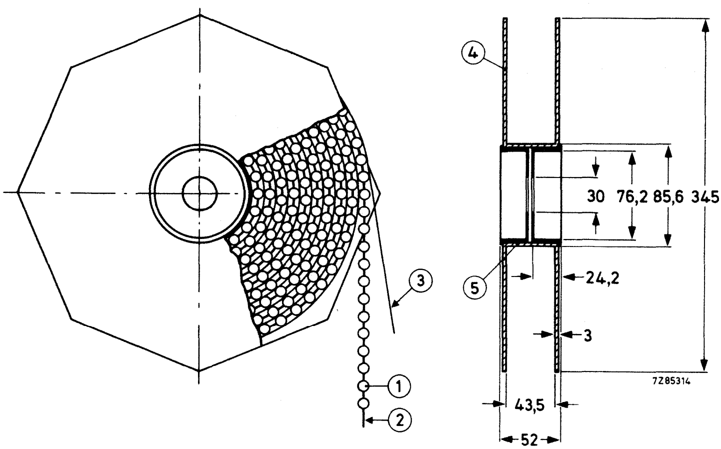


Fig. 15 Capacitors (style 4) on tape on reel.

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

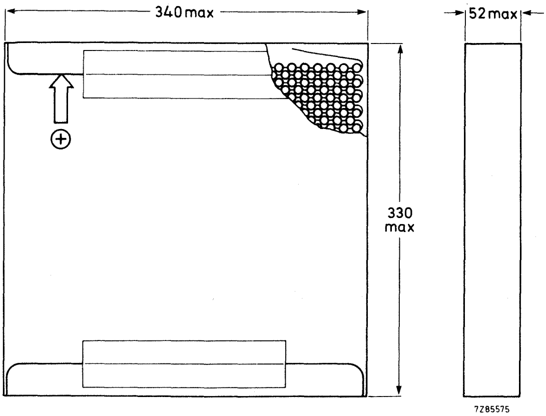


Fig. 16 Capacitors (style 5) on tape in ammunition pack.

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;

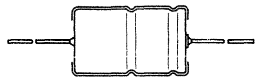
leakage current $\leqslant$ specified value.

After *shelf life test, 500 h, 85 °C,* the capacitors meet the same requirements. The rated voltage shall be applied to the capacitors for minimum 30 min, at least 24 h and not more than 48 h before measurements.

Note- Capacitors 2222 036 are miniature, long-life grade.

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
Shelf life at 0 V, 85 °C	500 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
63	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
	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

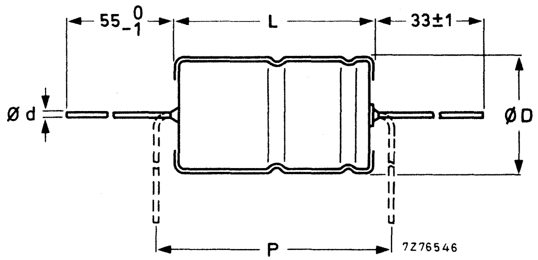


Fig. 1 For dimensions d, D, L and P, see Table 1.

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

→ WARNING

Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled. Caution is necessary should the outer case be fractured.

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
	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
63	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%.

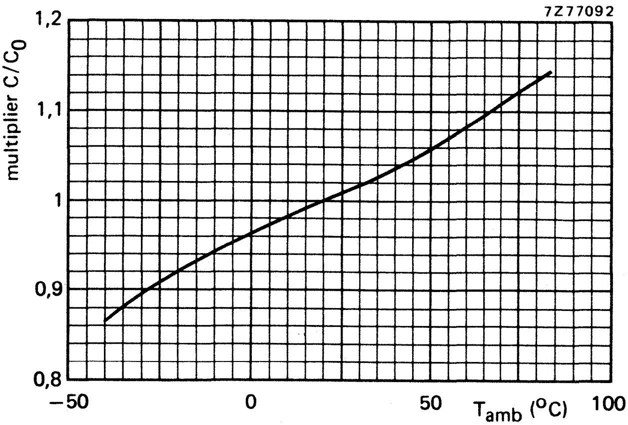


Fig. 2 Typical capacitance as a function of ambient temperature; C_0 = capacitance at 20 °C and 100 Hz.

* See also corresponding paragraph.

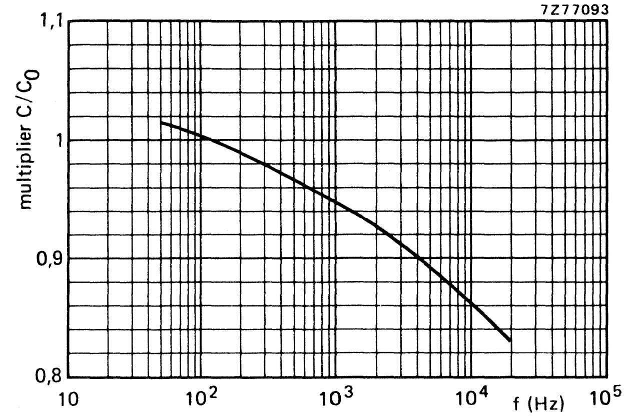


Fig. 3 Typical capacitance as a function of frequency; C_0 = capacitance at 20 °C and 100 Hz.

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.

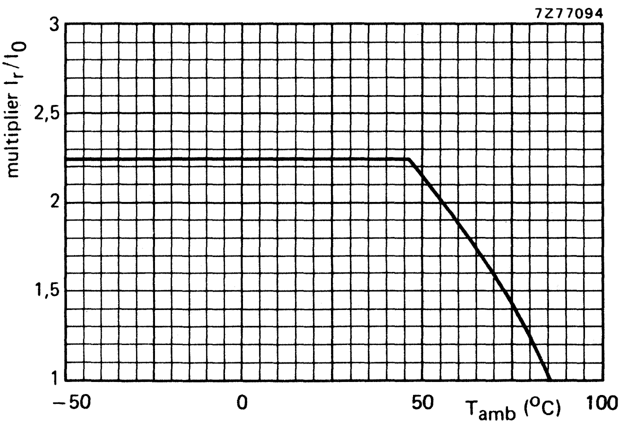


Fig. 4 Typical ripple current as a function of ambient temperature; I_0 = ripple current at 85 °C and 100 Hz.

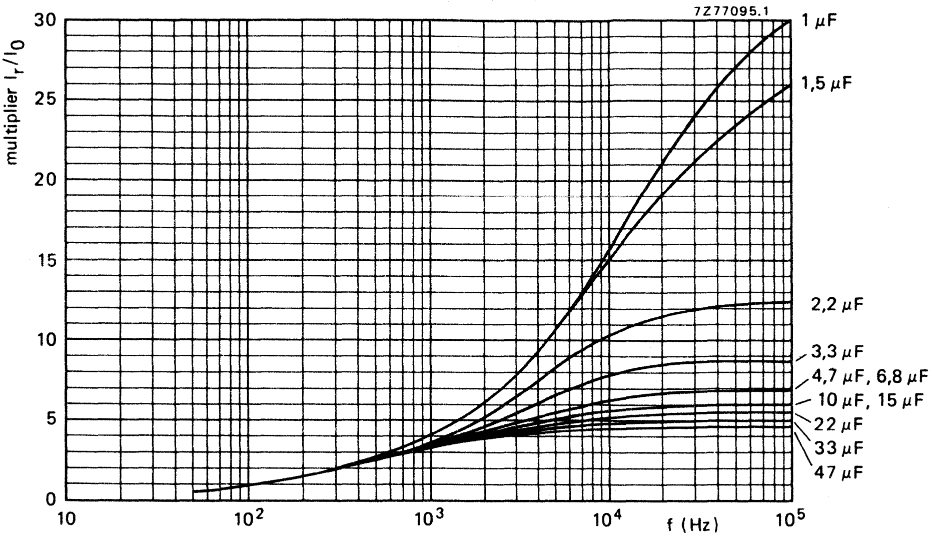


Fig. 5 Typical ripple current as a function of frequency; I_0 = ripple current at 85 °C and 100 Hz.

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.

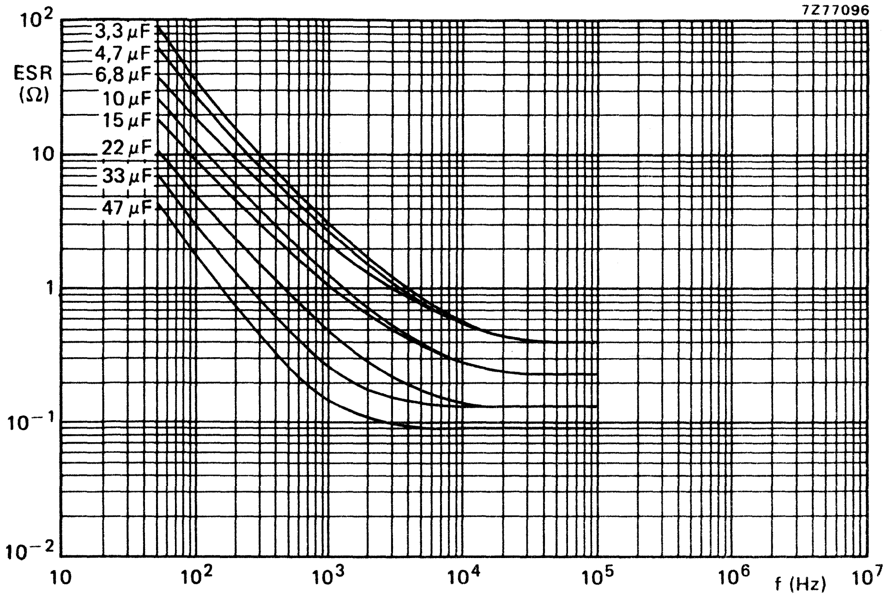


Fig. 6 Typical ESR as a function of frequency at 25 °C.

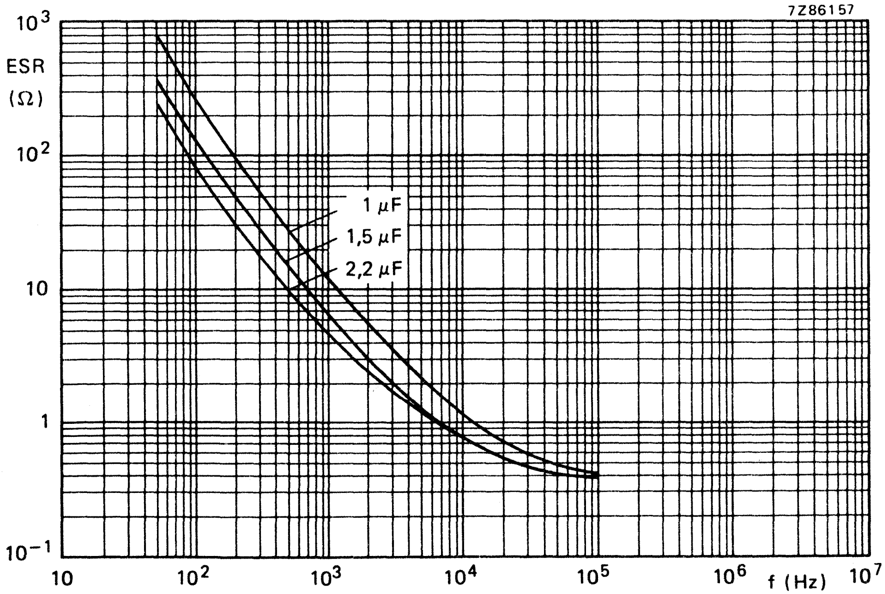


Fig. 7 Typical ESR as a function of frequency at 25 °C.

Impedance

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

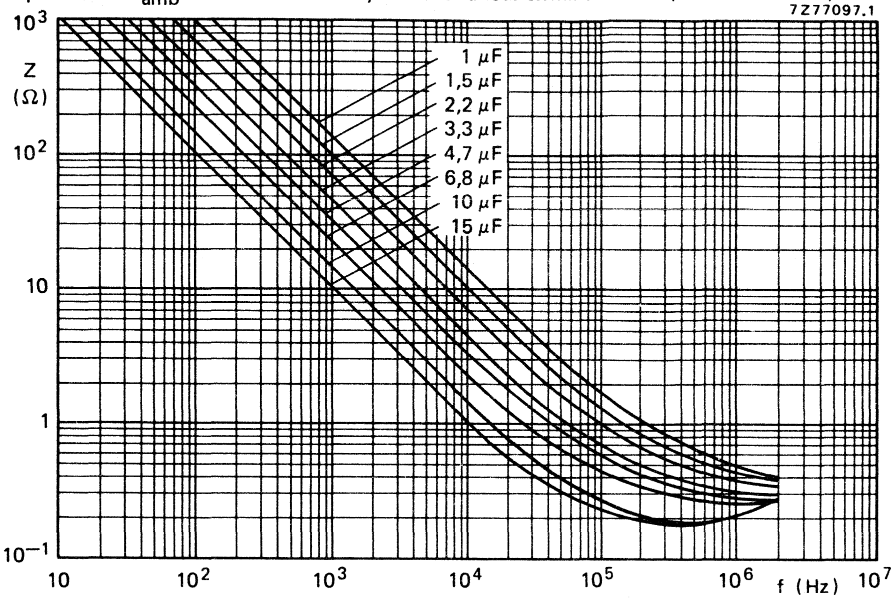


Fig. 8 Typical impedance as a function of frequency at 25 °C.

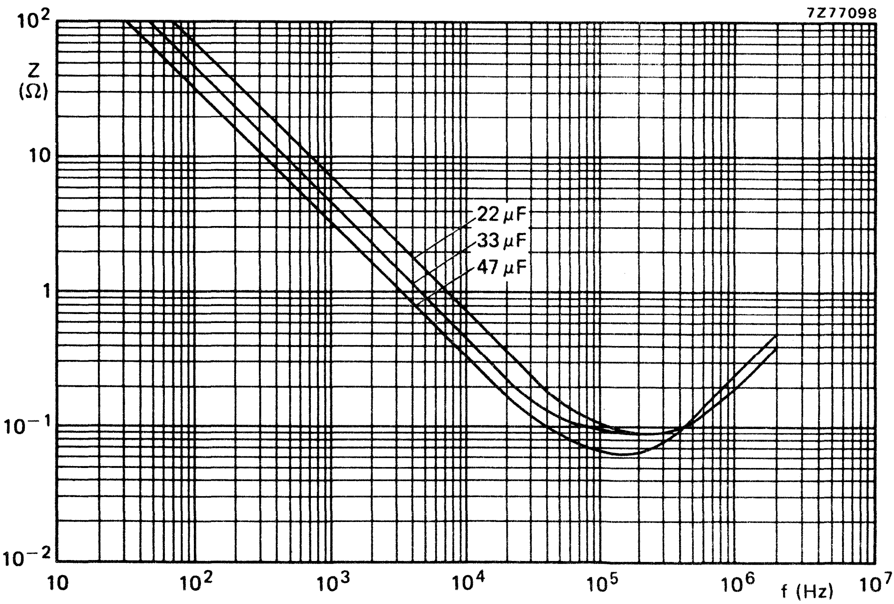


Fig. 9 Typical impedance as a function of frequency at 25 °C.

OPERATIONAL DATA

Category temperature range	−40 to + 85 °C
→ Typical life time	
at T_{amb} = 85 °C	10 000 h
at T_{amb} = 40 °C	> 200 000 h
→ Shelf life at 0 V and T_{amb} = 85 °C	500 h

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 ≤ stated limit, ESR ≤ 1,3 x stated limit, ΔC/C ≤ 15%, ratio of impedances at 10 kHz before and after test ≤ 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 ≤ 2 x stated limit, ΔC/C ≤ 15%, ratio of impedances at 10 kHz before and after test ≤ 2, insulation resistance > 100 MΩ, no breakdown or flashover.

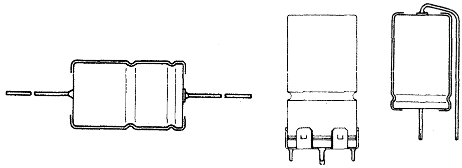
→ After *shelf life test,* 500 h, 85 °C, the capacitors meet the same requirements as after endurance test. The rated voltage shall be applied to the capacitors for minimum 30 min., at least 24 h and not more than 48 h before measurements.

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 and 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
Shelf life at 0 V, 85 °C	500 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 and oxidized 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 capacitors are available in 3 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.

MECHANICAL DATA

Dimensions in mm

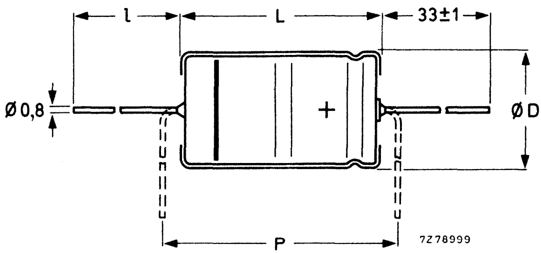


Fig. 1 Style 1; see Table 1a for dimensions D, L, l and P.

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

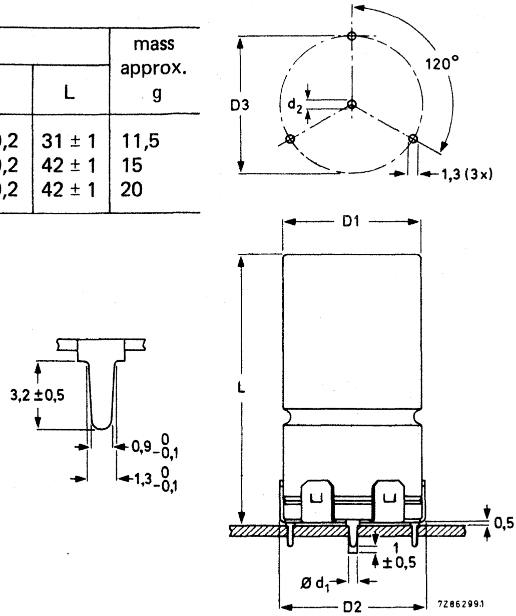


Fig. 2 Style 2; see Table 1b for dimensions d_1, d_2, D1, D2, D3 and L.

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

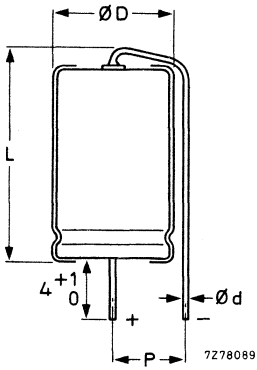


Fig. 3 Style 3 see Table 1c for dimensions d, D, L and P.

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 and 3 is 1 + 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

→ WARNING

Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled. Caution is necessary should the outer case be fractured.

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	35	4	041 .3228
	4,7	29	55	61,7	0,18	18	5	041 .3478
	10	55	95	29	0,18	7	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	12	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	40	4	041 .8108
	2,2	23	42	152	0,20	20	5	041 .8228
	4,7	43	71	71,3	0,20	8	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 (preferred for case size 4) } case sizes 4 to 7
3 for style 1 on bandoliers in box (preferred for case sizes 5 to 7) } case sizes 4 to 7
4 for style 2, case sizes 03, 04, 05;
8 for style 3.

Capacitance

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

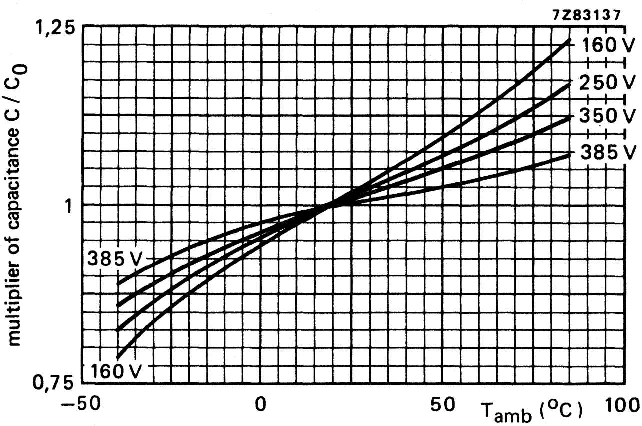


Fig. 4 Multiplier of capacitance as a function of ambient temperature; **case sizes 4 to 7**; C_0 = capacitance at 20 °C, 100 Hz.

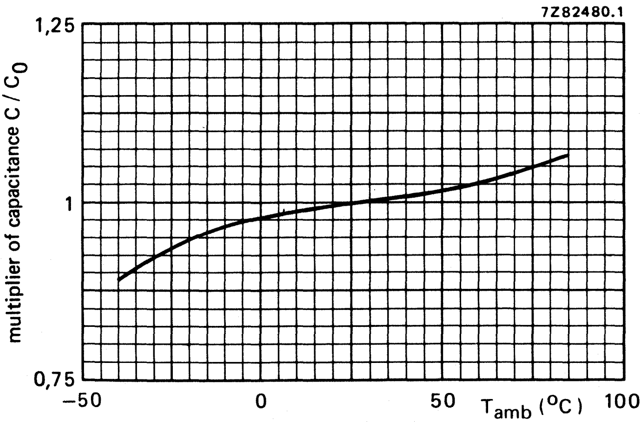


Fig. 5 Multiplier of capacitance as a function of ambient temperature; **case sizes 00 to 05**; C_0 = capacitance at 25 °C, 100 Hz.

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

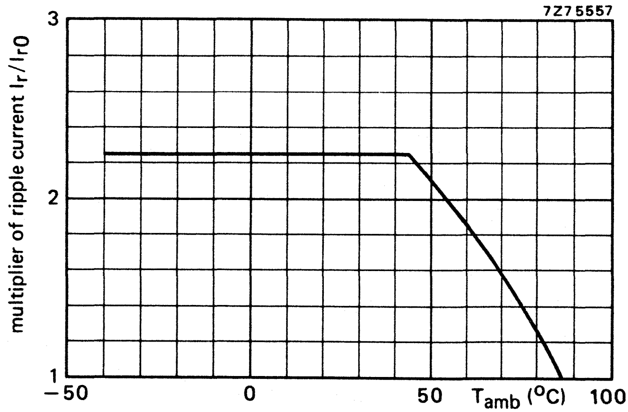


Fig. 6 Multiplier of ripple current as a function of ambient temperature; I_{r0} = ripple current at 85 °C, 100 Hz.

* 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.

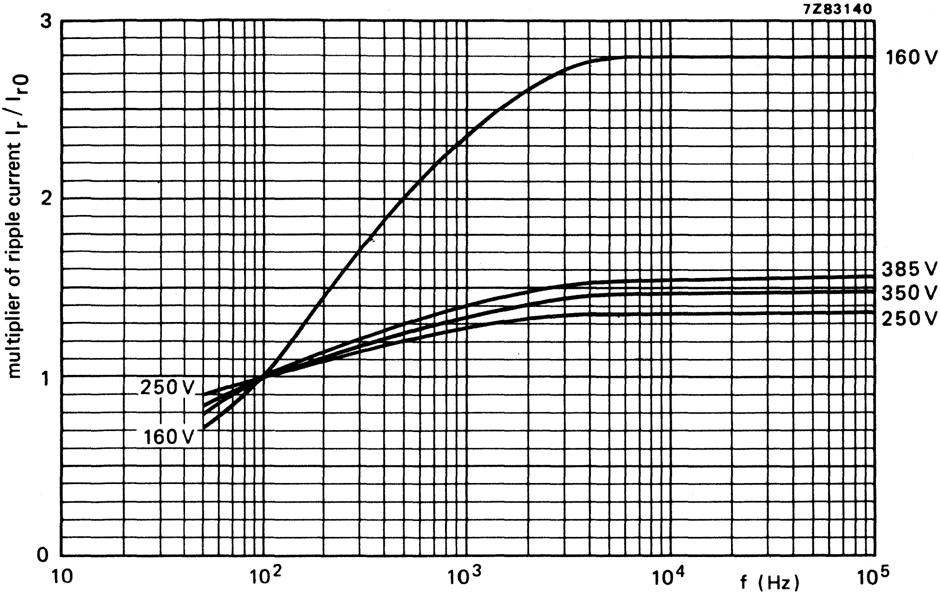


Fig. 7 Multiplier of ripple current as a function of frequency; **case sizes 4 to 7**; I_{r0} = ripple current at 85 °C, 100 Hz.

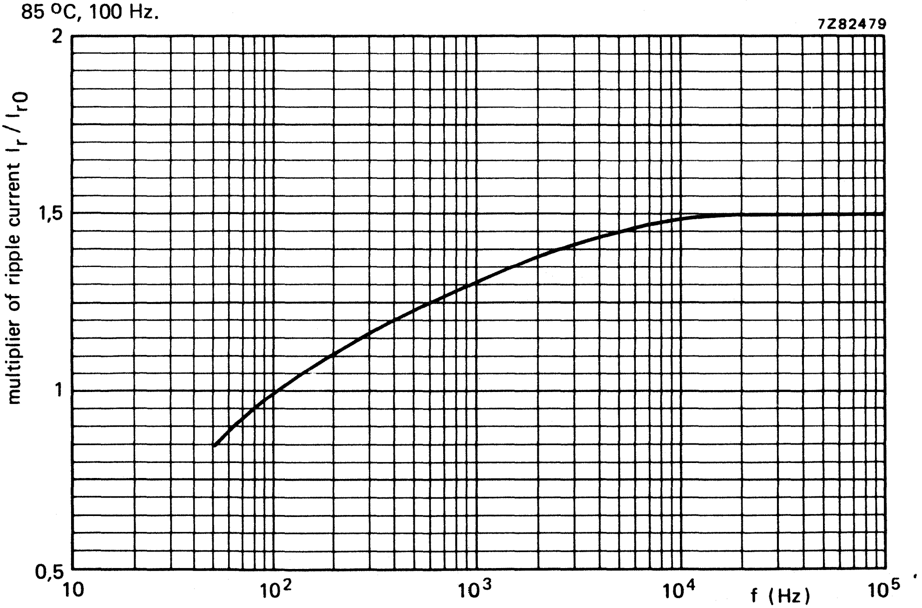


Fig. 8 Multiplier of ripple current as a function of frequency; **case sizes 00 to 05**; I_{r0} = ripple current at 85 °C, 100 Hz.

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;
$\sqrt{r_n} = I_r/I_{r0}$ = 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-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, whichever is greater for CU ⩽ 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 ⩽ 1000 μC; 0,006 CU + 4 μA for CU > 1000 μC 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.

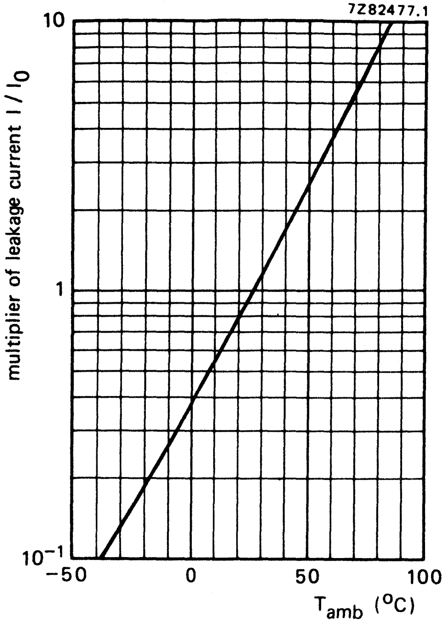


Fig. 9 Multiplier of leakage current as a function of ambient temperature; I_0 = leakage current during continuous operation at 25 °C and U_R.

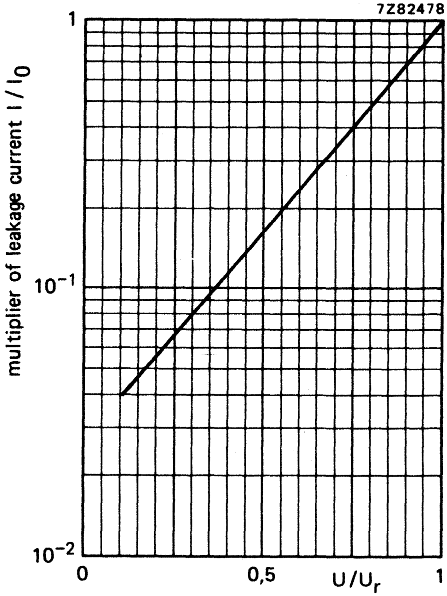


Fig. 10 Multiplier of leakage current as a function of U/U_R; I_0 = leakage current during continuous operation at 25 °C and U_R.

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

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

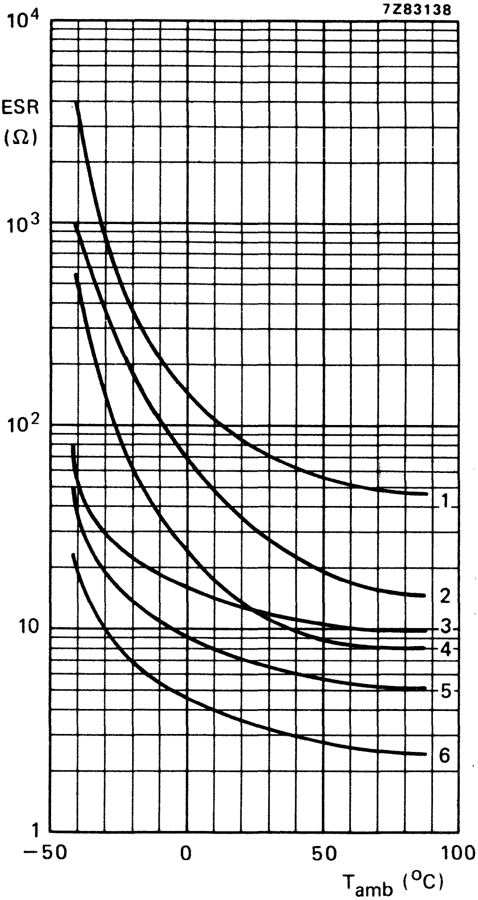


Fig. 11 Typical ESR as a function of ambient temperature at 100 Hz; **case sizes 4 to 7.**
Curve 1 = case size 4, 385 V;
curve 2 = case size 5, 385 V;
curve 3 = case size 4, 160 V;
curve 4 = case size 7, 385 V;
curve 5 = case size 5, 160 V;
curve 6 = case size 7, 160 V.

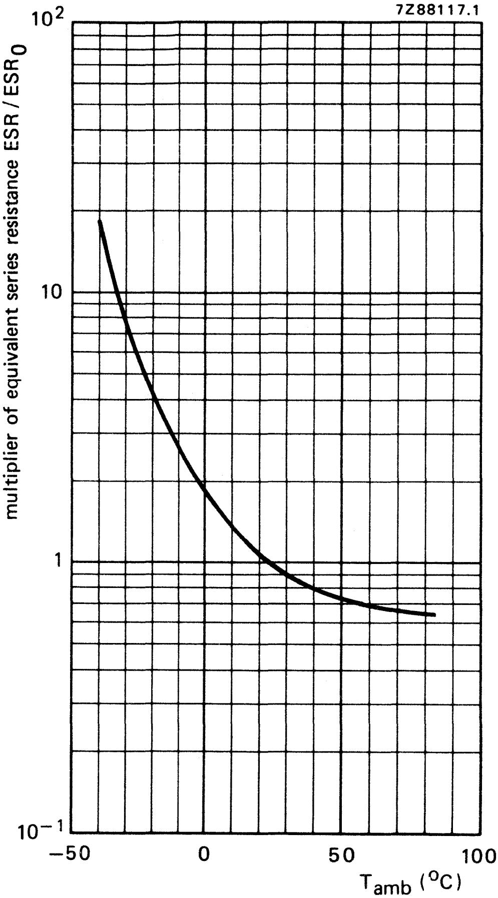


Fig. 12 Multiplier of ESR as a function of ambient temperature; **case sizes 00 to 05;** ESR_0 = typ. ESR at 25 °C, 100 Hz.

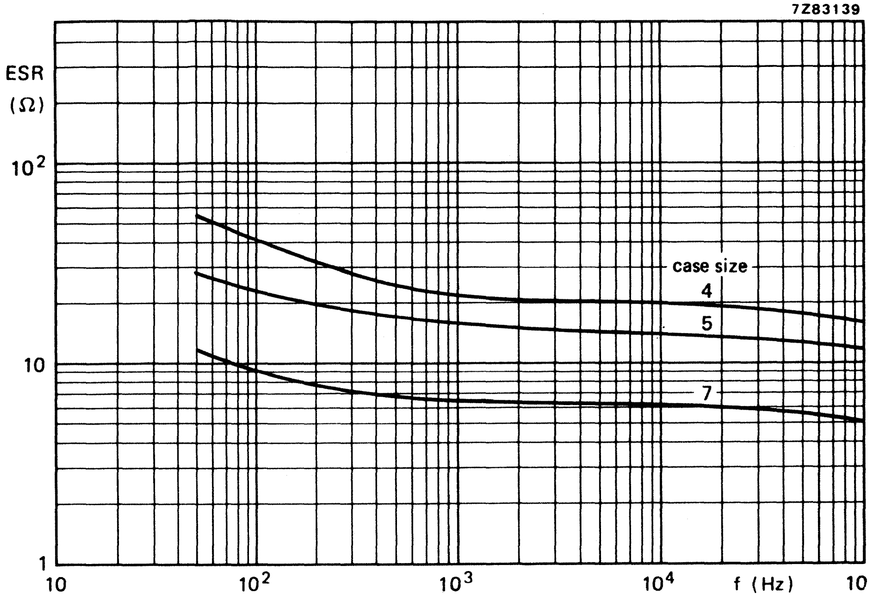


Fig. 13 Typical ESR as a function of frequency at 20 °C; U_R = 250 V; **case sizes 4 to 7.**

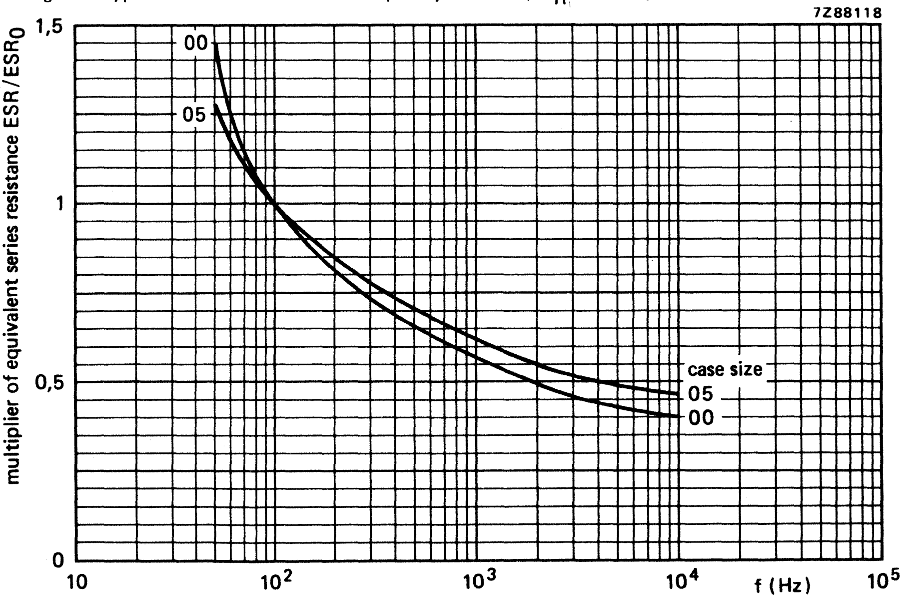


Fig. 14 Multiplier of ESR as a function of frequency; **case sizes 00 to 05**; ESR_0 = typ. ESR at 25 °C, 100 Hz.

Impedance

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

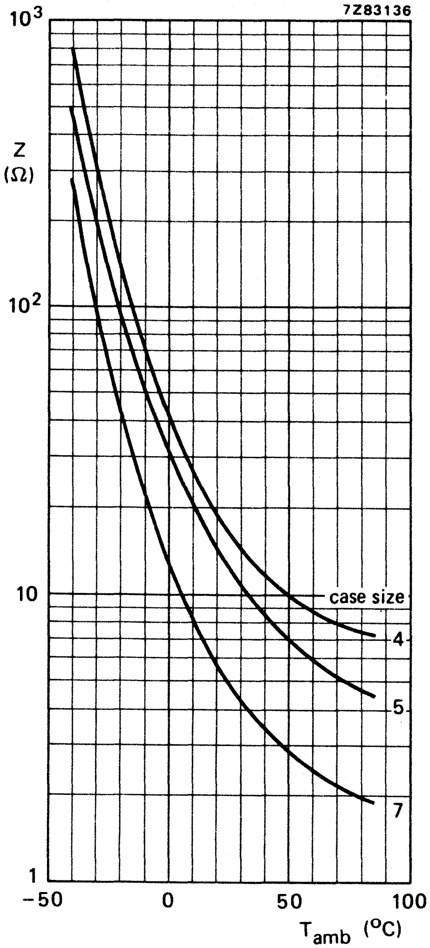


Fig. 15 Typical impedance as a function of ambient temperature at 10 kHz; U_R = 250 V; **case sizes 4 to 7.**

see Table 2

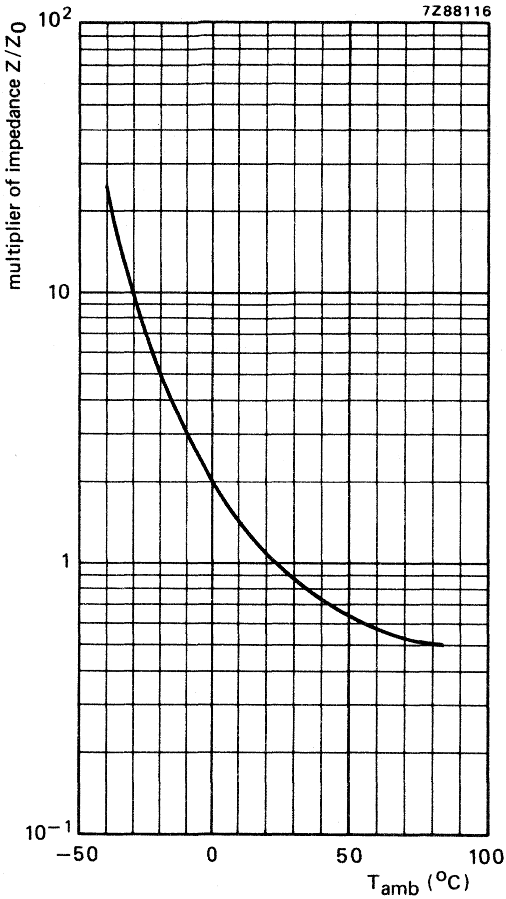


Fig. 16 Multiplier of impedance as a function of ambient temperature; **case sizes 00 to 05;** Z_0 = typ. impedance at 25 °C, 10 kHz (see Table 2).

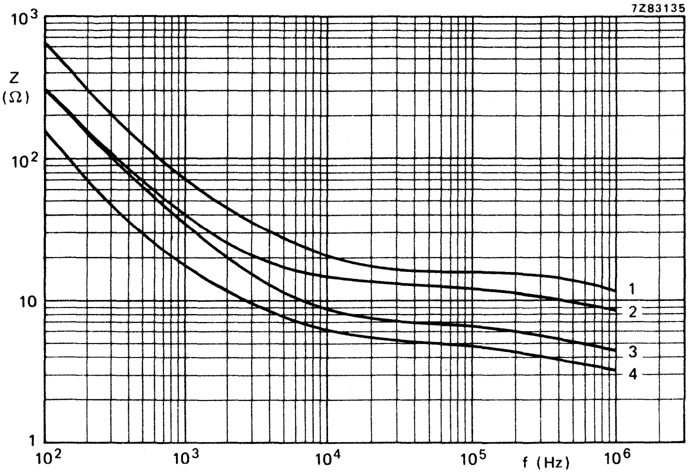


Fig. 17 Typical impedance as a function of frequency at 20 °C. **Case sizes 4 to 7.**

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.

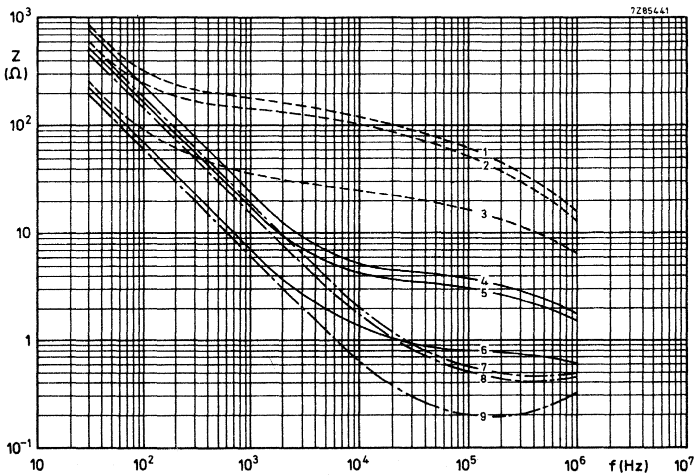


Fig. 18 Typical impedance as a function of frequency at different temperatures. **Case size 00.**

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.

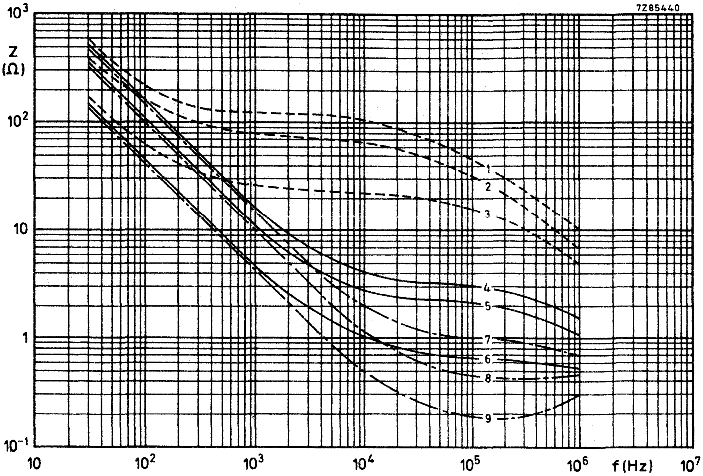


Fig. 19 Typical impedance as a function of frequency at different temperatures. **Case size 01.**

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.

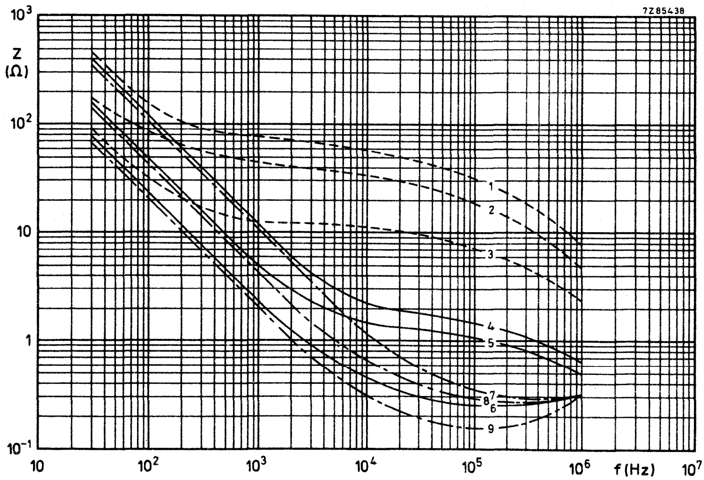


Fig. 20 Typical impedance as a function of frequency at different temperatures. **Case size 02.**

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.

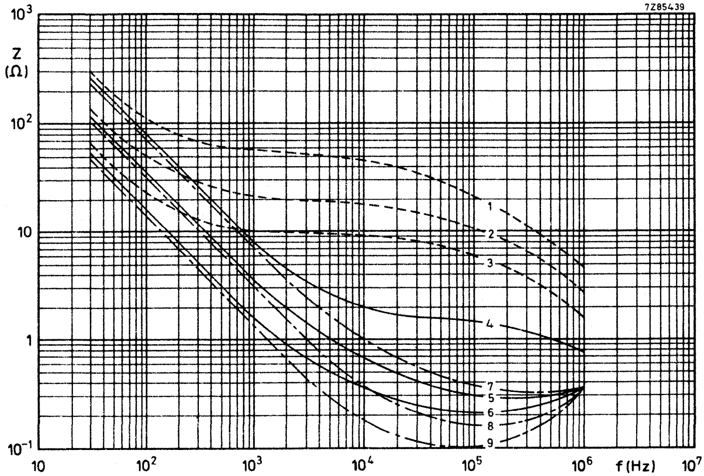


Fig. 21 Typical impedance as a function of frequency at different temperatures. **Case size 03.**

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.

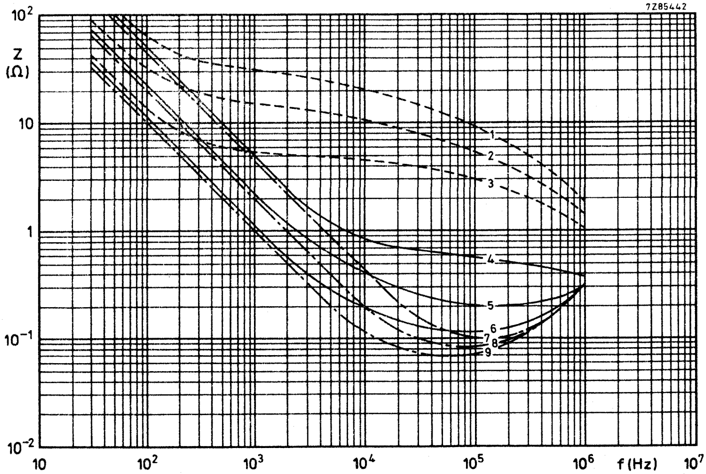


Fig. 22 Typical impedance as a function of frequency at different temperatures. **Case size 04.**

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.

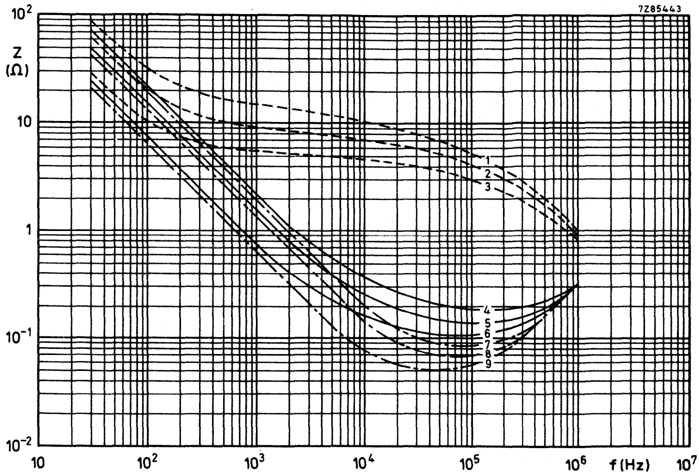


Fig. 23 Typical impedance as a function of frequency at different temperatures. **Case size 05.**

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 size 4	30 nH	typical values
Case size 5	50 nH	
Case sizes 6 and 7	65 nH	
Case sizes 00 and 01	50 nH	
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

	T_{amb} = 85 °C	T_{amb} = 40 °C
case sizes 4 to 7	5000 h	> 100 000 h
case sizes 00 to 05	10 000 h	> 200 000 h

Shelf life at 0 V and T_{amb} = 85 °C: 500 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		
	style 1 per reel	style 1 per box	styles 2 and 3 per box
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

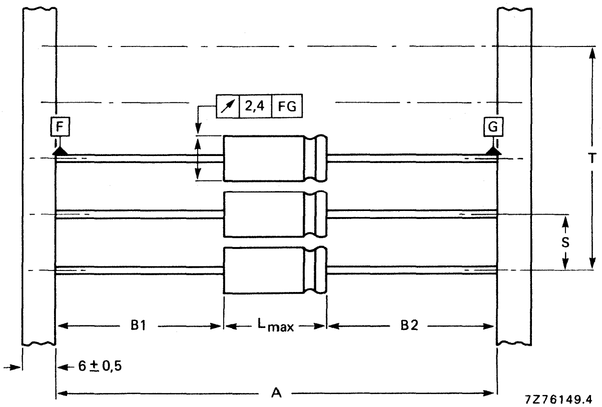


Fig. 24 Style 1 capacitors (case sizes 4 to 7) on bandoliers: the bandolier to which the negative capacitor terminals are connected is blue. See Table 4 for dimensions A, S, T and L. |B1 − B2| = max. 1,4 mm.

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

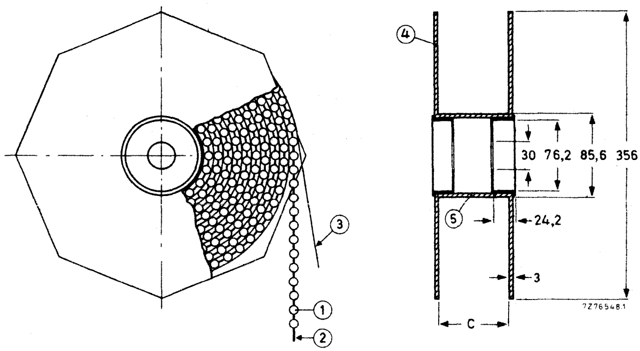


Fig. 25 Style 1 capacitors (case sizes 4 to 7) on bandoliers on reel; dimension C is 88,5 mm; the overall width of the reel is 99,5 mm.

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

TESTS AND REQUIREMENTS

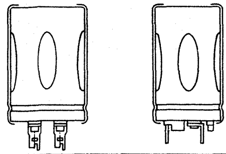
See Introduction, section 9, under aluminium electrolytic capacitors.

After *shelf life test, 500 h, 85 °C,* the capacitors meet the same requirements as after endurance test, except for leakage current: ≤ 200% of specified value. The rated voltage shall be applied to the capacitors for minimum 30 min, at least 24 h and not more than 48 h before measurements.

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
Shelf life at 0 V, 85 °C	500 h
Basic specification	IEC 384-4, long-life grade; DIN 41240
Dimensional specification	DIN 41238
Climatic category, IEC 68	40/085/56
DIN 40040	GPF (56 days)
Approval	CECC 30 301-033

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

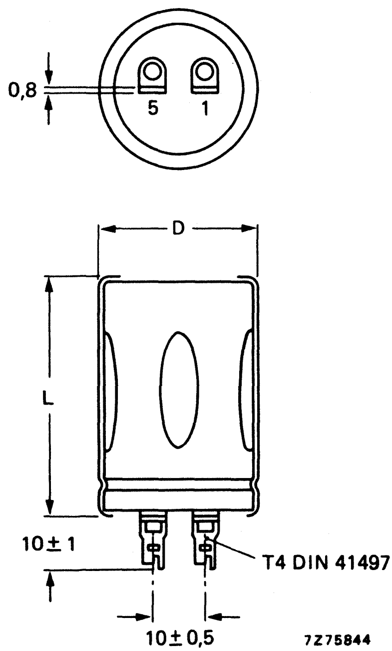


Fig. 1.

1 = positive terminal;
5 = negative terminal.

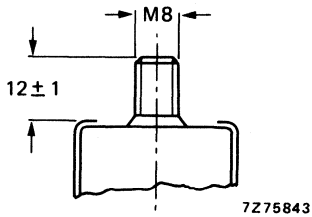


Fig. 2 Bolt version.

Table 1a

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

(D: all values + 0,6; L: all values + 1,3)

Capacitors with printed-wiring pins

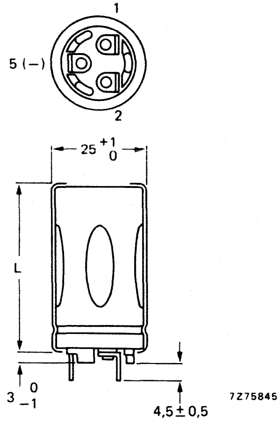


Fig. 3a.

1 = positive terminal;
5 = negative terminal.

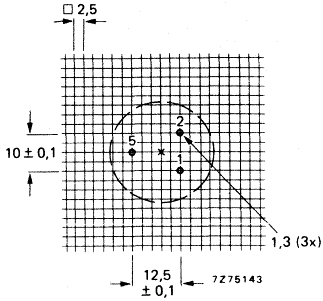


Fig. 3b Piercing diagram viewed from component side.

Table 1b

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

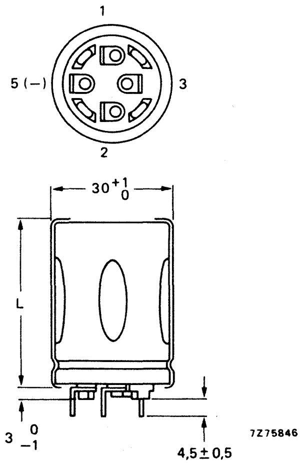


Fig. 4a.

1 = positive terminal;
5 = negative terminal.

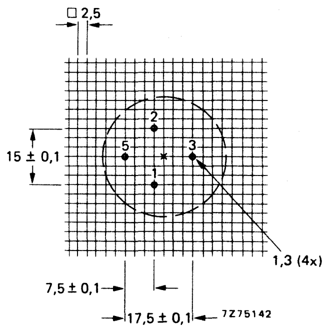


Fig. 4b Piercing diagram viewed from component side.

Table 1c

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

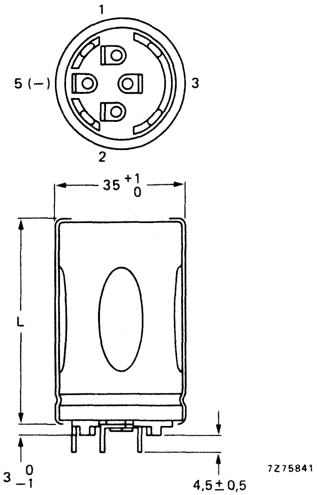


Fig. 5a.

1 = positive terminal;
5 = negative terminal.

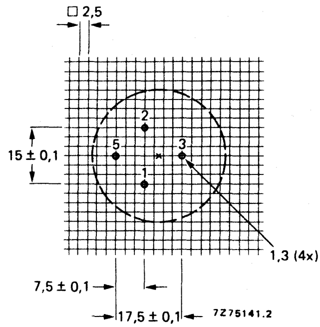


Fig. 5b Piercing diagram viewed from component side.

Table 1d

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

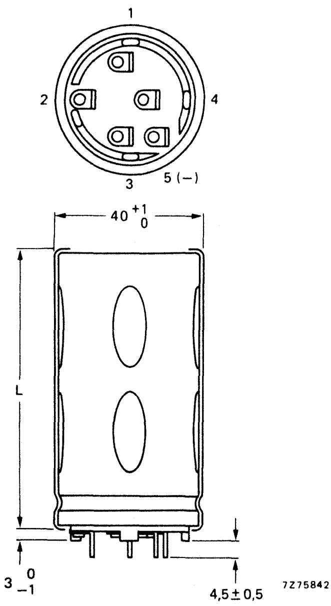


Fig. 6a.

1 = positive terminal;
5 = negative terminal.

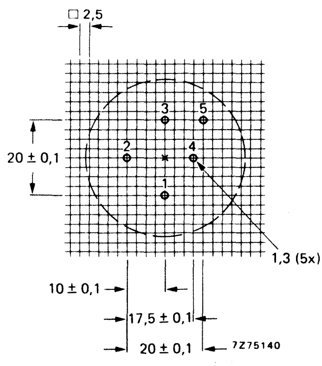


Fig. 6b Piercing diagram viewed from component side.

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

WARNING

Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled. Caution is necessary should the outer case be fractured. ←

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 V	nom cap. µF	max. r.m.s. ripple current (A) at 100 Hz, 85 °C	max. r.m.s. ripple current (A) at 20 kHz, 70 °C	max. leakage current at U_R after 5 min (mA)	typ. tan δ	max. ESR mΩ	max. impedance at 10 kHz mΩ	case size	catalogue number* 2222 followed by
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	429	300	1	. 9471
	680	1,7	3,2	0,41	0,087	297	210	2	. 9681
	1 000	2,2	4,2	0,60	0,092	208	150	3	. 9102
	1 500	2,6	4,9	0,90	0,10	152	120	4	. 9152
	2 200	3,2	6,1	1,32	0,11	109	90	5	. 9222
	2 200	3,0	5,7	1,32	0,12	124	110	6	. 9222
	3 300	3,6	6,8	1,98	0,14	91	75	7	. 9332
	4 700	5,0	9,5	2,82	0,13	63	55	8	. 9472
	6 800	6,9	13,1	4,08	0,14	44	40	9	. 9682
250	100	0,6	1,15	0,15	0,085	1800	1300	1	052 . 3101
	150	0,8	1,5	0,23	0,08	1100	850	2	. 3151
	220	1,0	1,9	0,33	0,08	750	550	3	. 3221
	330	1,4	2,65	0,49	0,08	500	400	4	. 3331
	470	1,8	3,4	0,70	0,08	360	290	5	. 3471
	470	1,8	3,4	0,70	0,095	420	350	6	. 3471
	680	2,3	4,4	1,02	0,08	250	190	7	. 3681
	1 000	3,0	5,7	1,50	0,08	170	140	8	. 3102
385	47	0,4	0,75	0,11	0,065	2800	2200	1	. 8479
	68	0,6	1,15	0,16	0,055	1700	1350	2	. 8689
	100	0,8	1,5	0,23	0,055	1100	850	3	. 8101
	150	1,0	1,9	0,34	0,055	725	525	4	. 8151
	220	1,3	2,45	0,50	0,055	500	350	5	. 8221
	220	1,3	2,45	0,50	0,065	600	420	6	. 8221
	330	1,7	3,2	0,75	0,055	340	230	7	. 8331
	470	2,8	5,3	1,06	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%

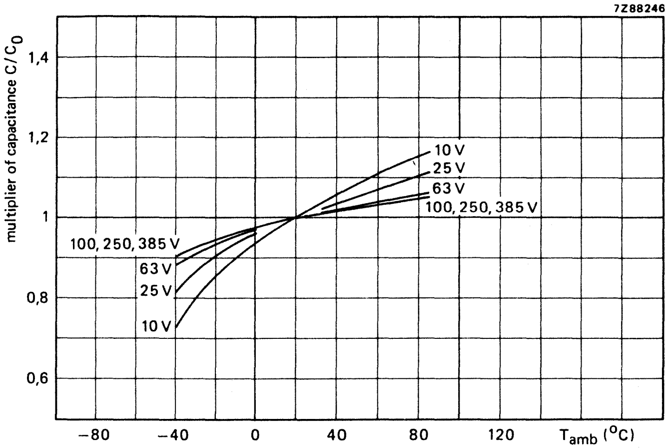


Fig. 7 Multiplier of capacitance as a function of ambient temperature; C_0 = capacitance at 25 °C, 100 Hz.

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:

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

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

I_n = ripple current at a certain frequency

$\sqrt{r_n}$ = multiplying factor at 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. 25 nH
Case sizes 3, 4 and 5	max. 30 nH
Case sizes 6, 7 and 8	max. 35 nH

Equivalent series resistance (ESR)

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

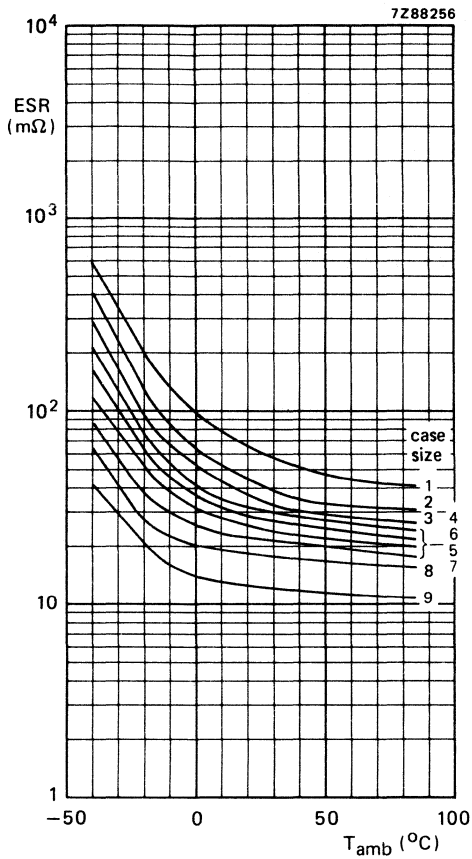


Fig. 8 Typical ESR as a function of temperature at 100 Hz, U_R = 10 V.

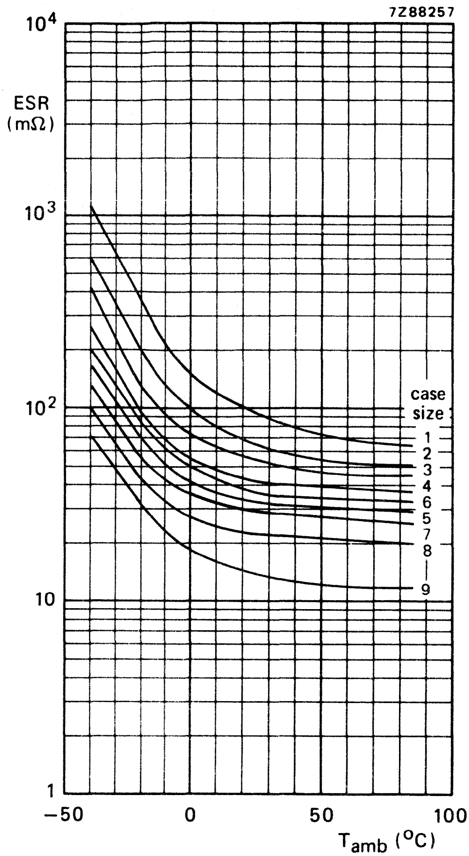


Fig. 9 Typical ESR as a function of temperature at 100 Hz, U_R = 63 V.

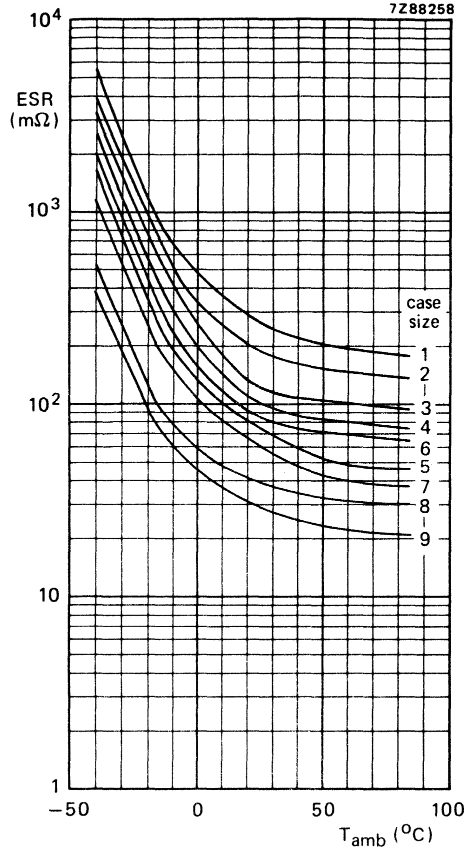


Fig. 10 Typical ESR as a function of temperature at 100 Hz, U_R = 100 V.

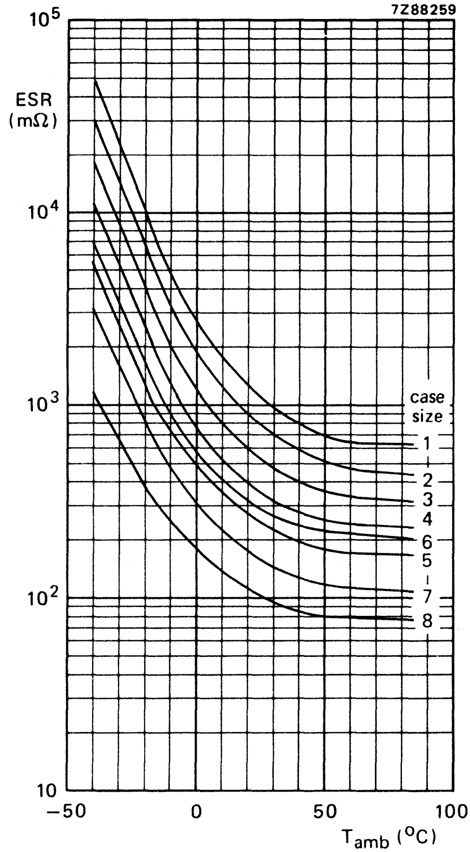


Fig. 11 Typical ESR as a function of temperature at 100 Hz, U_R = 250 V.

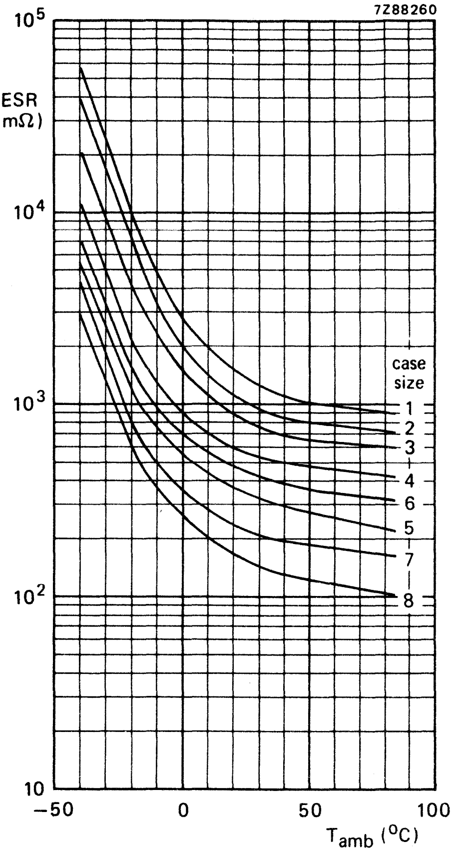


Fig. 12 Typical ESR as a function of temperature at 100 Hz, U_R = 385 V.

Impedance

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

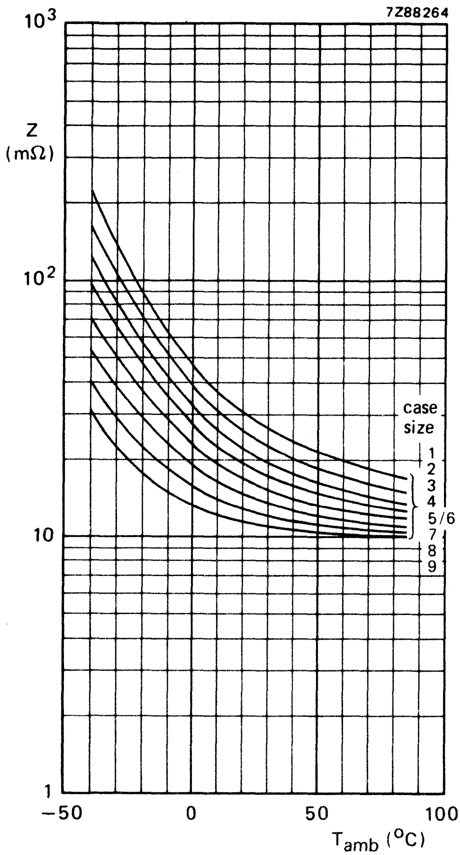


Fig. 13 Typical impedance as a function of temperature at 10 kHz, U_R = 10 V.

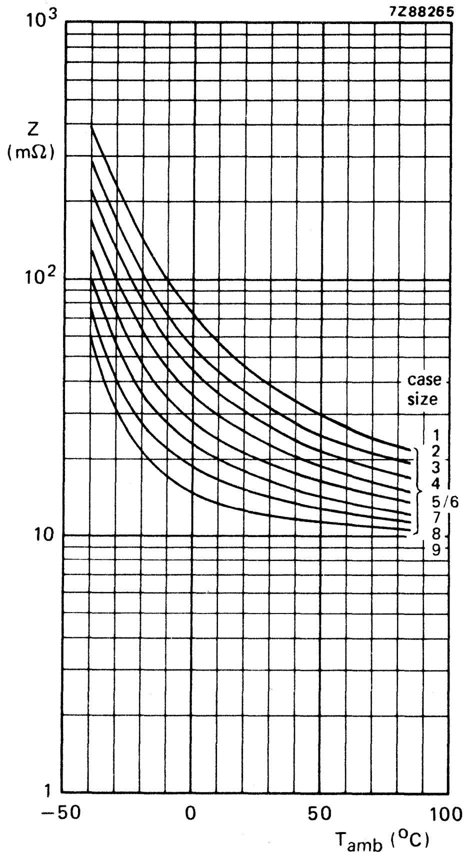


Fig. 14 Typical impedance as a function of temperature at 10 kHz, U_R = 63 V.

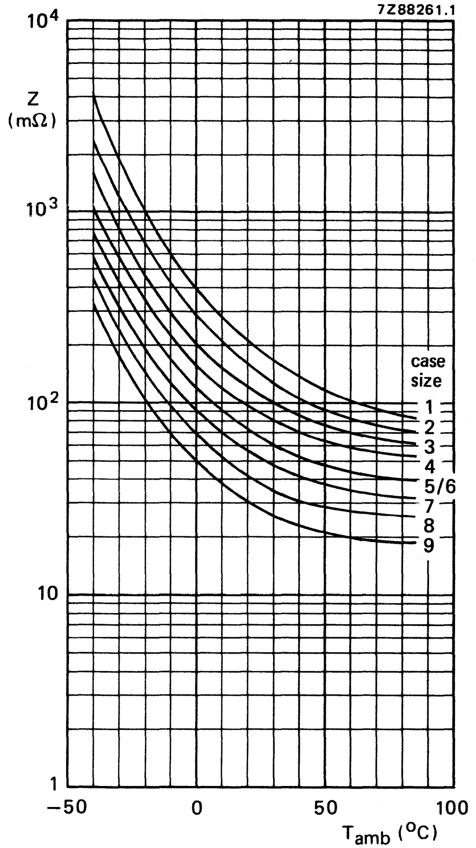


Fig. 15 Typical impedance as a function of temperature at 10 kHz, U_R = 100 V.

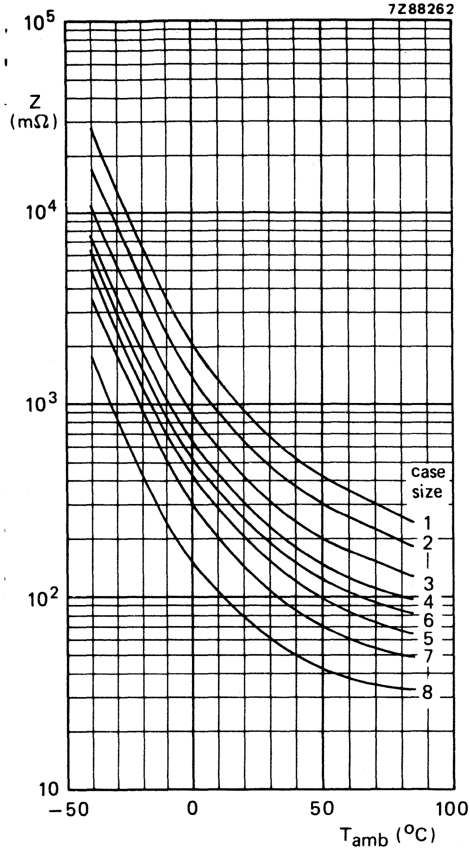


Fig. 16 Typical impedance as a function of temperature at 10 kHz, U_R = 250 V.

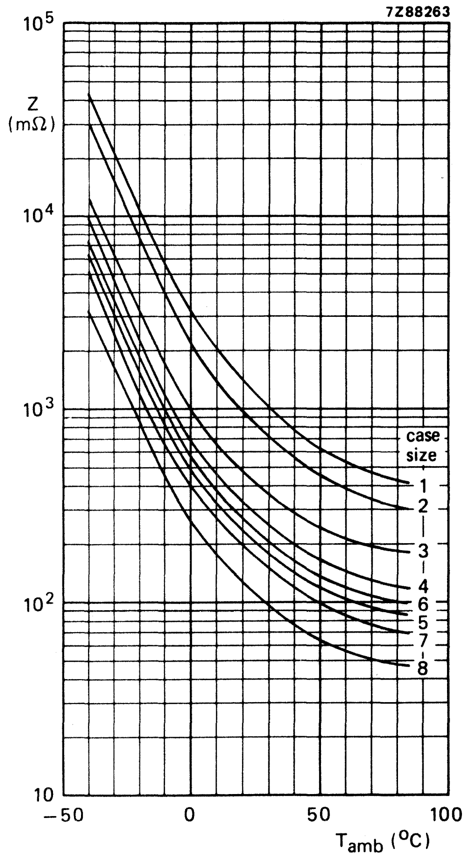


Fig. 17 Typical impedance as a function of temperature at 10 kHz, U_R = 385 V.

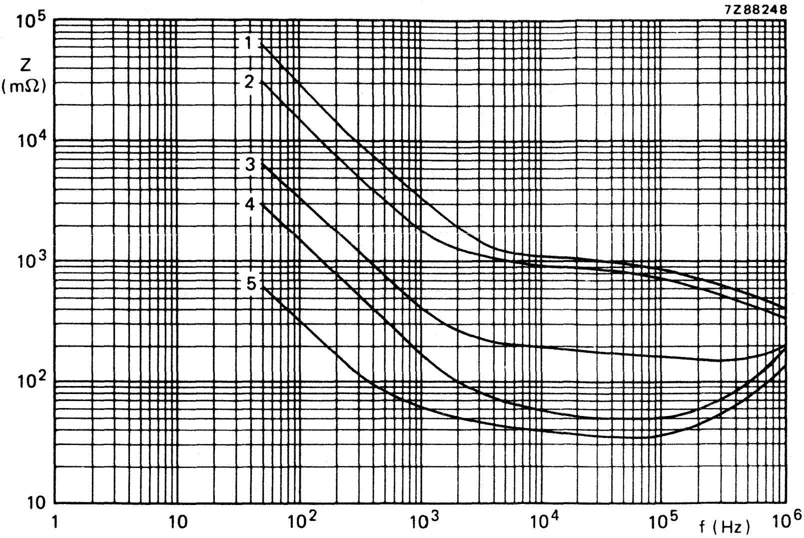


Fig. 18 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 1:**
curve 1 = 47 μF, 385 V;
curve 2 = 100 μF, 250 V;
curve 3 = 470 μF, 100 V;
curve 4 = 1000 μF, 63 V;
curve 5 = 4700 μF, 10 V.

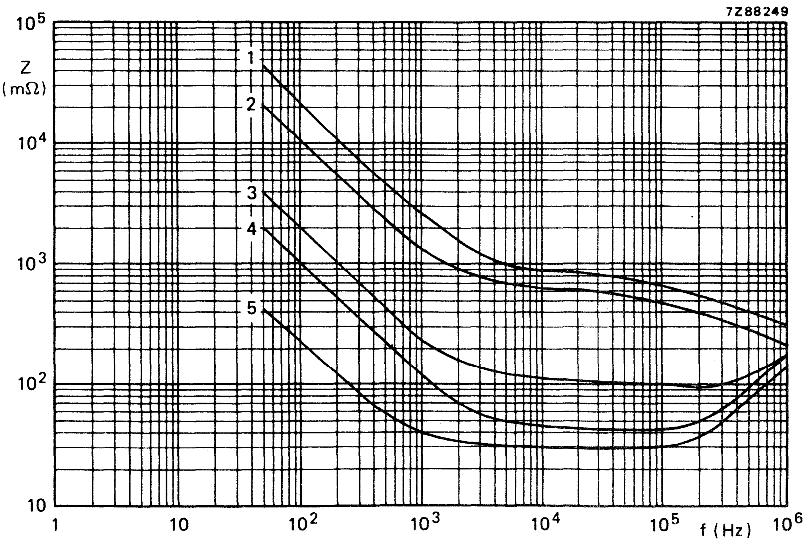


Fig. 19 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 2:**
curve 1 = 68 μF, 385 V;
curve 2 = 150 μF, 250 V;
curve 3 = 680 μF, 100 V;
curve 4 = 1500 μF, 63 V;
curve 5 = 6800 μF, 10 V.

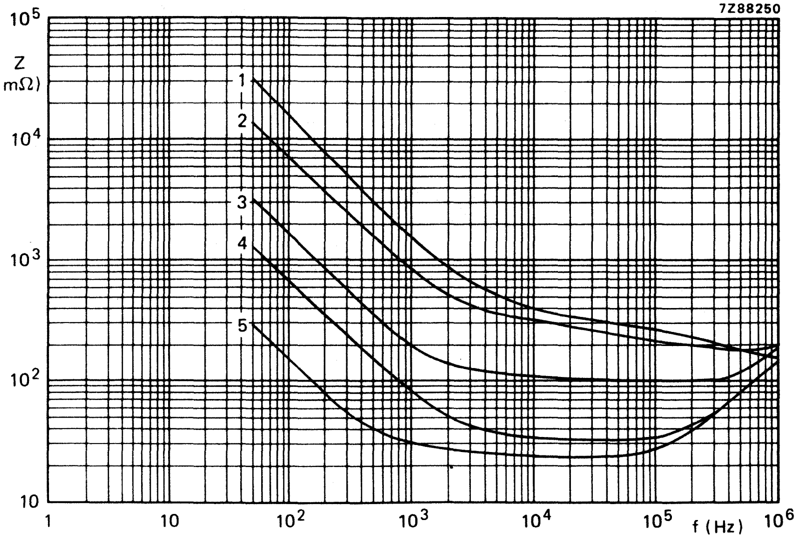


Fig. 20 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 3:**
curve 1 = 100 μF, 385 V;
curve 2 = 220 μF, 250 V;
curve 3 = 1000 μF, 100 V;
curve 4 = 2200 μF, 63 V;
curve 5 = 10 000 μF, 10 V.

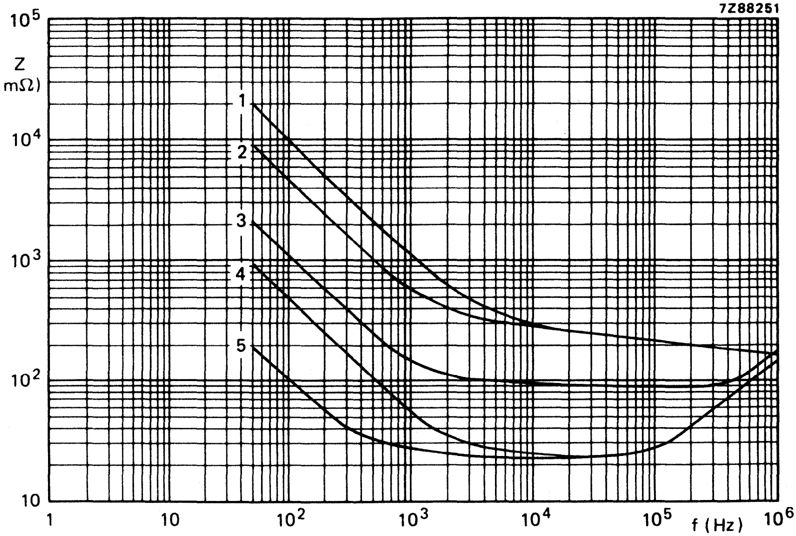


Fig. 21 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 4:**
curve 1 = 150 μF, 385 V;
curve 2 = 330 μF, 250 V;
curve 3 = 1500 μF, 100 V;
curve 4 = 3300 μF, 63 V;
curve 5 = 15 000 μF, 10 V.

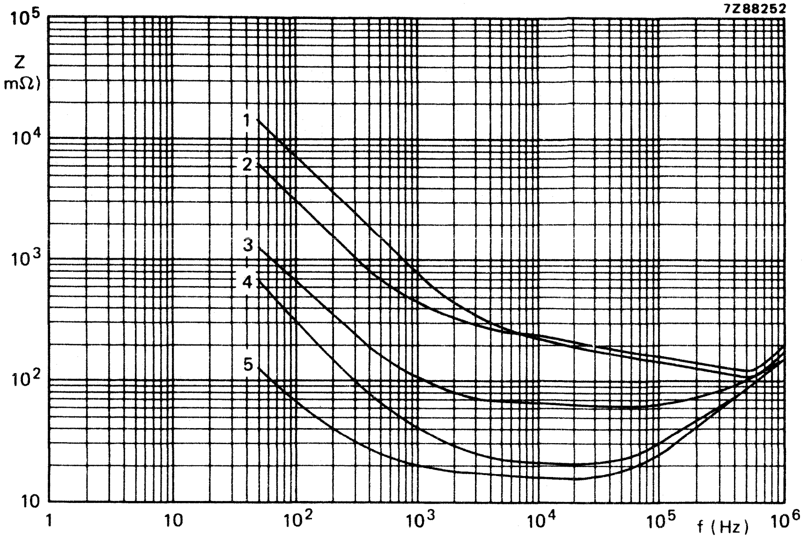


Fig. 22 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 5:**
curve 1 = 220 μF, 385 V;
curve 2 = 470 μF, 250 V;
curve 3 = 2200 μF, 100 V;
curve 4 = 4700 μF, 63 V;
curve 5 = 22 000 μF, 10 V.

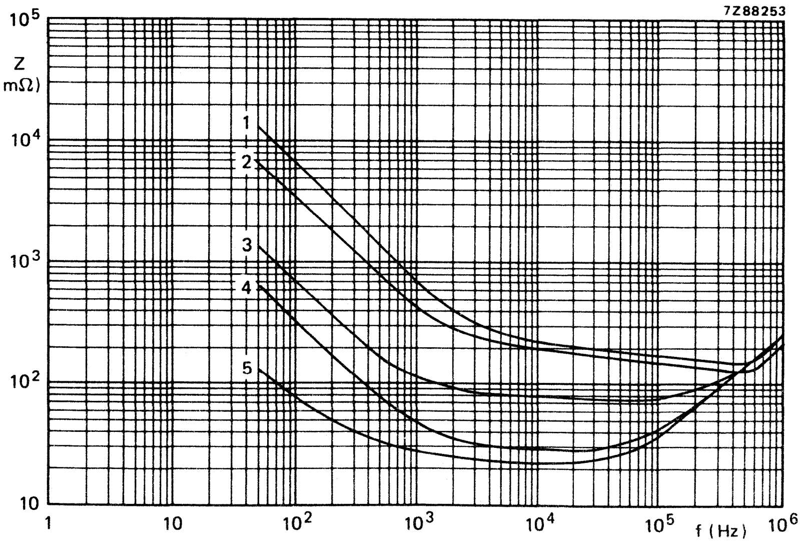


Fig. 23 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 6:**
curve 1 = 220 μF, 385 V;
curve 2 = 470 μF, 250 V;
curve 3 = 2200 μF, 100 V;
curve 4 = 4700 μF, 63 V;
curve 5 = 22 000 μF, 10 V.

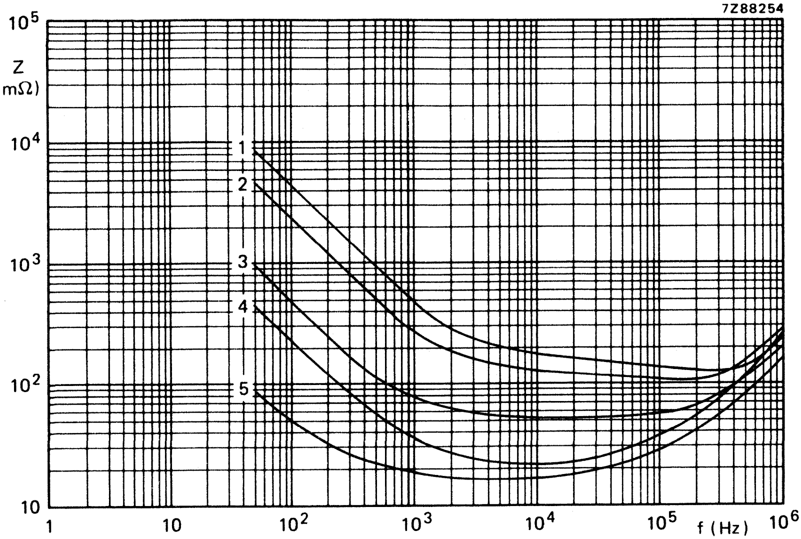


Fig. 24 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 7:**
curve 1 = 330 μF, 385 V;
curve 2 = 680 μF, 250 V;
curve 3 = 3300 μF, 100 V;
curve 4 = 6800 μF, 63 V;
curve 5 = 33 000 μF, 10 V.

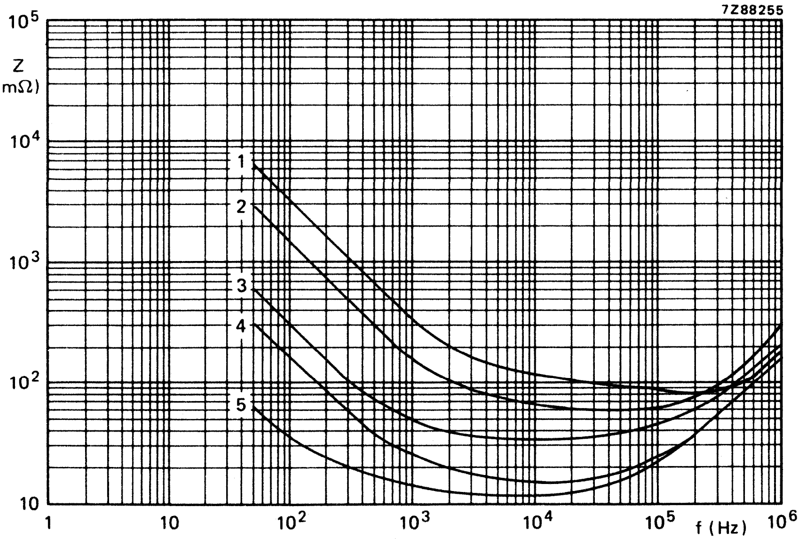


Fig. 25 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 8:**
curve 1 = 470 μF, 385 V;
curve 2 = 1000 μF, 250 V;
curve 3 = 4700 μF, 100 V;
curve 4 = 10 000 μF, 63 V;
curve 5 = 47 000 μF, 10 V.

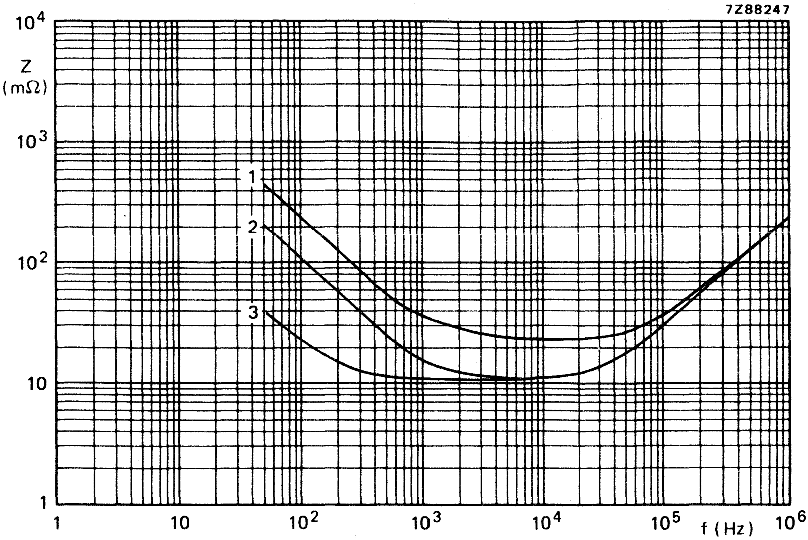


Fig. 26 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 9:**
curve 1 = 6800 μF, 100 V;
curve 2 = 15 000 μF, 63 V;
curve 3 = 68 000 μF, 10 V.

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	> 100 000 h
→ Shelf life at 0 V and T_{amb} = 85 °C	500 h
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.

→ After *shelf life test, 500 h, 85 °C,* the capacitors meet the same requirements as after endurance test. The rated voltage shall be applied to the capacitors for minimum 30 min., at least 24 h and not more than 48 h before measurements.

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.

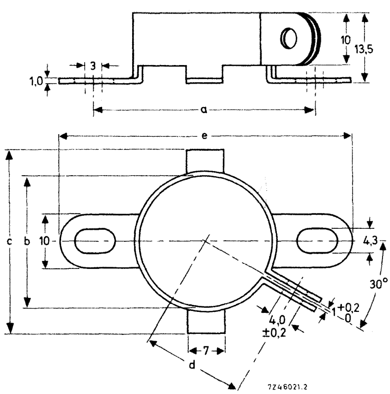


Fig. 27 Clamp for case sizes 1, 2, 3, 7, 8 and 9.

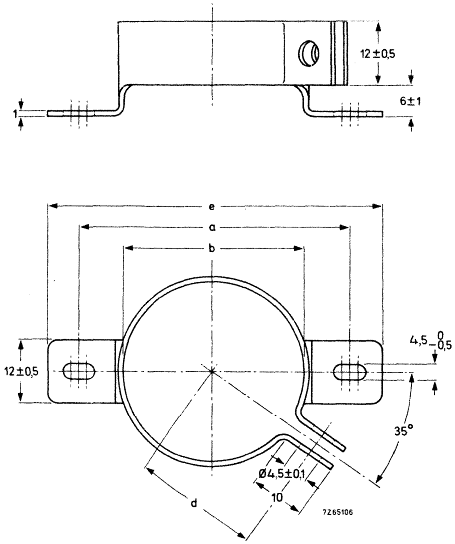


Fig. 28 Clamp for case sizes 4 and 5.

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.

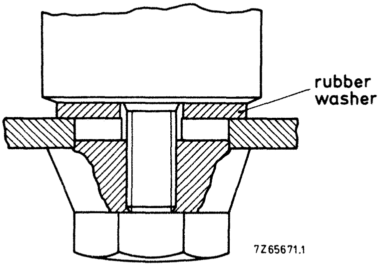


Fig. 29.

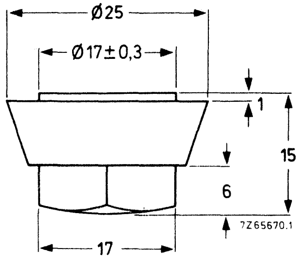


Fig. 30 Synthetic cap nut M8, threaded depth min 11,5 mm. Catalogue number 4322 043 05561.

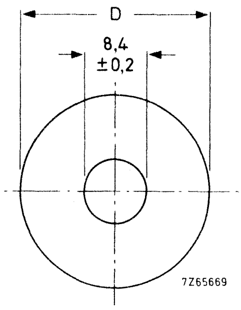
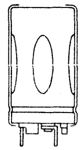


Fig. 31 Rubber washer (thickness 2 mm).

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

ALUMINIUM ELECTROLYTIC CAPACITORS

- Very high CU-product per unit volume
- Large type with printed-wiring pins
- Long life
- Industrial applications



QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	68 to 150 000 μF
Tolerance on nominal capacitance	± 20%
Rated voltage range, U_R	10 to 385 V
Category temperature range	
for $U_R \leq 63$ V	−55 to + 85 °C
for $U_R > 63$ V	−40 to + 85 °C
Endurance test at 85 °C	2000 h
Shelf life at 0 V, 85 °C	500 h
Basic specification	IEC 384-4, long-life grade
Climatic category, IEC 68	40/085/56

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

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

case size	nominal dimensions mm
1	Ø 25 x 35
2	Ø 25 x 45
3	Ø 30 x 45
4	Ø 35 x 45
5	Ø 35 x 55
6	Ø 40 x 45
7	Ø 40 x 55
8	Ø 40 x 75
9	Ø 40 x 105

APPLICATION

These capacitors have low ESR and ESL values and feature extremely small dimensions which render them suitable for applications such as:

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

DESCRIPTION

The capacitors have deeply etched anode foil electrodes, which achieves extremely small dimensions for a given CU-product. They are completely cold welded and charge/discharge proof. The aluminium case is fully insulated. A safety vent is located in the case bottom.

MECHANICAL DATA

Capacitors with printed-wiring pins

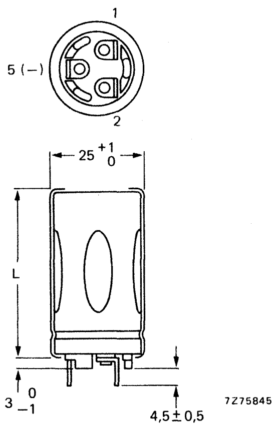


Fig. 1a.

1 = positive terminal;
5 = negative terminal.

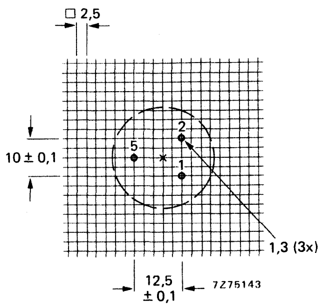


Fig. 1b Piercing diagram viewed from component side.

Table 1a

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

DEVELOPMENT SAMPLE DATA

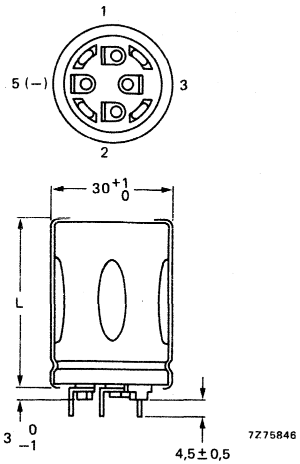


Fig. 2a.

1 = positive terminal;
5 = negative terminal.

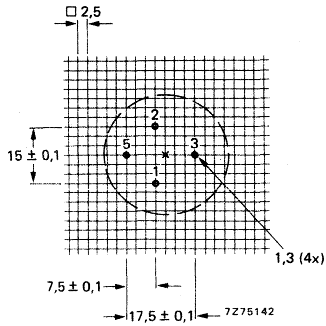


Fig. 2b Piercing diagram viewed from component side.

Table 1b

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

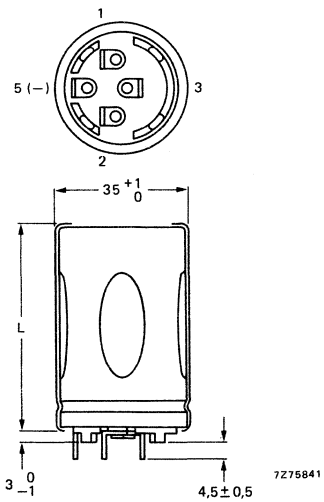


Fig. 3a.

1 = positive terminal;
5 = negative terminal.

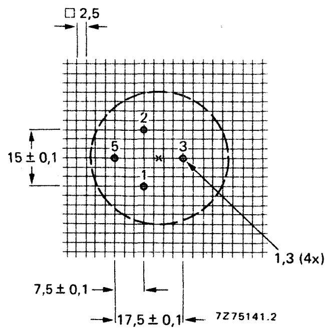


Fig. 3b Piercing diagram viewed from component side.

Table 1c

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

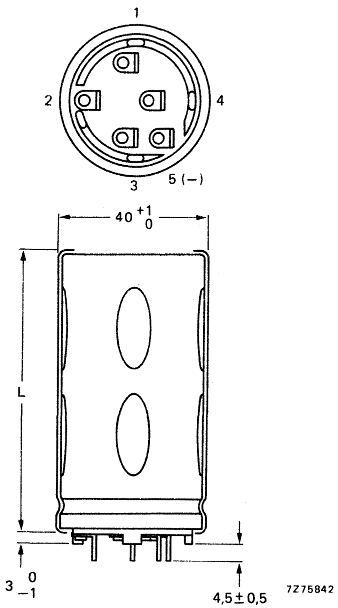


Fig. 4a.

1 = positive terminal;
5 = negative terminal.

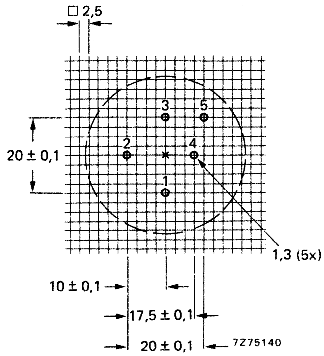


Fig. 4b Piercing diagram viewed from component side.

Table 1d

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

Marking

The capacitors are marked with: nominal capacitance, tolerance on capacitance, rated voltage, temperature range, date code according to IEC 62, name of manufacturer, indication of production centre, polarity of the terminals and rill to identify the negative terminal.

Mounting

The capacitors may be mounted in any position with or without a mounting clamp. Where 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 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

WARNING

Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled. Caution is necessary should the outer case be fractured.

ELECTRICAL DATA

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

Table 2 (see also corresponding paragraphs)

U_R V	nom. cap. µF	max. r.m.s. ripple current at 100 Hz/85 °C A	max. r.m.s. ripple current at 20 kHz/70 °C A	max. leakage current at U_R after 1 min mA	max. ESR mΩ	max. impedance at 10 kHz mΩ	case size	catalogue number 2222 followed by
10	10 000	3,1	5,9	0,60	51	40	1	051 54103
	15 000	4,1	7,8	0,90	37	30	2	54153
	22 000	5,0	9,5	1,32	30	25	3	54223
	33 000	5,5	10,4	1,98	28	24	4	54333
	47 000	6,8	12,9	2,82	23	20	5	54473
	47 000	5,8	10,4	2,82	29	22	6	44473
	68 000	7,1	13,5	4,08	24	20	7	54683
	100 000	9,2	17,4	6,00	19	16	8	54104
	150 000	12,0	22,7	9,00	16	14	9	54154
16	6 800	3,1	5,9	0,65	53	42	1	55682
	10 000	4,0	7,6	0,96	39	34	2	55103
	15 000	5,0	9,5	1,44	31	27	3	55153
	22 000	5,5	10,4	2,12	29	26	4	55223
	33 000	6,7	12,7	3,17	23	21	5	55333
	33 000	5,7	10,8	3,17	30	24	6	45333
	47 000	7,0	13,3	4,52	24	20	7	55473
	68 000	9,2	17,4	6,53	19	16	8	55683
	100 000	12,0	22,7	9,60	16	14	9	55104
25	4 700	2,9	5,5	0,71	60	42	1	56472
	6 800	3,9	7,4	1,02	42	34	2	56682
	10 000	4,8	9,1	1,50	34	27	3	56103
	15 000	5,3	10,0	2,25	30	26	4	56153
	22 000	6,5	12,3	3,30	24	21	5	56223
	22 000	5,7	10,8	3,30	31	24	6	46223
	33 000	7,0	13,3	4,95	25	20	7	56333
	47 000	9,2	17,4	7,05	19	16	8	56473
	68 000	12,0	22,7	10,20	16	14	9	56683
40	3 300	2,9	5,5	0,80	68	46	1	57332
	4 700	3,8	7,2	1,13	50	38	2	57472
	6 800	4,7	8,9	1,64	40	28	3	57682
	10 000	5,2	9,8	2,40	38	27	4	57103
	15 000	6,3	11,9	3,60	32	23	5	57153
	15 000	5,6	10,6	3,60	40	27	6	47153
	22 000	5,8	11,0	5,28	37	24	7	57223
	33 000	7,8	14,8	7,92	28	18	8	57333
	47 000	10,4	19,7	11,28	22	15	9	57473

DEVELOPMENT SAMPLE DATA

Table 2 (continued)

U_R V	nom. cap. μF	max. r.m.s. ripple current at 100 Hz/85 °C A	max. r.m.s. ripple current at 20 kHz/70 °C A	max. leakage current at U_R after 1 min mA	max. ESR mΩ	max. impedance at 10 kHz mΩ	case size	catalogue number 2222 followed by
63	2 200	2,5	4,7	0,84	80	54	1	051 58222
	3 300	3,3	6,2	1,25	57	39	2	58332
	4 700	4,1	7,8	1,78	46	32	3	58472
	6 800	4,5	8,5	2,57	43	30	4	58682
	10 000	5,4	10,2	3,78	34	24	5	58103
	10 000	4,6	8,7	3,78	44	30	6	48103
	15 000	7,5	14,2	5,67	29	22	8	58153
	22 000	10	19	8,32	22	18	9	58223
100	680	1,74	3,30	0,41	160	100	1	59681
	1 000	2,34	4,44	0,60	110	70	2	59102
	1 500	2,95	5,59	0,90	85	55	3	59152
	2 200	3,69	7,00	1,32	65	45	4	59222
	3 300	4,37	8,29	1,98	55	38	5	59332
	3 300	4,16	7,89	1,98	60	41	6	49332
	4 700	5,21	9,88	2,82	45	31	7	59472
	6 800	6,97	13,22	4,08	33	23	8	59682
	10 000	9,50	18,00	6,00	24	18	9	59103
200	150	0,70	1,33	0,18	1000	770	1	053 52151
	220	0,94	1,78	0,26	680	525	2	52221
	330	1,27	2,41	0,40	460	360	3	52331
	470	1,66	3,15	0,57	320	250	4	52471
	680	2,19	4,15	0,82	220	170	5	52681
	680	2,17	4,11	0,82	220	170	6	42681
	1 000	2,86	5,42	1,20	150	115	7	52102
	1 500	3,81	7,22	1,80	110	85	8	52152
	2 200	5,20	9,86	2,64	80	60	9	52222
385	68	0,47	0,89	0,16	2200	1400	1	58689
	100	0,64	1,21	0,23	1500	940	2	58101
	150	0,90	1,71	0,35	1000	620	3	58151
	220	1,15	2,18	0,51	680	420	4	58221
	330	1,53	2,90	0,77	450	270	5	58331
	330	1,52	2,88	0,77	450	270	6	48331
	470	1,96	3,72	1,09	320	190	7	58471
	680	2,70	5,12	1,58	220	135	8	58681
	1 000	3,70	7,02	2,31	180	125	9	58102

Capacitance

Nominal capacitance values at 100 Hz and T_{amb} = 20 °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 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	
Surge voltage = max. permissible voltage for short periods	1,25 x U_R	1,15 x U_R (⩽ 100 V)
	1,15 x U_R (200 V version)	
	1,1 x U_R (385 V version)	
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 or 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

DEVELOPMENT SAMPLE DATA

* 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 intc 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 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.

Leakage current

Maximum leakage current 1 min after application of the rated voltage at T_{amb} = 20 °C	see Table 2 (0,006 CU + 4 μA)

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.

Impedance

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

Equivalent series resistance (ESR)

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

Inductance (ESL)

Case sizes 1 and 2	max. 25 nH
Case sizes 3, 4 and 5	max. 30 nH
Case sizes 6, 7, 8 and 9	max. 35 nH

OPERATIONAL DATA

Category temperature range

For $U_R \leqslant 63$ V	−55 to + 85 °C
For $U_R > 63$ V	−40 to + 85 °C

Life expectancy

Typical life time	
at T_{amb} = 85 °C	> 5000 h
at T_{amb} = 40 °C	> 100 000 h
→ Shelf life at 0 V and T_{amb} = 85 °C	500 h

Failure rate

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

PACKING

The capacitors are packed in boxes containing 100 pieces.

TESTS AND REQUIREMENTS

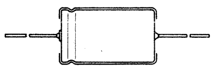
See Introduction, section 9, under aluminium electrolytic capacitors.
After *shelf life test, 500 h, 85 °C,* the capacitors meet the same requirements as after endurance test. ←
The rated voltage shall be applied to the capacitors for minimum 30 min., at least 24 h and not more than 48 h before measurements.
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. ←

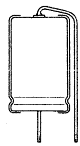
Note: Capacitors 2222 051 and 2222 053 are large types, long-life grade.

DEVELOPMENT SAMPLE DATA

ALUMINIUM ELECTROLYTIC CAPACITORS

- **Low-leakage version of 2222 030/031 series**
- **Miniature type**
- **Axial leads and single ended**
- **Long life**
- **General and industrial applications**
- **Alternative for tantalum capacitors**





QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	0,1 to 470 μF
Tolerance on nominal capacitance	−10 to + 50%
Rated voltage range, U_R (R5 series)	6,3 to 25 V
Leakage current after 2 min	0,002 CU or 0,7 μA
Category temperature range	−55 to + 85 °C
Endurance test at 85 °C	
case size 1	1000 h
case sizes 2 to 7	2000 h
Shelf life at 0 V, 85 °C	500 h
Basic specification	IEC 384-4, general-purpose grade (case size 1), long-life grade (case sizes 2 to 7); DIN 41316
Climatic category	
IEC 68	55/085/56
DIN 40040	FPF

case size	nominal dimensions (mm)
1	Ø 3,3 x 10
2	Ø 4,5 x 10
3	Ø 6 x 10
4	Ø 6,5 x 18
5	Ø 8 x 18
6	Ø 10 x 18
7	Ø 10 x 25

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

C_{nom} μF	U_R (V)			
	6,3	10	16	25
0,1				1
0,15				1
0,22				1
0,33				2
0,47				2
0,68				2
1				2
1,5				2
2,2			1	2
3,3		1		2
4,7	1			2
6,8			2	2
10		2	2	3
15	2		2	3
22		2	3	4
33	2		3	
47		3	4	5
68	3		5	6
100		4	5	7
150	4	5	6	
220	5	6	7	
330	6	7		
470	7			

APPLICATION

These capacitors are suited for those applications where a low leakage current is required. In many cases they are a cost-effective substitute for tantalum capacitors.
The capacitors are mainly used for 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 and oxidized 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 2 styles, both with soldered-copper leads.

Style 1: axial leads; supplied on bandoliers.
Style 3: single ended.

MECHANICAL DATA

Dimensions in mm

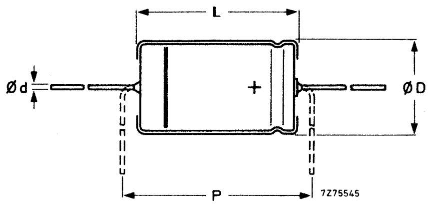


Fig. 1 Style 1; see Table 1a for dimensions d, D, L and P.

Table 1a

case size	style 1						mass approx. g
	d	D_{nom}	L_{nom}	D_{max}	L_{max}	P_{min}	
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
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

Table 1b

case size	style 3				mass approx. g
	d	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
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

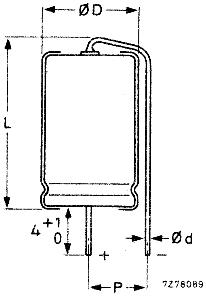


Fig. 2 Style 3; see Table 1b for dimensions d, D, L and P.

DEVELOPMENT SAMPLE DATA

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, 2 and 3).

Mounting

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

Table 1c

lead/pin diameter	required hole diameter
0,6 mm lead	0,8 + 0,1 mm
0,8 mm lead	1,0 + 0,1 mm

Minimum atmospheric pressure 8,5 kPa

WARNING

Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled; caution is necessary should the outer case be fractured.

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 2 min. μA	max. tan δ	max. impedance at 10 kHz Ω	case size	catalogue number* 2222 065 followed by
6,3	4,7	12	0,7	0,16	26	1	. 3478
	15	26,5	0,7	0,16	8	2	. 3159
	33	39	0,7	0,16	3,6	2	. 3339
	68	67	0,9	0,16	1,8	3	. 3689
	150	133	1,9	0,16	0,80	4	. 3151
	220	182	2,8	0,16	0,55	5	. 3221
	330	254	4,2	0,16	0,36	6	. 3331
	470	347	5,9	0,16	0,26	7	. 3471
10	3,3	11	0,7	0,14	27	1	. 4338
	10	23	0,7	0,14	9	2	. 4109
	22	34	0,7	0,14	4,1	2	. 4229
	47	60	0,9	0,14	1,9	3	. 4479
	100	116	2,0	0,14	0,90	4	. 4101
	150	160	3,0	0,14	0,60	5	. 4151
	220	222	4,4	0,14	0,41	6	. 4221
	330	310	6,6	0,14	0,27	7	. 4331
16	2,2	9,8	0,7	0,12	32	1	. 5228
	6,8	21	0,7	0,12	10	2	. 5688
	10	25	0,7	0,12	7	2	. 5109
	15	31	0,7	0,12	4,7	2	. 5159
	22	44	0,7	0,12	3,2	3	. 5229
	33	54	1,1	0,12	2,1	3	. 5339
	47	86	1,5	0,12	1,5	4	. 5479
	100	141	3,2	0,12	0,70	5	. 5101
	150	198	4,8	0,12	0,47	6	. 5151
	220	274	7,1	0,12	0,32	7	. 5221

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

U_R V	nom. cap. µF	max. r.m.s. ripple current at $T_{amb} = 85\,^oC$ mA	max. leakage current at U_R after 2 min. µA	max. tan δ	max. impedance at 10 kHz Ω	case size	catelogue number* 2222 065 followed by
25	0,1	2,6	0,7	0,08	550	1	. 6107
	0,15	3,1	0,7	0,08	370	1	. 6157
	0,22	3,8	0,7	0,08	250	1	. 6227
	0,33	5,6	0,7	0,08	170	2	. 6337
	0,47	6,6	0,7	0,08	120	2	. 6477
	0,68	8,0	0,7	0,08	81	2	. 6687
	1,0	9,7	0,7	0,08	55	2	. 6108
	1,5	11,2	0,7	0,09	37	2	. 6158
	2,2	13,5	0,7	0,09	25	2	. 6228
	3,3	16,6	0,7	0,09	17	2	. 6338
	4,7	20	0,7	0,09	12	2	. 6478
	6,8	24	0,7	0,09	8,1	2	. 6688
	10	34	0,7	0,09	5,5	3	. 6109
	15	42	0,8	0,09	3,7	3	. 6159
	22	68	1,1	0,09	2,5	4	. 6229
	47	112	2,4	0,09	1,2	5	. 6479
	68	154	3,4	0,09	0,81	6	. 6689
	100	213	5,0	0,09	0,55	7	. 6101

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

DEVELOPMENT SAMPLE DATA

Capacitance

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

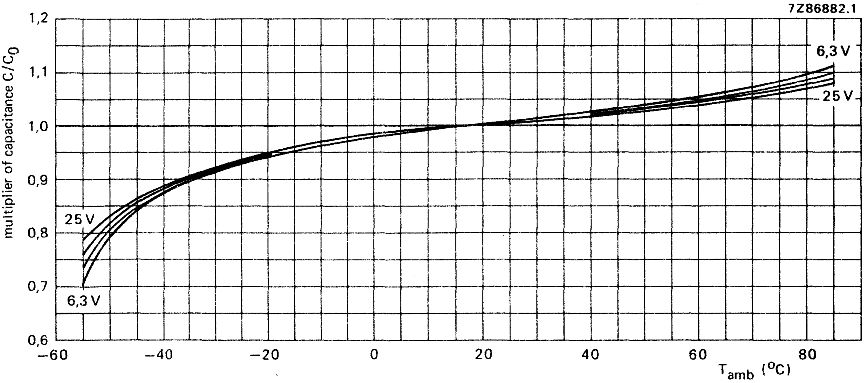


Fig. 3 Multiplier of capacitance as a function of ambient temperature; C_0 = capacitance at 20 °C, 100 Hz.

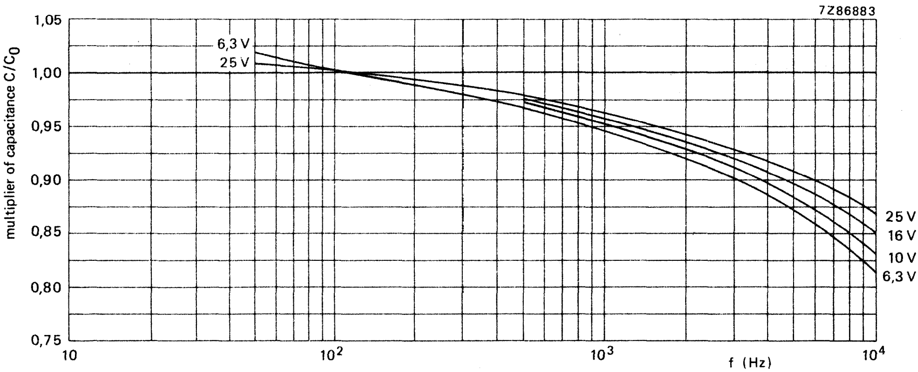


Fig. 4 Multiplier of capacitance as a function of frequency; C_0 = capacitance at 20 °C, 100 Hz.

Voltage

Max. permissible voltage at $T_{amb} \leq 85\ ^oC$	1,6 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	1,6 x U_R
(b) max. peak a.c. voltage without d.c. voltage applied	2 V
(c) momentary value of applied voltage	between 1,6 x U_R and −2 V
Surge voltage = max. permissible voltage for short periods	1,6 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 $T_{amb} = 85\ ^oC$	see Table 2
100 Hz and $T_{amb} = 40\ ^oC$	2,24 x values stated in Table 2

DEVELOPMENT SAMPLE DATA

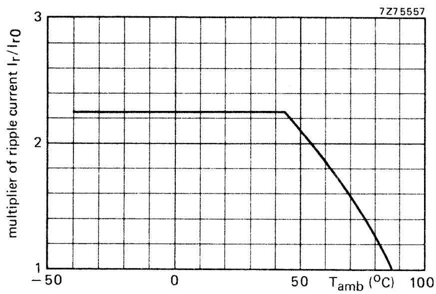


Fig. 5 Multiplier of ripple current as a function of ambient temperature; I_{r0} = ripple current at 85 °C, 100 Hz.

* 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.

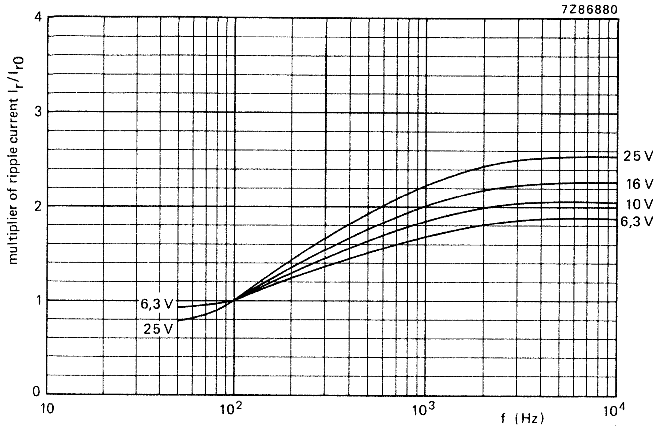


Fig. 6 Multiplier of ripple current as a function of frequency; I_{r0} = ripple current at 85 °C, 100 Hz.

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;

$\sqrt{r_n} = I_r/I_{r0}$ = 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-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 2 min after application of U_R, at T_{amb} = 20 °C	see Table 2 (0,002 CU or 0,7 μA, whichever is greater)

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.

DEVELOPMENT SAMPLE DATA

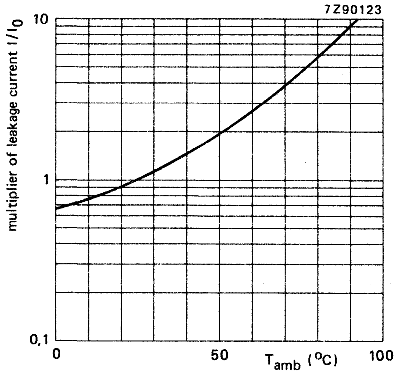


Fig. 7 Multiplier of leakage current as a function of ambient temperature; I_0 = leakage current during continuous operation at 25 °C and U_R.

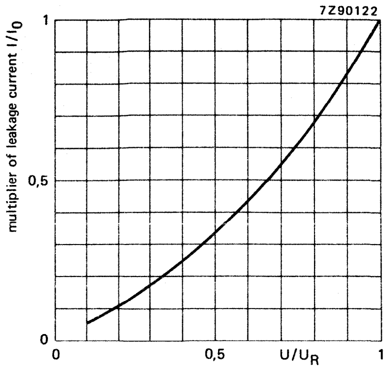


Fig. 8 Multiplier of leakage current as a function of U/U_R; I_0 = leakage current during continuous operation at 25 °C and U_R.

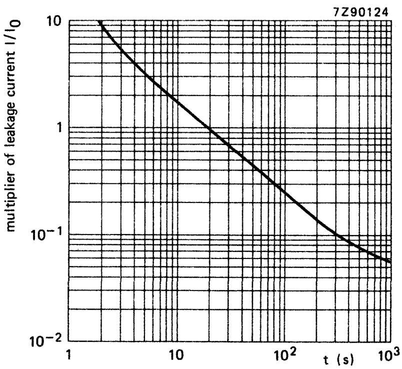


Fig. 9 Multiplier of typical leakage current as a function of time; I_0 is leakage current value as specified in Table 2.

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

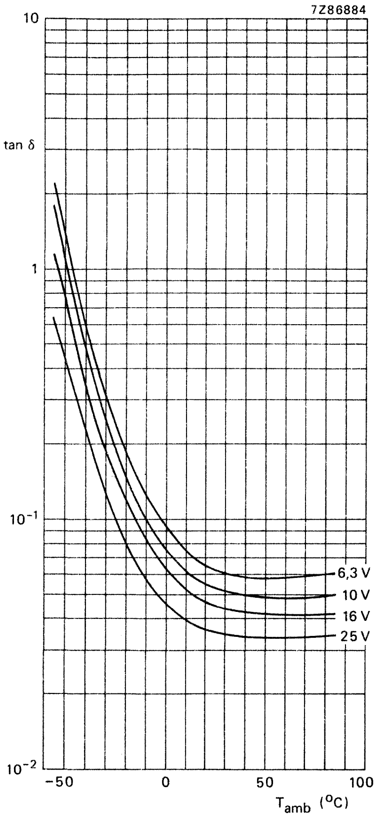


Fig. 10 Typical tan δ as a function of ambient temperature at 100 Hz.

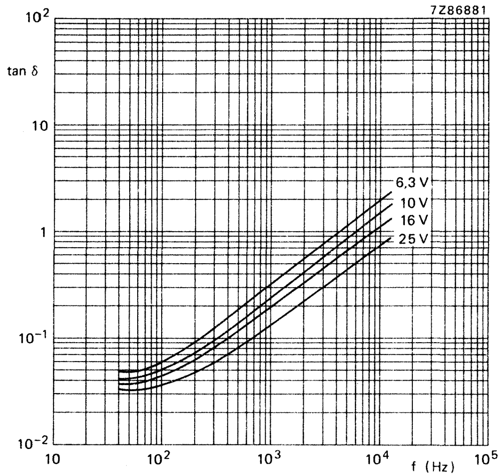


Fig. 11 Typical tan δ as a function of frequency at 25 °C.

Equivalent series resistance (ESR)

ESR = tan $\delta/\omega C$
Maximum tan δ and C at 100 Hz and T_{amb} = 25 °C — see Table 2

Equivalent series inductance (ESL)

Case size 1	typ. 15 nH
Case size 2	typ. 17 nH
Case sizes 3 and 4	typ. 30 nH
Case size 5	typ. 50 nH
Case sizes 6 and 7	typ. 65 nH

Impedance (Z)

Maximum impedance at T_{amb} = 20 °C and 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

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
+20 °C	⩽ 120	⩽ 90	⩽ 70	⩽ 55
−25 °C	⩽ 560	⩽ 400	⩽ 300	⩽ 180
−40 °C	⩽ 1500	⩽ 1100	⩽ 900	⩽ 500
−55 °C	typ. 3300	typ. 2400	typ. 1500	typ. 850

DEVELOPMENT SAMPLE DATA

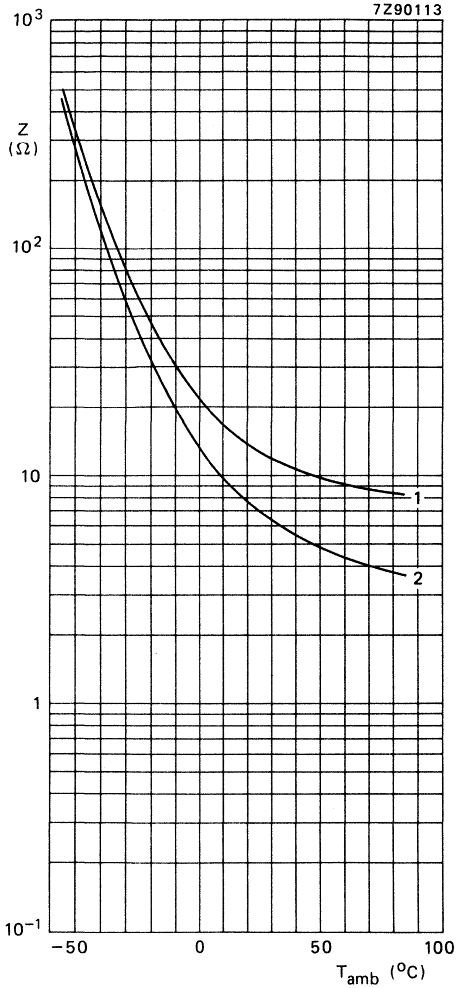


Fig. 12 Typical impedance as a function of ambient temperature at 10 kHz; **case size 1:**

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

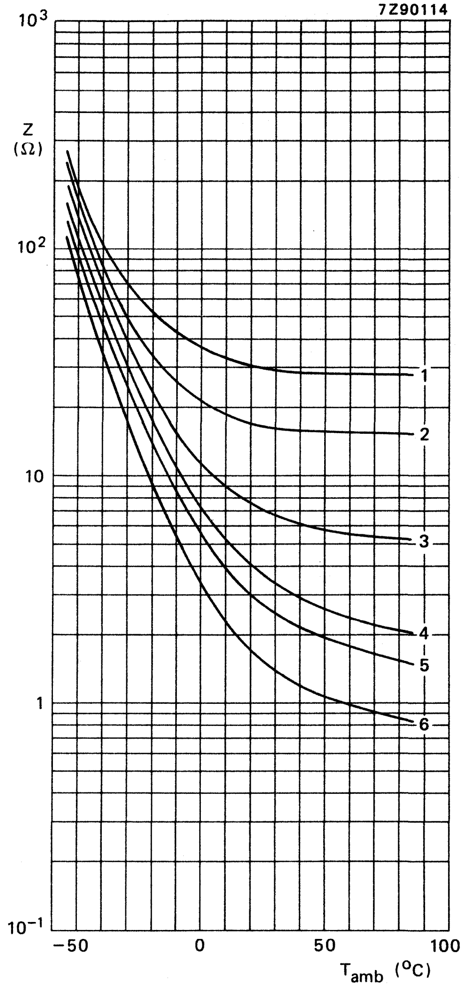


Fig. 13 Typical impedance as a function of ambient temperature at 10 kHz; **case size 2:**

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

DEVELOPMENT SAMPLE DATA

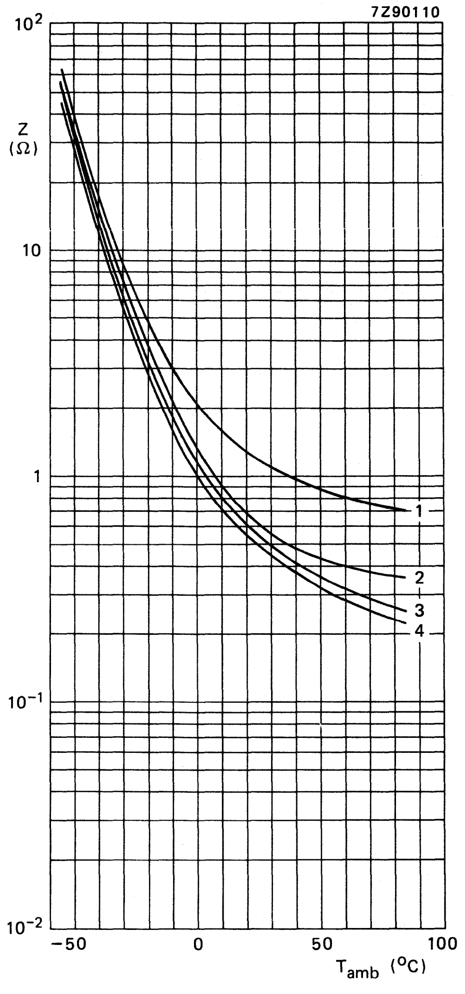


Fig. 14 Typical impedance as a function of ambient temperature at 10 kHz; **case size 3:**

curve 1 = 10 μF, 25 V;
curve 2 = 22 μF, 16 V;
curve 3 = 47 μF, 10 V;
curve 4 = 68 μF, 6,3 V.

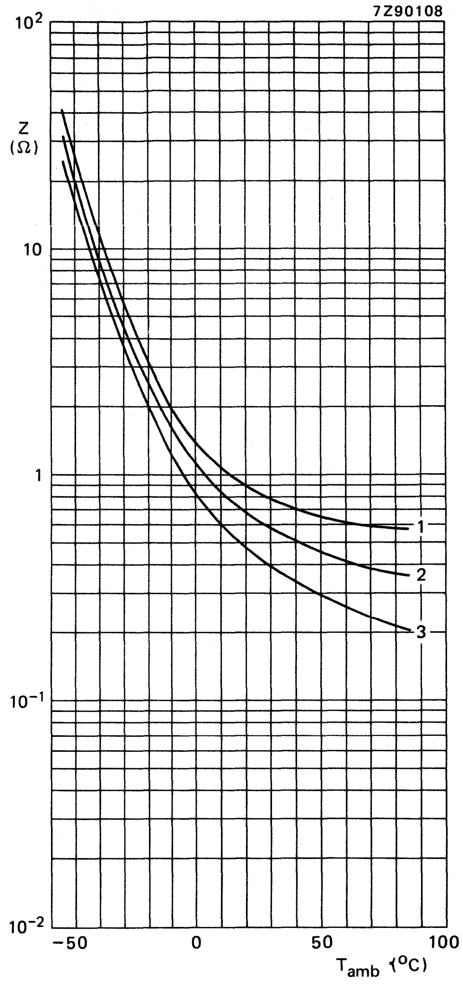


Fig. 15 Typical impedance as a function of ambient temperature at 10 kHz; **case size 4:**

curve 1 = 22 μF, 25 V;
curve 2 = 47 μF, 16 V;
curve 3 = 100 μF, 10 V.

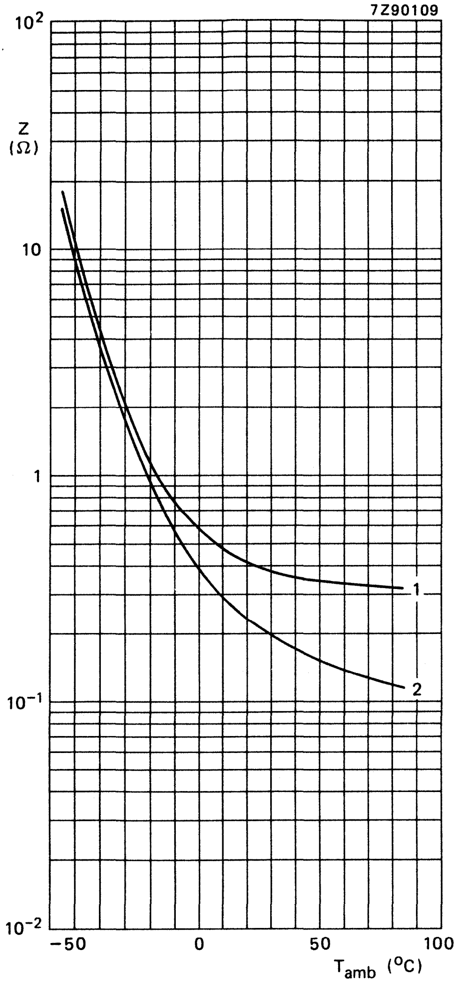


Fig. 16 Typical impedance as a function of ambient temperature at 10 kHz; **case size 5:**
curve 1 = 47 μF, 25 V;
curve 2 = 150 μF, 10 V.

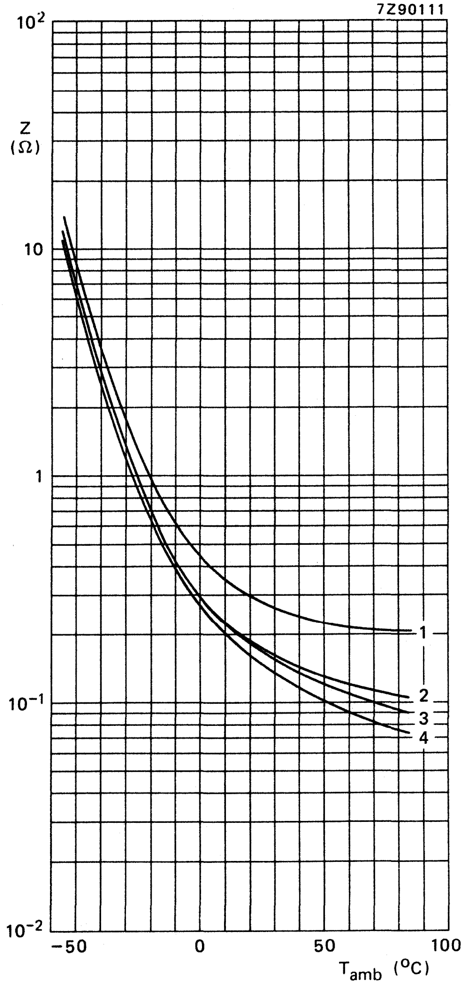


Fig. 17 Typical impedance as a function of ambient temperature at 10 kHz; **case size 6:**
curve 1 = 68 μF, 25 V;
curve 2 = 150 μF, 16 V;
curve 3 = 220 μF, 10 V;
curve 4 = 330 μF, 6,3 V.

DEVELOPMENT SAMPLE DATA

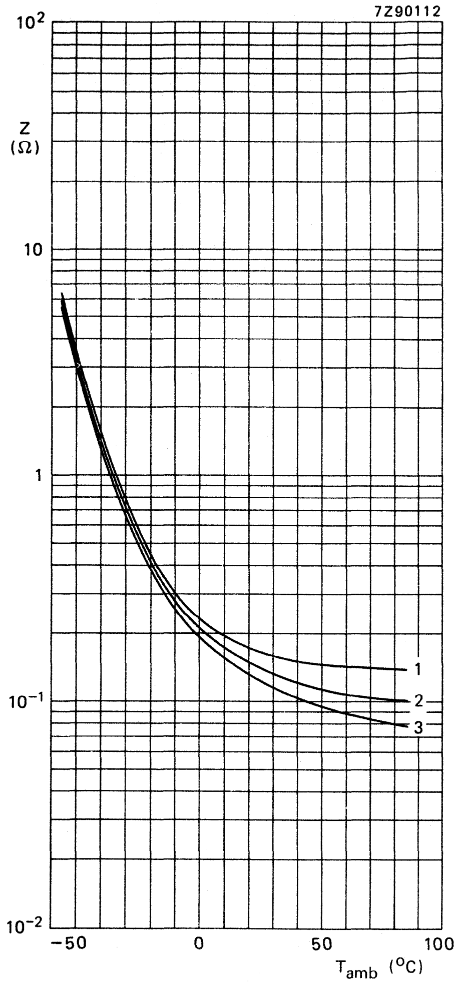


Fig. 18 Typical impedance as a function of ambient temperature at 10 kHz; **case size 7:**

curve 1 = 100 μF, 25 V;
curve 2 = 220 μF, 16 V;
curve 3 = 470 μF, 6,3 V.

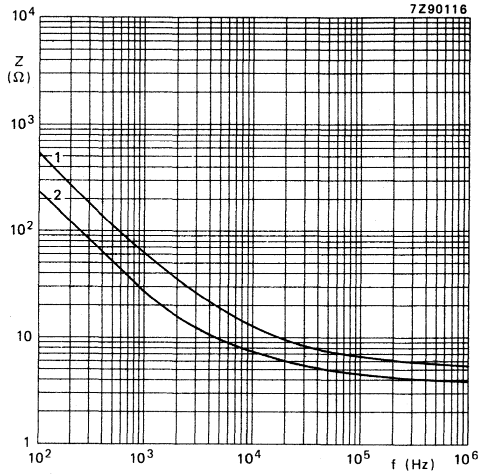


Fig. 19 Typical impedance as a function of frequency at 20 °C; **case size 1:**
curve 1 = 2,2 μF, 16 V;
curve 2 = 4,7 μF, 6,3 V.

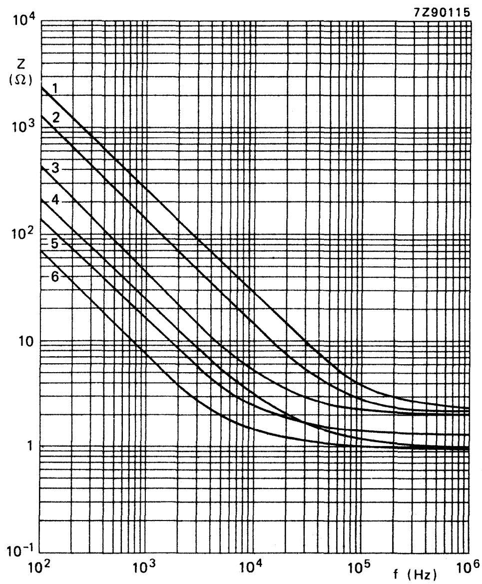


Fig. 20 Typical impedance as a function of frequency at 20 °C; **case size 2:**

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

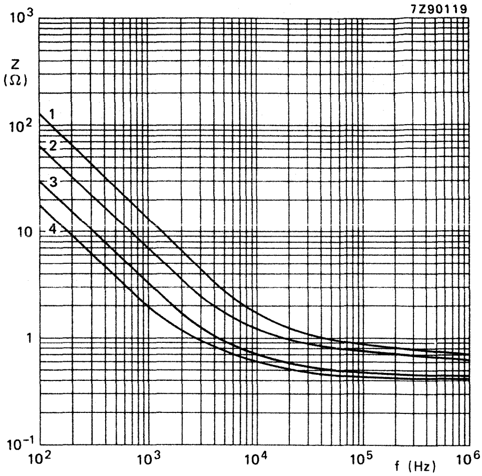


Fig. 21 Typical impedance as a function of frequency at 20 °C; **case size 3:**
curve 1 = 10 μF, 25 V;
curve 2 = 22 μF, 16 V;
curve 3 = 47 μF, 10 V;
curve 4 = 68 μF, 6,3 V.

DEVELOPMENT SAMPLE DATA

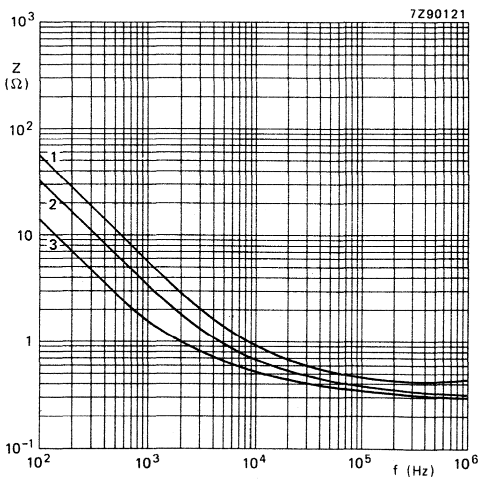


Fig. 22 Typical impedance as a function of frequency at 20 °C; **case size 4:**
curve 1 = 22 μF, 25 V;
curve 2 = 47 μF, 16 V;
curve 3 = 100 μF, 10 V.

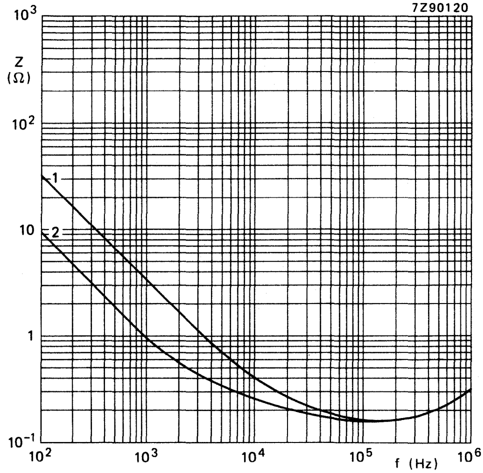


Fig. 23 Typical impedance as a function of frequency at 20 °C; **case size 5:**
curve 1 = 47 μF, 25 V;
curve 2 = 150 μF, 10 V.

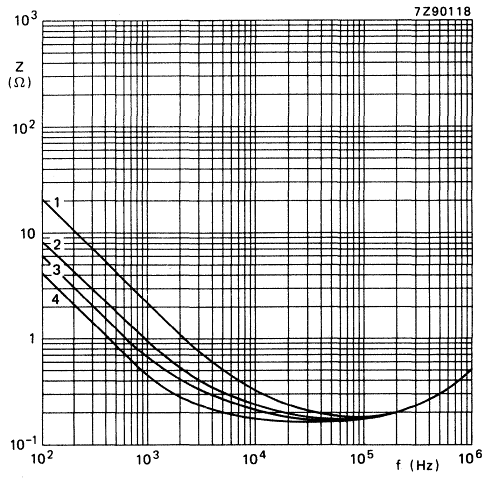


Fig. 24 Typical impedance as a function of frequency at 20 °C; **case size 6:**
curve 1 = 68 μF, 25 V;
curve 2 = 150 μF, 16 V;
curve 3 = 220 μF, 10 V;
curve 4 = 330 μF, 6,3 V.

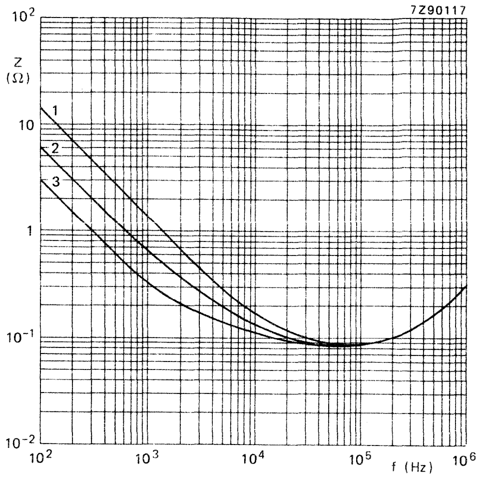


Fig. 25 Typical impedance as a function of frequency at 20 °C; **case size 7:**
curve 1 = 100 μF, 25 V;
curve 2 = 220 μF, 16 V;
curve 3 = 470 μF, 6,3 V.

DEVELOPMENT SAMPLE DATA

OPERATIONAL DATA

Category temperature range	−55 to + 85 °C	
Typical life time	T_{amb} = 85 °C	T_{amb} = 40 °C
case size 1	1500 h	35 000 h
case sizes 2 to 7	3000 h	70 000 h
Shelf life at 0 V and T_{amb} = 85 °C	500 h	

PACKING

Capacitors of style 3 are supplied in boxes, capacitors of style 1 are supplied on bandoliers in boxes or on reels. The number of capacitors per box or per reel is shown in Table 4.

Table 4

case size	number of capacitors		
	style 1 per reel	style 1 per box	style 3 per box
1	4000	1000	1000
2	3000	1000	1000
3	1000	1000	1000
4	1000	1000	1000
5	500	500	1000
6	500	500	1000
7	500	500	500

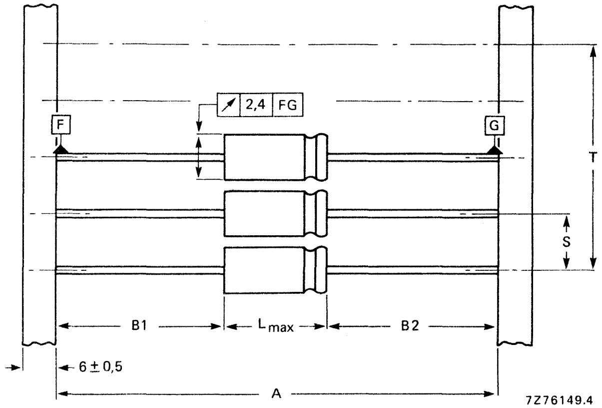


Fig. 26 Style 1 capacitors on bandoliers: the bandolier to which the negative capacitor terminals are connected is blue. See Table 5 for dimensions A, S, T and L.
| B1—B2 | = max. 1,4 mm.

Table 5

Dimensions in mm

case size	A	S	T for number (n) of capacitors n < 50	T for number (n) of capacitors 50 < n < 100	L_{max}
1	63,5 ± 1,5	5 ± 0,4	5 (n-1) ± 2	5 (n-1) ± 4	11,0
2	63,5 ± 1,5	5 ± 0,4	5 (n-1) ± 2	5 (n-1) ± 4	10,5
3	63,5 ± 1,5	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	10,5
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

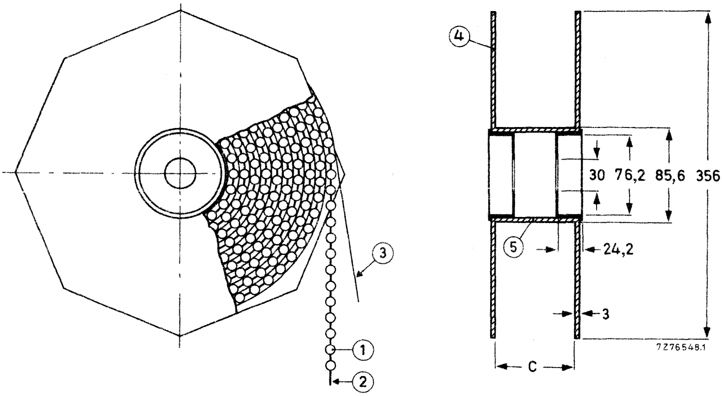


Fig. 27 Style 1 capacitors on bandoliers on reel; dimension C is 83,5 mm for case sizes 1, 2 and 3, and 88,5 mm for case sizes 4, 5, 6 and 7; the overall width of the reel is 94,5 mm and 99,5 mm respectively.

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

DEVELOPMENT SAMPLE DATA

TESTS AND REQUIREMENTS

See Introduction, section 9, under aluminium electrolytic capacitors, with the following addition.

After *endurance test, 2000 h, 85 °C (case sizes 2 to 7) or 1000 h, 85 °C (case size 1),* the capacitors meet the following requirements:

$\Delta C/C \leqslant \pm$ 15%, for U_R = 10 to 25 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;

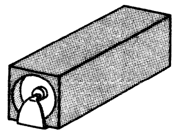
impedance at 10 kHz $\leqslant$ 200% of specified value.

After *shelf life test, 500 h, 85 °C,* the capacitors meet the same requirements, except for leakage current: $\leqslant$ 200% of specified value. The rated voltage shall be applied to the capacitors for minimum 30 min., at least 24 h and not more than 48 h before measurements.

Note:

Capacitors 2222 065 are miniature types, long-life grade except case size 1 which is general-purpose grade.

ALUMINIUM ELECTROLYTIC CAPACITORS



- **Surface mounted type**
- **Supplied in boxes or in blister tape on reel**
- **General applications**

QUICK REFERENCE DATA

Nominal capacitance range (E6 series	0,1 to 22 μF
Tolerance on nominal capacitance	−10 to + 50% (± 20% under consideration)
Rated voltage range, U_R (R5 series)	6,3 to 63 V
Category temperature range	−40 to + 85 °C
Endurance test at 85 °C	1000 h
Shelf life at 0 V, 85 °C	500 h
Resistance to soldering heat	260 °C, 10 s; immersion in solder permitted
Basic specifications	IEC 384-4, G.P. grade DIN 41332, type II
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	40	63
0,1						1
0,15						1
0,22						1
0,33						1
0,47						1
0,68						1
1						1
1,5						1
2,2						1
3,3						1
4,7					1	
6,8				1		
10			1			
15		1				
22	1					

case size	maximum dimensions (mm) length x width x height
1	12 x 3,7 x 3,7

APPLICATION

These capacitors with high CU-product per unit volume are for surface mounted assembly. They 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.
The taped versions are suitable for automatic placement.

DESCRIPTION

The capacitors have etched and oxidized aluminium foil electrodes rolled up with a paper strip impregnated with an electrolyte. The capacitors are in a rectangular plastic case with flat soldered-copper tags.

The capacitors are supplied in boxes or in blister tape on reel.

MECHANICAL DATA

Dimensions in mm

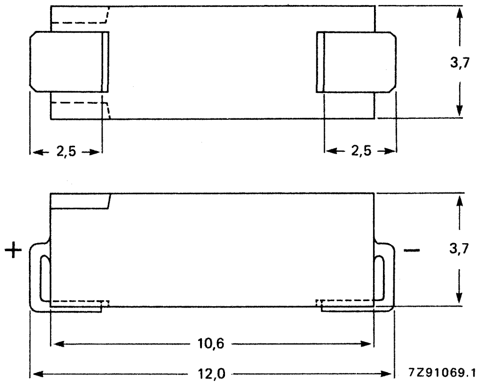


Fig. 1.

Marking

The capacitors are marked on the top with nominal capacitance, "–" sign to identify the cathode, and code for rated voltage, see Table 1. The numerals are those of the capacitance in μF, and the position of the letter indicating the rated voltage, marks the position of the decimal point in the capacitance value.
Example: 3H3 indicates 3,3 μF, 63 V.
Bevelled edges identify the anode end.

Table 1

rated voltage V	code letter
6,3	C
10	D
16	E
25	F
40	G
63	H

Mounting

The capacitors can be placed and soldered on to printed-circuit boards or on to hybrid circuits. Suitable mounting methods include those where the device is totally immersed in a solder bath (260 °C, 10 s), as in wave soldering, and reflow methods where the solder and device are heated together, as in vapour phase soldering.

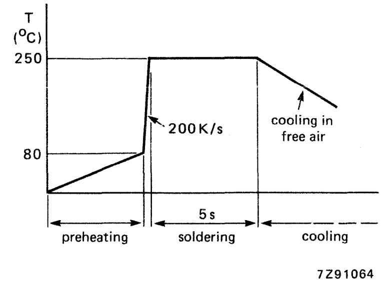


Fig. 2 Typical temperature-time curve for wave soldering.

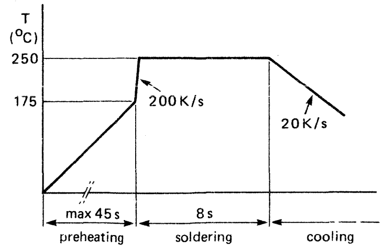


Fig. 3 Typical temperature-time curve for reflow soldering.

In both soldering processes, the capacitors reach the actual soldering temperature. The temperature rise caused by preheating and immersion in solder has no adverse effects on the life of the capacitors, provided the restrictions indicated by Fig. 4 are observed. This curve indicates the acceptable combination of temperature and time. The conditions indicated by the solid parts of the curve can be applied once to each capacitor: a preheating stage at or below one of the temperature-time points on part A, and a soldering stage at or below one of the temperature-time points on part B. Furthermore, the time in part B can be split into two, for double soldering. Typically, an example might be a preheating stage at 165 °C for 60 s followed by a first soldering stage for 4 s at 260 °C and directly followed by a second soldering stage for 6 s at 260 °C (total soldering 10 s at 260 °C).

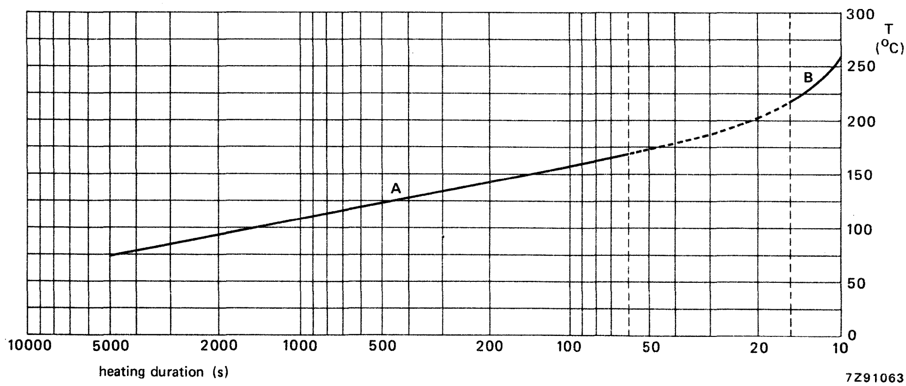


Fig. 4 Preheating and soldering limits for undiminished life expectancy.

DEVELOPMENT SAMPLE DATA

Minimum atmospheric pressure 8,5 kPa

WARNING

Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled; caution is necessary should the outer case be fractured.

DEVELOPMENT SAMPLE DATA

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	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. ESR	max. impedance (Ω) at 10 kHz, at T_{amb} =			case size*	catalogue number 2222 085 followed by	
V	μF	mA	μA		Ω	20 °C	−25 °C	−40 °C		in box	in tape
6,3	22	20	6	0,30	22	9	55	145	1	13229	23229
10	15	18	6	0,25	27	11	50	133	1	14159	24159
16	10	14	6	0,20	40	12	56	150	1	15109	25109
25	6,8	14	6	0,18	42	13	59	162	1	16688	26688
40	4,7	13	7	0,16	54	15	64	191	1	17478	27478
63	0,1	2	4	0,10	1590	550	1800	5000	1	90008	90017
	0,15	3	4	0,10	1060	367	1200	3330	1	90007	90016
	0,22	3	4	0,10	723	250	818	2270	1	90006	90015
	0,33	4	4	0,10	482	167	545	1520	1	90005	90014
	0,47	4	4	0,10	339	117	383	1060	1	90001	90009
	0,68	5	4	0,10	234	81	265	735	1	90004	90013
	1	6	4	0,12	191	55	180	500	1	90002	90011
	1,5	7	4	0,14	149	37	120	333	1	90003	90012
	2,2	11	7	0,14	87	25	82	227	1	18228	28228
	3,3	13	7	0,14	68	17	55	152	1	18338	28338

* Case size 1: 12 mm x 3,7 mm x 3,7 mm (max. dimensions).

Capacitance

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

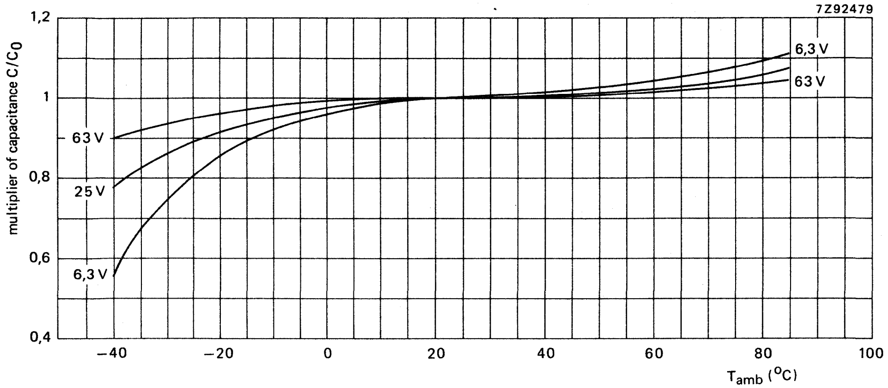


Fig. 5 Multiplier of capacitance as a function of ambient temperature; C_0 = capacitance at T_{amb} = 20 °C, 100 Hz.

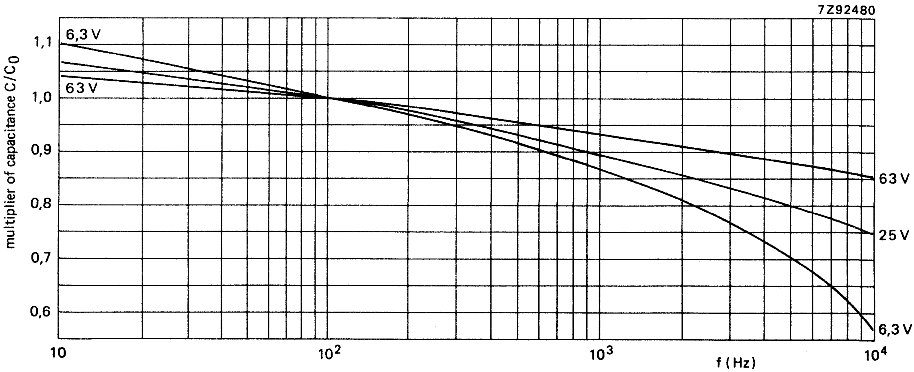


Fig. 6 Multiplier of capacitance as a function of frequency; C_0 = capacitance at T_{amb} = 20 °C, 100 Hz.

DEVELOPMENT SAMPLE DATA

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 for short periods	2 V	

Ripple current**

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

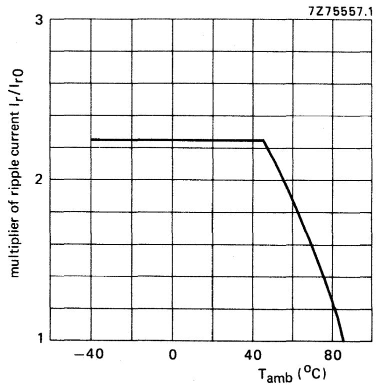


Fig. 7 Multiplier of ripple current as a function of ambient temperature; I_{r0} = ripple current at T_{amb} = 85 °C, 100 Hz.

* 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.

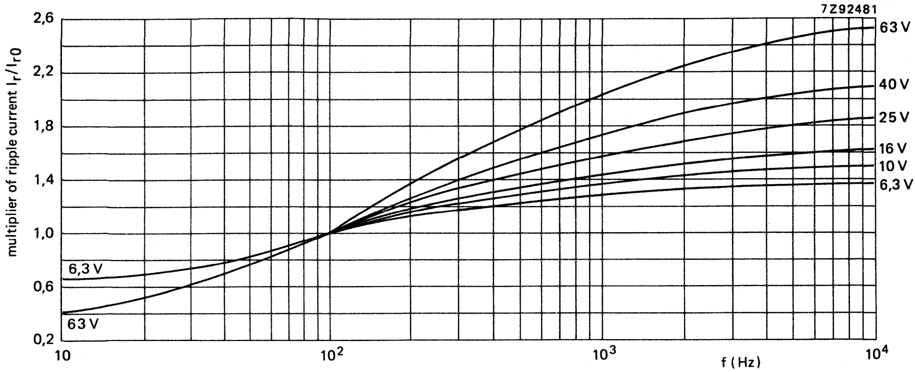


Fig. 8 Multiplier of ripple current as a function of frequency; I_{r0} = ripple current at T_{amb} = 85 °C, 100 Hz.

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;

$\sqrt{r_n} = I_r/I_{r0}$ = 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 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 — see Table 2 (0,02 CU + 3 μA)

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

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

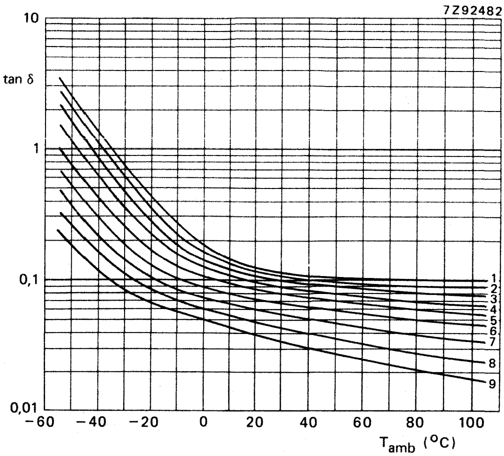


Fig. 9 Typical tan δ as a function of ambient temperature at 100 Hz.

Curve 1 = 22 μF, 6,3 V;
curve 2 = 15 μF, 10 V;
curve 3 = 10 μF, 16 V;
curve 4 = 6,8 μF, 25 V;
curve 5 = 4,7 μF, 40 V;
curve 6 = 1,5 to 3,3 μF, 63 V;
curve 7 = 0,68 and 1 μF, 63 V;
curve 8 = 0,22 to 0,47 μF, 63 V;
curve 9 = 0,1 and 0,15 μF, 63 V.

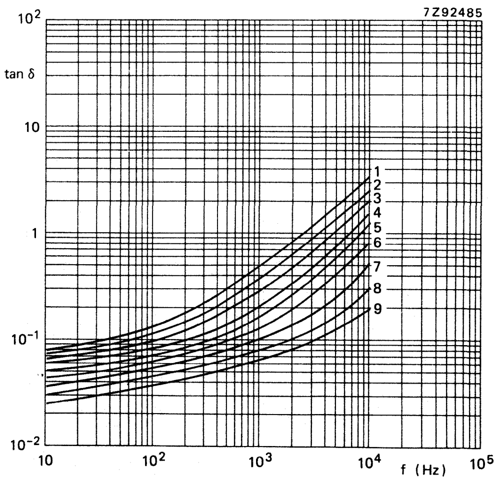


Fig. 10 Typical tan δ as a function of frequency at T_{amb} = 20 °C.

Curve 1 = 22 μF, 6,3 V;
curve 2 = 15 μF, 10 V;
curve 3 = 10 μF, 16 V;
curve 4 = 6,8 μF, 25 V;
curve 5 = 4,7 μF, 40 V;
curve 6 = 1,5 to 3,3 μF, 63 V;
curve 7 = 0,68 and 1 μF, 63 V;
curve 8 = 0,22 to 0,47 μF, 63 V;
curve 9 = 0,1 and 0,15 μF, 63 V.

DEVELOPMENT SAMPLE DATA

Equivalent series resistance (ESR)

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

Impedance (Z)

Maximum impedance at 10 kHz and T_{amb} = 20 °C, −25 °C and −40 °C, measured by means of a four-terminal circuit (Thomson circuit) — see Table 2

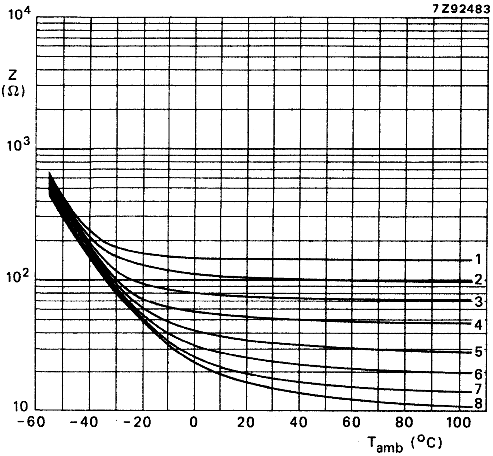


Fig. 11 Typical impedance as a function of ambient temperature at 10 kHz.

Curve 1 = 0,1 μF, 63 V;
curve 2 = 0,15 μF, 63 V;
curve 3 = 0,22 μF, 63 V;
curve 4 = 0,33 μF, 63 V;
curve 5 = 0,47 μF, 63 V;
curve 6 = 0,68 μF, 63 V;
curve 7 = 1 μF, 63 V;
curve 8 = 1,5 μF, 63 V.

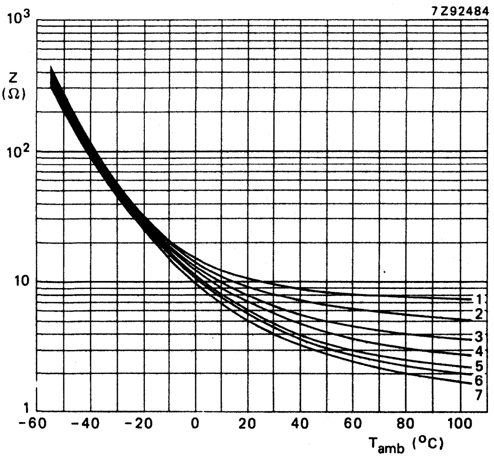


Fig. 12 Typical impedance as a function of ambient temperature at 10 kHz.

Curve 1 = 2,2 μF, 63 V;
curve 2 = 3,3 μF, 63 V;
curve 3 = 4,7 μF, 40 V;
curve 4 = 6,8 μF, 25 V;
curve 5 = 10 μF, 16 V;
curve 6 = 15 μF, 10 V;
curve 7 = 22 μF, 6,3 V.

DEVELOPMENT SAMPLE DATA

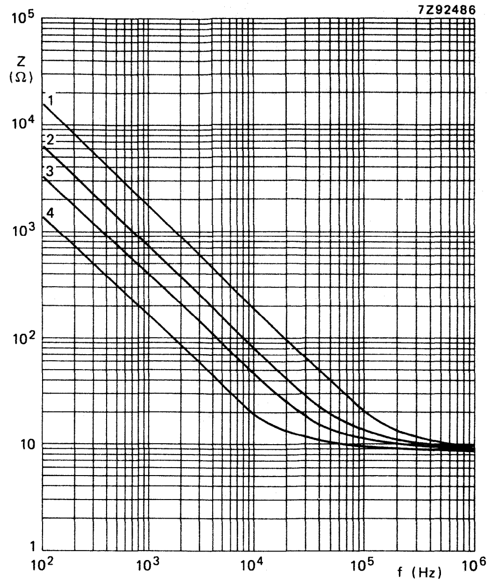


Fig. 13 Typical impedance as a function of frequency at T_{amb} = 20 °C.

Curve 1 = 0,1 μF, 63 V;
curve 2 = 0,22 μF, 63 V;
curve 3 = 0,47 μF, 63 V;
curve 4 = 1 μF, 63 V.

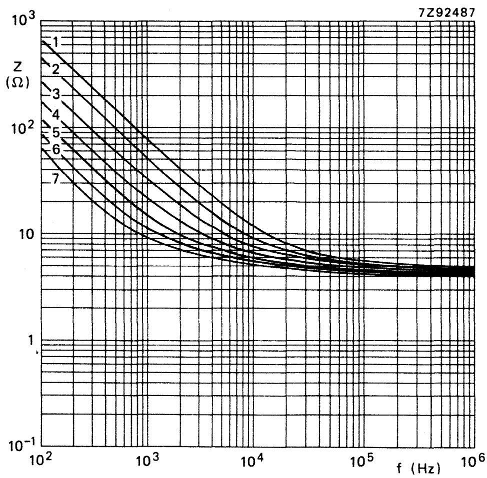


Fig. 14 Typical impedance as a function of frequency at T_{amb} = 20 °C.

Curve 1 = 2,2 μF, 63 V;
curve 2 = 3,3 μF, 63 V;
curve 3 = 4,7 μF, 40 V;
curve 4 = 6,8 μF, 25 V;
curve 5 = 10 μF, 16 V;
curve 6 = 15 μF, 10 V;
curve 7 = 22 μF, 6,3 V.

Equivalent series inductance (ESL) typ. 15 nH

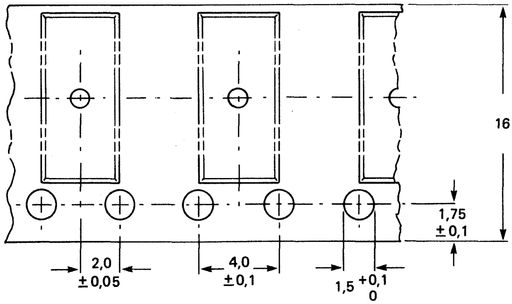
OPERATIONAL DATA

Category temperature range −40 to + 85 °C

PACKING

Dimensions in mm

The capacitors are supplied in boxes of 200 or boxes of 1000 (which contain 5 boxes of 200 each), and in 16 mm blister tape of 2000 on reel.



Cumulative pitch error : 0,2 mm over 10 pitches

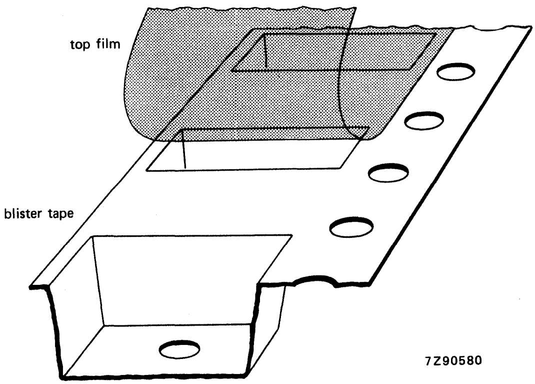


Fig. 15 Blister tape.

TESTS AND REQUIREMENTS

See Introduction, section 9, under aluminium electrolytic capacitors, with the following addition.

After *endurance test, 1000 h, 85 °C,* the capacitors meet the following requirements:

$\Delta C/C \leqslant \pm 20\%$,

tan $\delta \leqslant$ 200% of specified value,

leakage current $\leqslant$ specified value.

After *shelf life test, 500 h, 85 °C,* the capacitors meet the same requirements as after endurance test, except for leakage current: $\leqslant$ 200% of specified value. The rated voltage shall be applied to the capacitors for minimum 30 min, at least 24 h and not more than 48 h before measurements.

Resistance to soldering heat: 260 ± 5 °C, 10 ± 1 s.

After soldering test, the capacitors meet the following requirements:

$\Delta C/C \leqslant \pm 10\%$,

tan $\delta \leqslant$ specified value,

leakage current $\leqslant$ 200% of specified value,

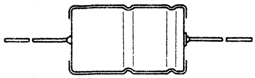
no visible damage.

DEVELOPMENT SAMPLE DATA

Note: Capacitors 2222 085 are miniature types, general purpose grade.

ALUMINIUM ELECTROLYTIC CAPACITORS

- Miniature and small types
- Axial leads
- 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 100 V
Category temperature range	−40 to + 85 °C
Endurance test	
at 85 °C	5000 h
at 105 °C	1000 h*
Shelf life at 0 V, 85 °C	500 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*

* Not applicable to 100 V range.

Selection chart for C—U_R and relevant case sizes.

C_{nom} μF	U_R (V) 6,3	10	16	25	40	63	100
2,2						5	
3,3						5	
4,7						5	5
6,8						5	5
10						5	5
15					5	6	6
22					5	6	6
33				5	6	00	00
47				5	6	00	00
68			5		00	01	01
100		5		6	01	02	02
150	5		6	00	01	03	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 telephony equipment.

DESCRIPTION

The capacitor has etched and oxidized 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 soldered-copper 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

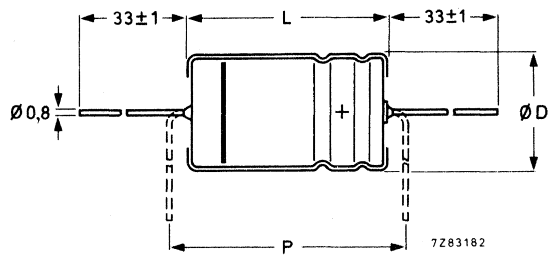


Fig. 1 Case sizes 5 and 6. For dimensions D, L and P, see Table 1.

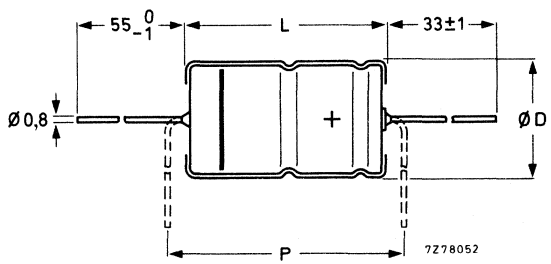


Fig. 2 Case sizes 00, 01, 02 and 03. For dimensions D, L and P, see Table 1.

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, code of origin, 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

WARNING

Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled. Caution is necessary should the outer case be fractured.

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 1 min μA	max. tan δ *	typ. ESR * Ω	impedance at 100 kHz Ω max.	impedance at 100 kHz Ω typ.	case size	catalogue number
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.
** Measured after 5 min.

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. tan δ*	typ. ESR* Ω	impedance at 100 kHz Ω max.	impedance at 100 kHz Ω typ.	case size	catalogue number
100	4,7	40	5**	0,07	8,5	1,6	0,8	5	2222 108 39478
	6,8	50	7**	0,07	5,9	1,6	0,8	5	39688
	10	60	10	0,07	4,0	1,6	0,8	5	39109
	15	80	13	0,07	2,7	0,84	0,4	6	39159
	22	90	17	0,07	1,8	0,84	0,4	6	39229
	33	105	24	0,15	4,8	1,9	0,9	00	39339
	47	125	33	0,15	3,4	1,9	0,9	00	39479
	68	165	45	0,15	2,4	1,6	0,7	01	39689
	100	225	64	0,15	1,6	1,3	0,5	02	39101
	150	300	94	0,15	1,1	0,9	0,3	03	39151

Capacitance

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

Tolerance on nominal capacitance at 100 Hz — −10 to + 50%

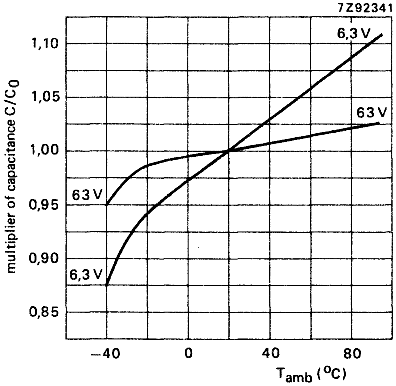


Fig. 3 Typical capacitance as a function of temperature, U_R = 6,3 to 63 V; C_0 = capacitance at 20 °C, 100 Hz.

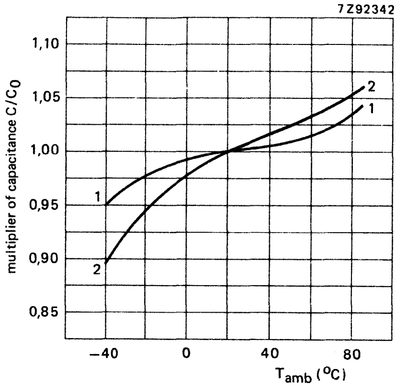


Fig. 4 Typical capacitance as a function of temperature, U_R = 100 V; C_0 = capacitance at 20 °C, 100 Hz.
curve 1 = case sizes 5 and 6;
curve 2 = case sizes 00 to 03.

* See also corresponding paragraph.
** Measured after 5 min.

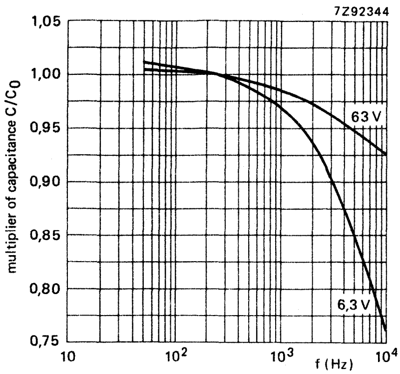


Fig. 5 Typical capacitance as a function of frequency, U_R = 6,3 to 63 V;
C_o = capacitance at 20 °C, 100 Hz.

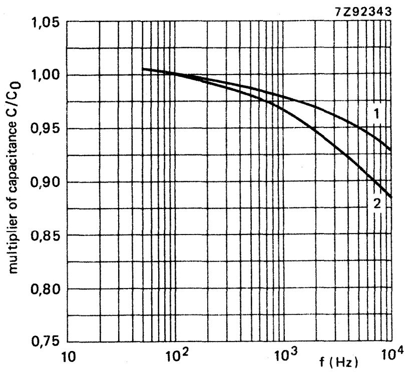


Fig. 6 Typical capacitance as a function of frequency, U_R = 100 V;
C_o = capacitance at 20 °C, 100 Hz.
curve 1 = case sizes 5 and 6;
curve 2 = case sizes 00 to 03.

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, without d.c. voltage applied	1 V
	c) momentary value of applied voltage	between 1,1 x U_R and −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
$T_{amb} \leqslant$ 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.

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

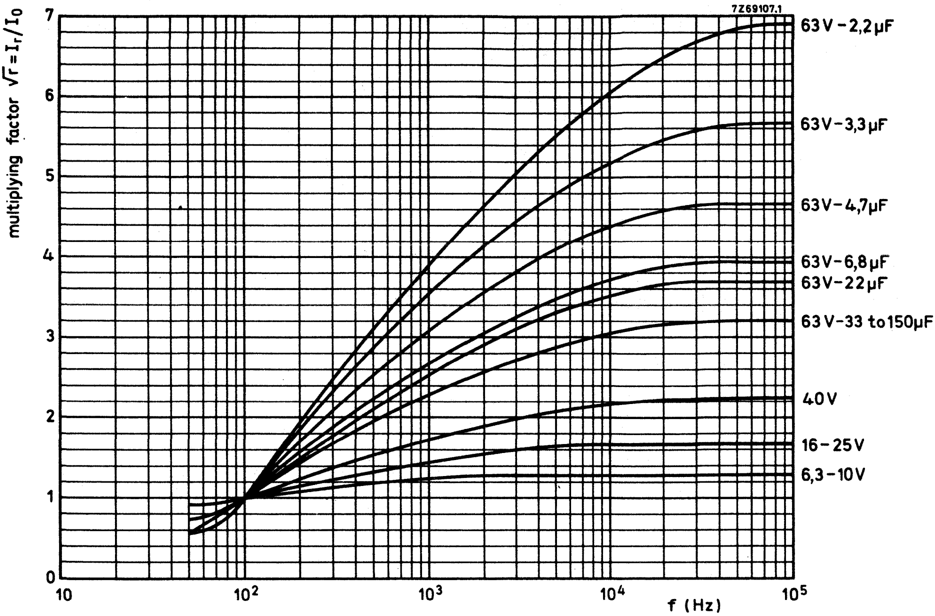


Fig. 7 Multiplying factor as a function of frequency, U_R = 6,3 to 63 V; I_0 = maximum ripple current at 85 °C, 100 Hz.

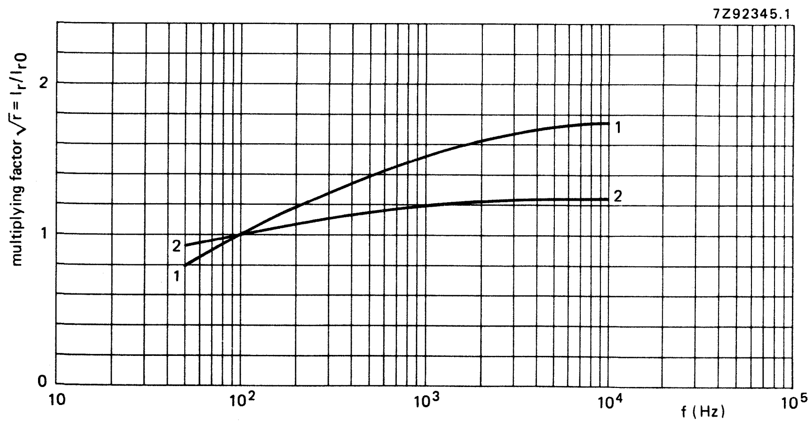


Fig. 8 Multiplying factor as a function of frequency, U_R = 100 V; I_0 = maximum ripple current at 85 °C, 100 Hz.
Curve 1 = case sizes 5 and 6;
Curve 2 = case sizes 00 to 03.

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 1 min* after application of U_R, at T_{amb} = 20 °C	see Table 2
Leakage current during continuous operation at U_R	
at 20 °C	approx. 0,2 x values stated in Table 2
at 85 °C	⩽ values stated in Table 2

* For capacitors < 10 μF the leakage current shall be measured 5 min after application of U_R.

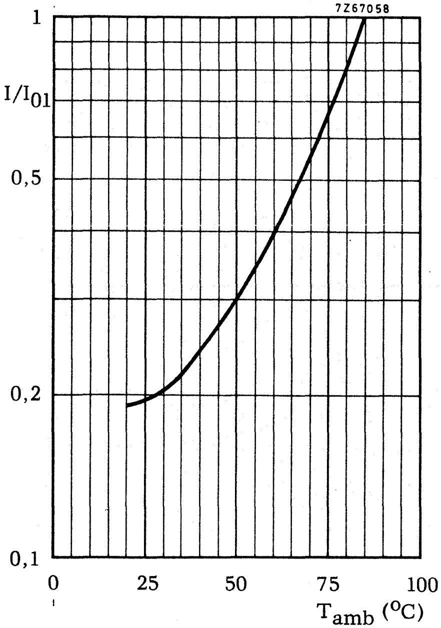


Fig. 9 Multiplier I/I_{01} as a function of temperature. I_{01} = leakage current during continuous operation at T_{amb} = 85 °C at U_R.

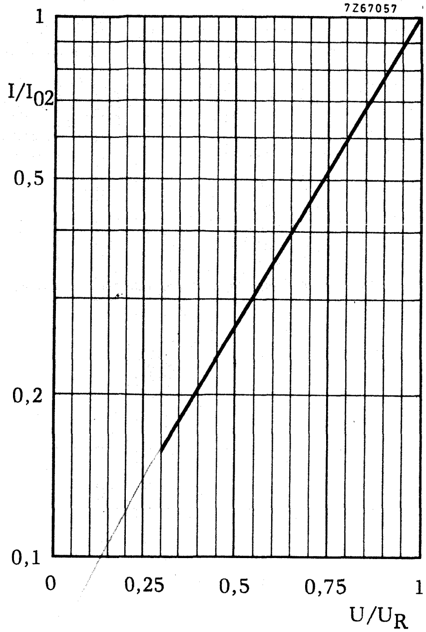


Fig. 10 Multiplier I/I_{02} as a function of U/U_R. I_{02} = leakage current at U_R at a discrete constant temperature within category temperature range.

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)

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 = tan δ/ωC)

Typical ESR at 100 Hz and T_{amb} = 20 °C	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

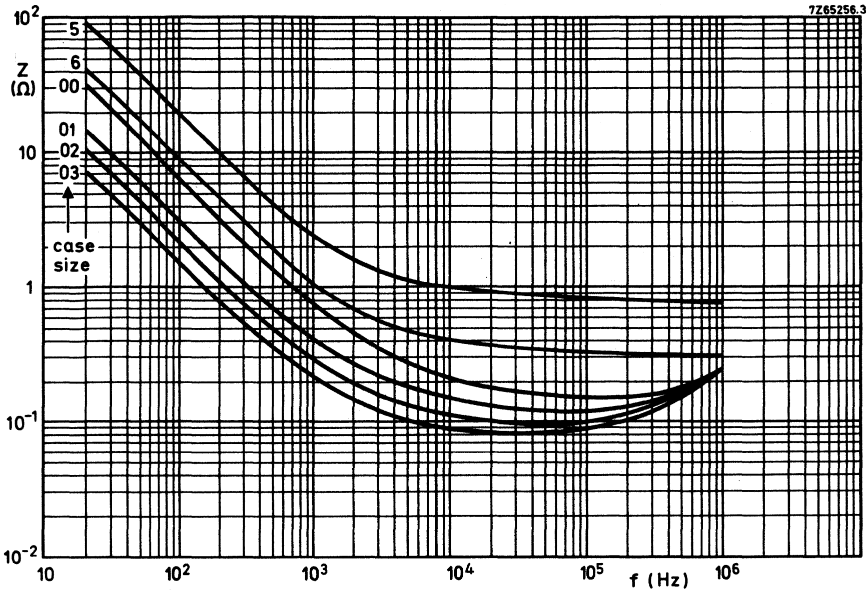


Fig. 11 Typical impedance as a function of frequency at 20 °C, U_R = 16 V.

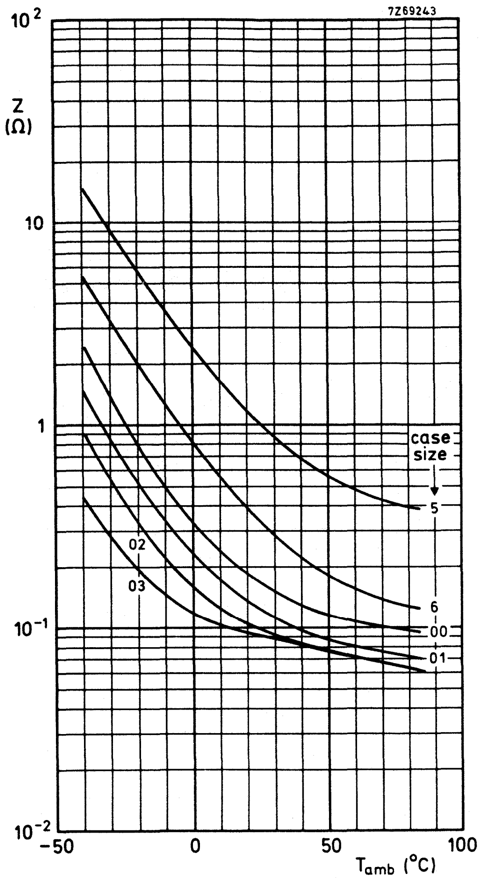


Fig. 12 Typical impedance as a function of temperature at 100 kHz, U_R = 6,3 to 63 V.

Equivalent series inductance (ESL)

Case size 5	typ. 40 nH
Case size 6	typ. 50 nH
Case sizes 00 and 01	typ. 50 nH
Case size 02	typ. 55 nH
Case size 03	typ. 60 nH

OPERATIONAL DATA

Category temperature range

for rated voltage: –40 to + 85 °C

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

→ Shelf life at 0 V and T_{amb} = 85 °C: 500 h

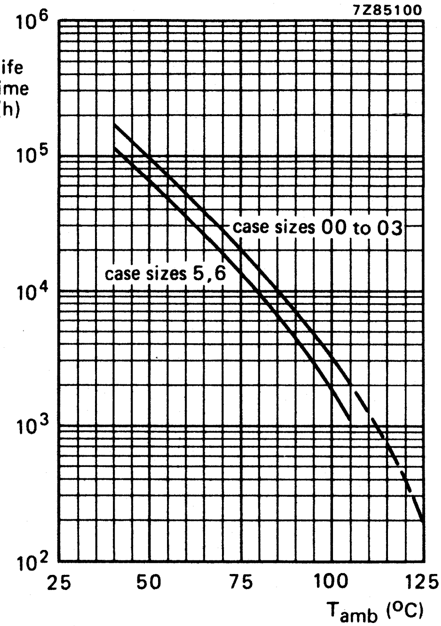


Fig. 13 Typical lifetime as a function of temperature.

* Not applicable to 100 V range.

PACKING

Capacitors with case sizes 00 to 03 are supplied in boxes of 200. Capacitors with case sizes 5 and 6 are supplied on bandoliers in boxes of 500.

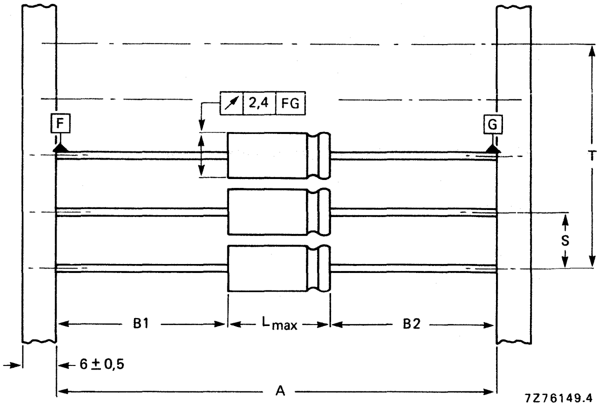


Fig. 14 Capacitors (case size 5 or 6) on bandoliers: the bandolier to which the negative capacitor terminals are connected is blue. See Table 3 for simendions A, S, T and L.

$|B1-B2|$ = max. 1,4 mm.

Table 3

Dimensions in mm

case size	A	S	T for number (n) of capacitors		L_{max}
			n < 50	50<n<100	
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

TESTS AND REQUIREMENTS

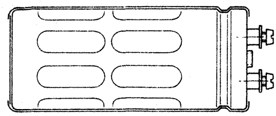
See Introduction, section 9, under aluminium electrolytic capacitors, with the exception of IEC 384–4 sub clause 9. 14, for which the following is valid.

IEC 384–4 sub clause 9. 14.
IEC 68–2 test method: no reference.
Name of test: Endurance.
Procedure: 5000 h at 85 °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 ⩽ stated limit, tan $\delta \leqslant$ 1,3 x stated limit, impedance at 100 kHz ⩽ 2 x stated limit, $\Delta C/C \leqslant$ 15%.

After *shelf life test, 500 h, 85 °C,* the capacitors meet the same requirements as after endurance test. The rated voltage shall be applied to the capacitors for minimum 30 min., at least 24 h and not more than 48 h before measurements.

Note:
Capacitors 2222 108 are miniature and 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
Shelf life at 0 V, 85 °C	500 h
Basic specifications	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

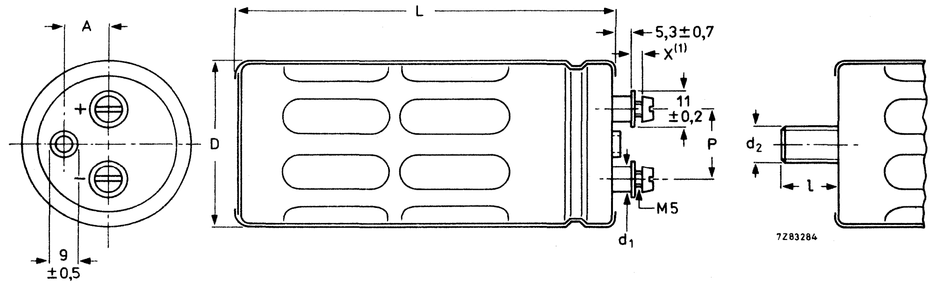


Fig. 1 See Table 1 for dimensions D, L, P, A, d_1, d_2, and l.

(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	d$_1$		d$_2$ 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 capacitor may be mounted vertically or horizontally, with or without mounting clamp. For proper functioning the vent should be on the upper side, whether the capacitor is mounted horizontally or vertically. 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

WARNING

Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled. Caution is necessary should the outer case be fractured.

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	nom. cap.	max. r.m.s.* ripple current (A)		max. leakage current at U_R after 5 min	typ.* ESR	max. tan δ*	impedance at 20 kHz* mΩ		case size	catalogue number**
		at T_{amb} = 85 °C 100 Hz	at T_{amb} = 70 °C 20 kHz							
V	μF			mA	mΩ		typ.	max.		
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	nom. cap.	max. r.m.s.* ripple current (A)		max. leakage current at U_R after 5 min	typ.* ESR	max. tan δ*	impedance at 20 kHz* mΩ		case size	catalogue number**
		at T_{amb} = 85 °C 100 Hz	at T_{amb} = 70 °C 20 kHz							
V	µF			mA	mΩ		typ.	max.		
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	
	(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	
	U_R = 350 V and 385 V	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	

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:

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

$I_{r\,max}$ = 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 (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

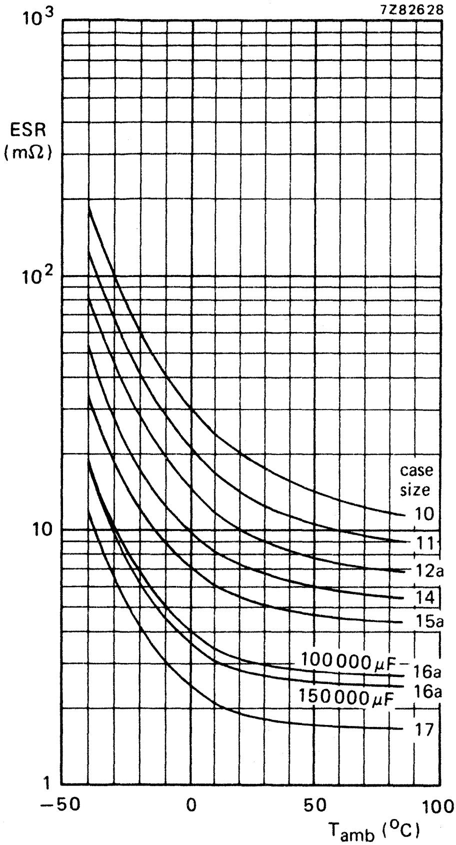


Fig. 2 Typical ESR as a function of temperature at 100 Hz, U_R = 10 V.

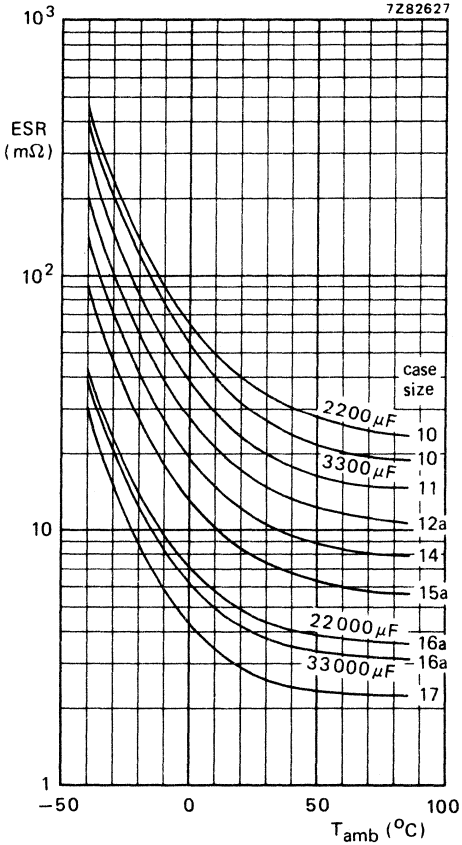


Fig. 3 Typical ESR as a function of temperature at 100 Hz, U_R = 63 V.

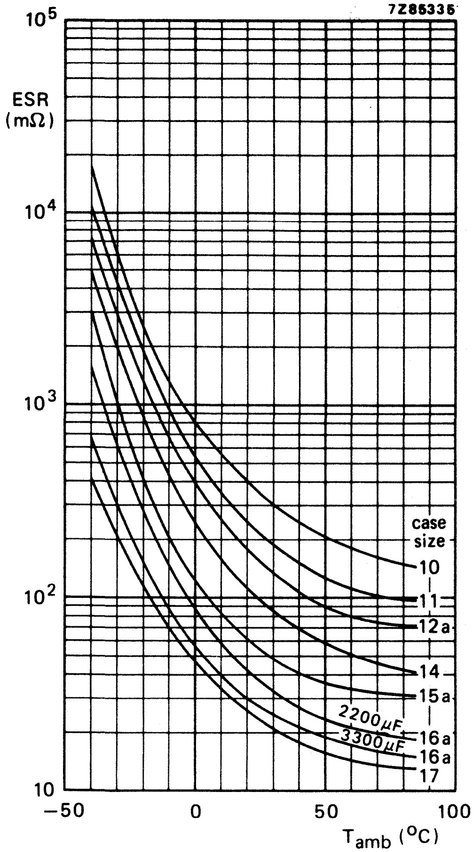


Fig. 4 Typical ESR as a function of temperature at 100 Hz, U_R = 250 V.

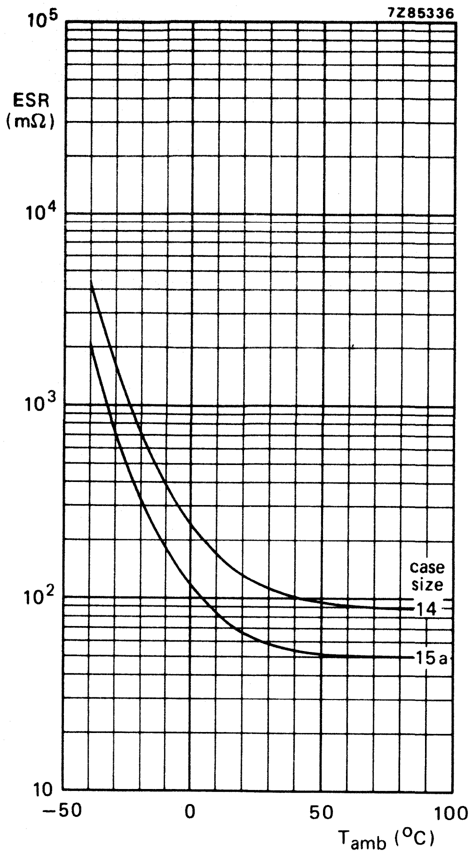


Fig. 5 Typical ESR as a function of temperature at 100 Hz, U_R = 350 V.

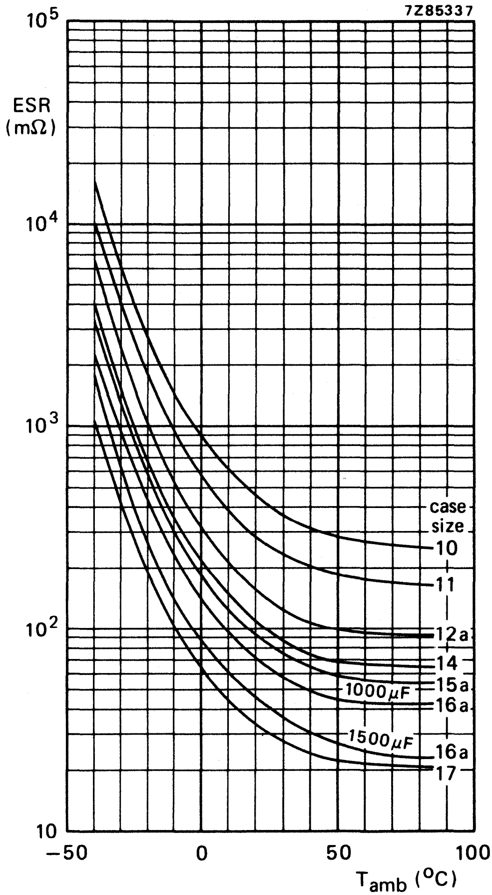


Fig. 6 Typical ESR as a function of temperature at 100 Hz, U_R = 385 V.

Impedance

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

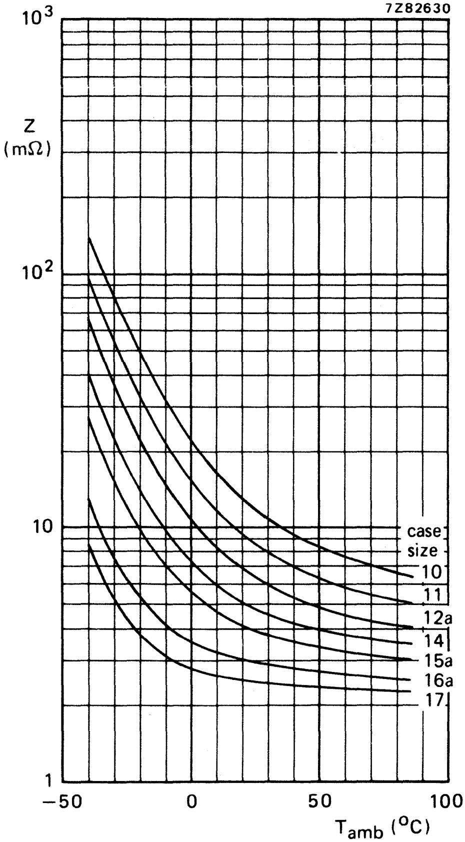


Fig. 7 Typical impedance as a function of temperature at 20 kHz, U_R = 10 V.

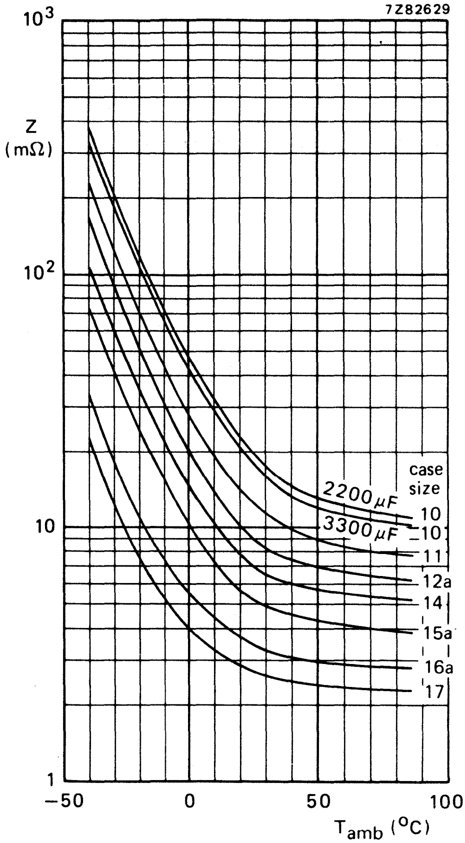


Fig. 8 Typical impedance as a function of temperature at 20 kHz, U_R = 63 V.

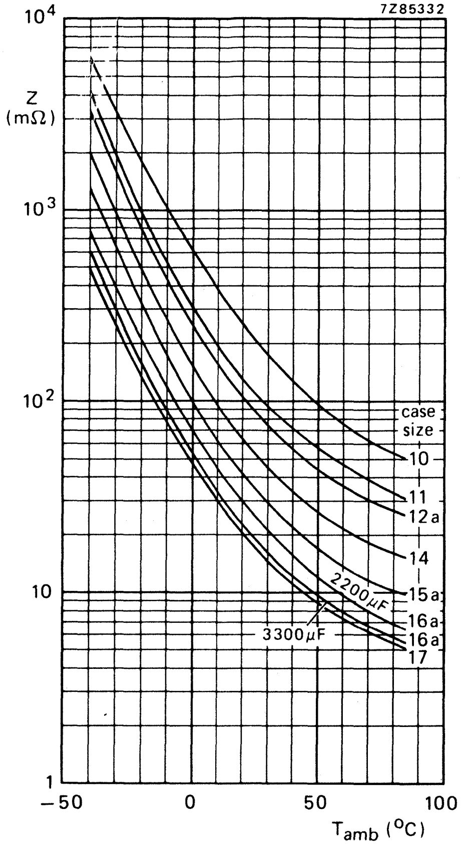


Fig. 9 Typical impedance as a function of temperature at 20 kHz, U_R = 250 V.

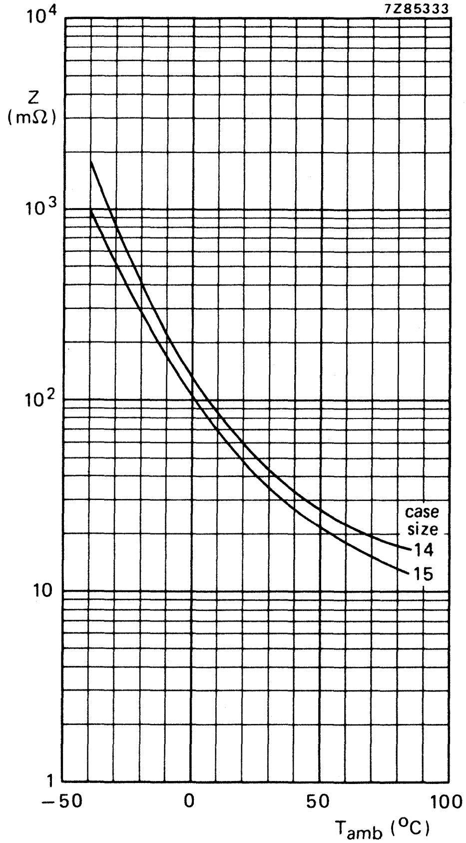


Fig. 10 Typical impedance as a function of temperature at 20 kHz, U_R = 350 V.

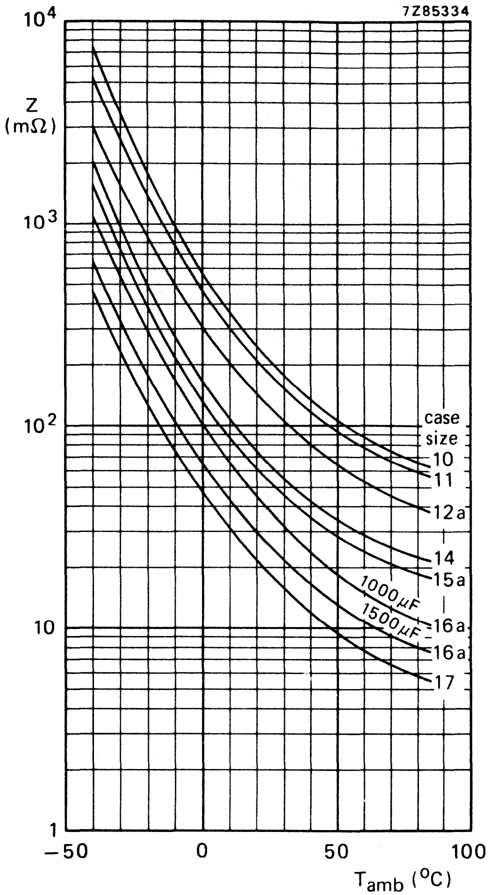


Fig. 11 Typical impedance as a function of temperature at 20 kHz, U_R = 385 V.

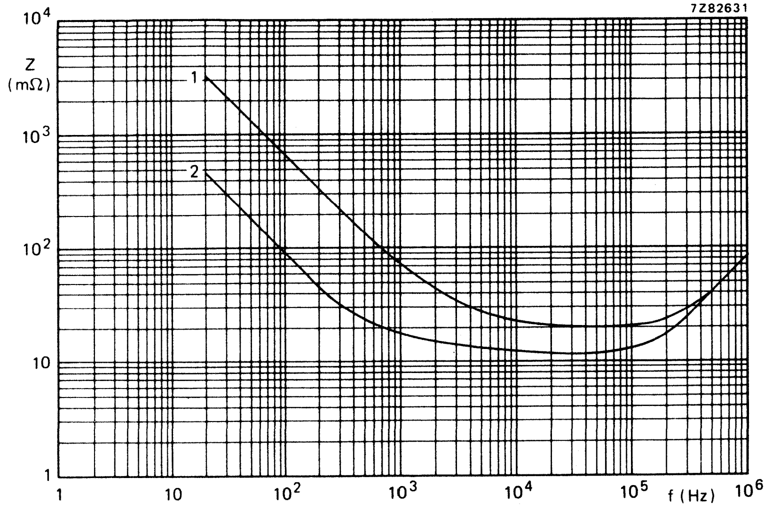


Fig. 12 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 10:**
curve 1 = 2200 μF, 63 V; curve 2 = 15 000 μF, 10 V.

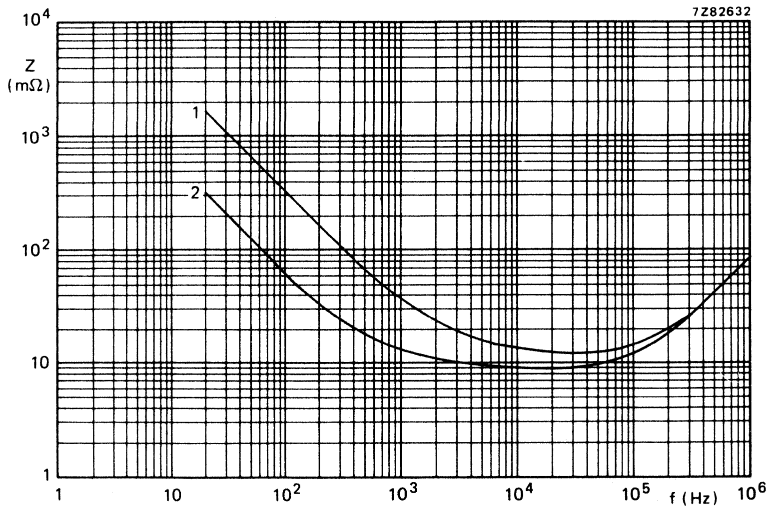


Fig. 13 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 11:**
curve 1 = 4700 μF, 63 V; curve 2 = 22 000 μF, 10 V.

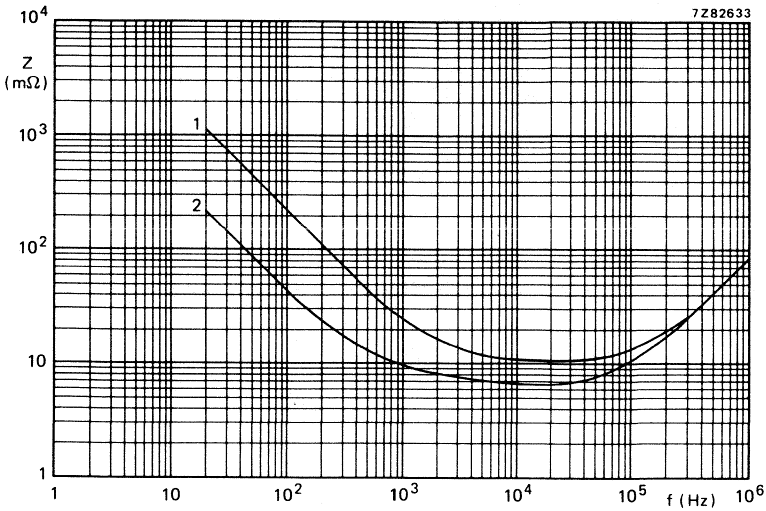


Fig. 14 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 12a:** curve 1 = 6800 μF, 63 V; curve 2 = 33 000 μF, 10 V.

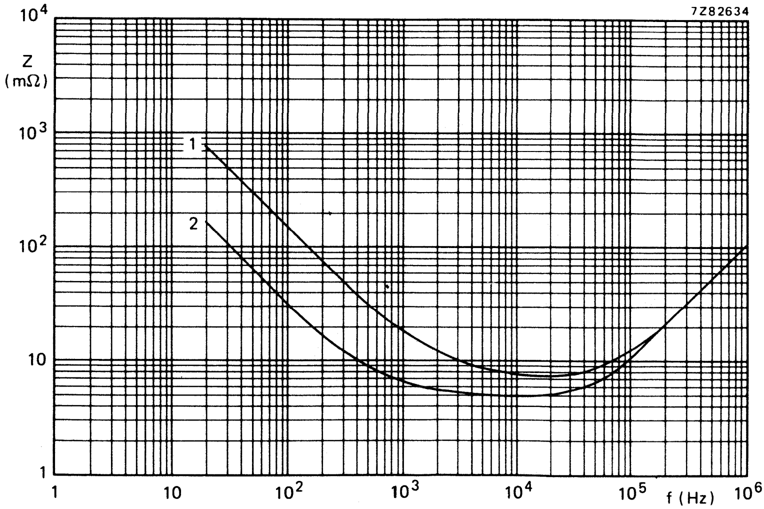


Fig. 15 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 14:** curve 1 = 10 000 μF, 63 V; curve 2 = 47 000 μF, 10 V.

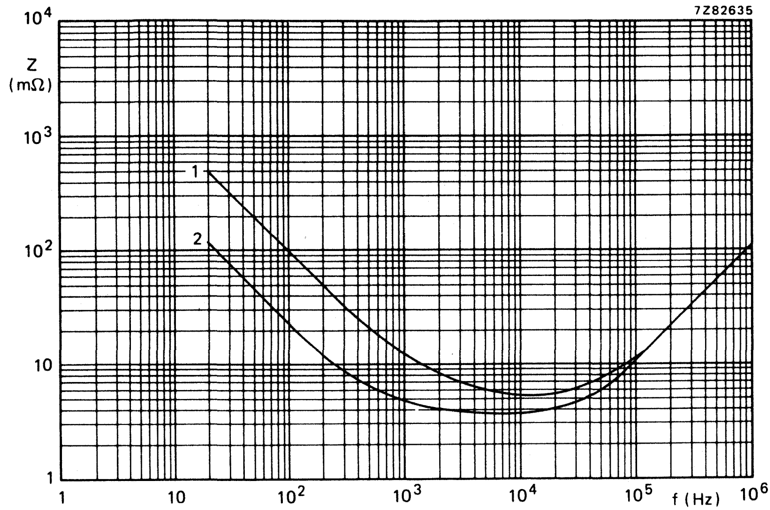


Fig. 16 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 15a:**
curve 1 = 15 000 μF, 63 V; curve 2 = 68 000 μF, 10 V.

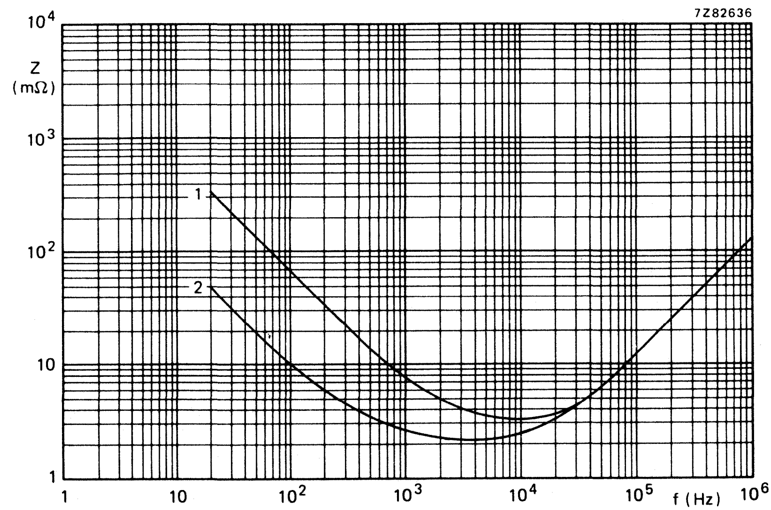


Fig. 17 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 16a:**
curve 1 = 22 000 μF, 63 V; curve 2 = 150 000 μF, 10 V.

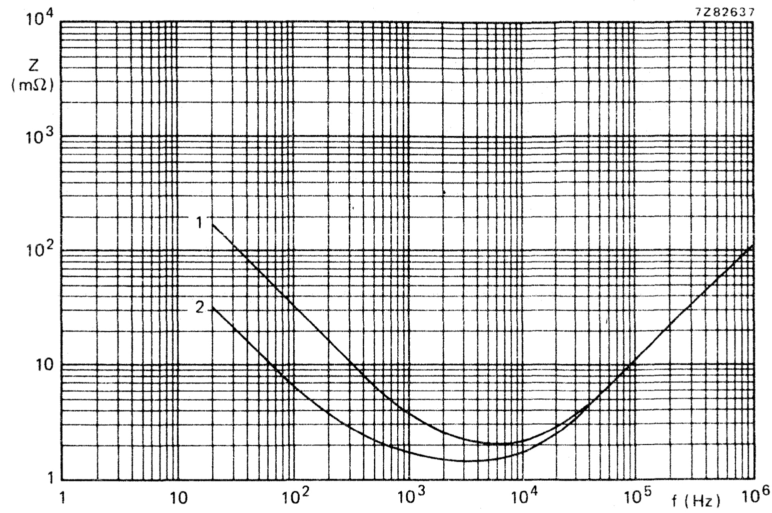


Fig. 18 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 17:**
curve 1 = 47 000 μF, 63 V; curve 2 = 220 000 μF, 10 V.

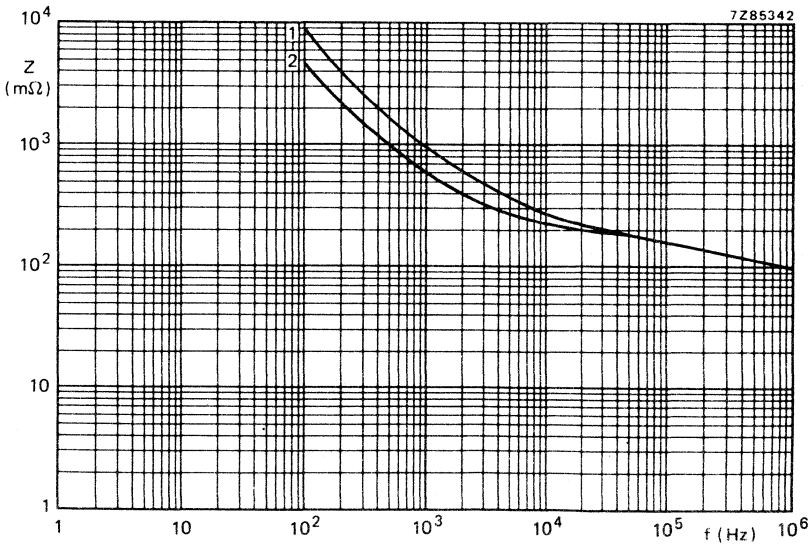


Fig. 19 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 10:**
curve 1 = 150 μF, 385 V; curve 2 = 330 μF, 250 V.

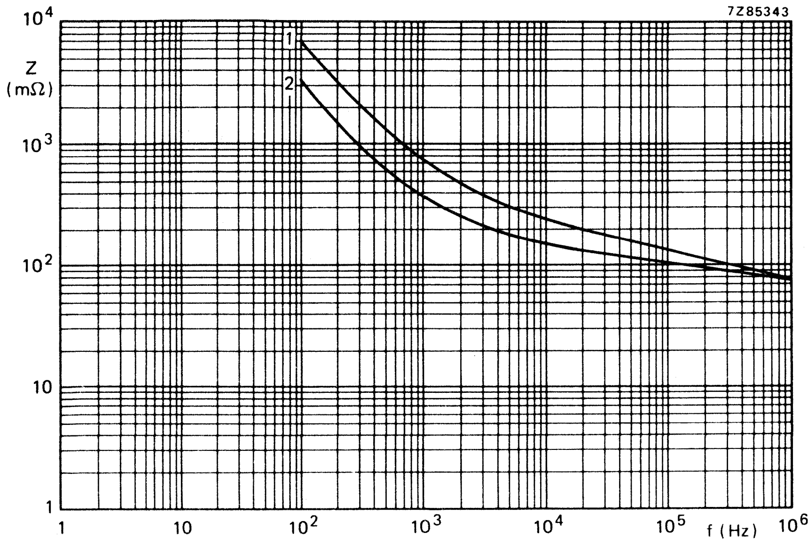


Fig. 20 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 11:**
curve 1 = 220 μF, 385 V; curve 2 = 470 μF, 250 V.

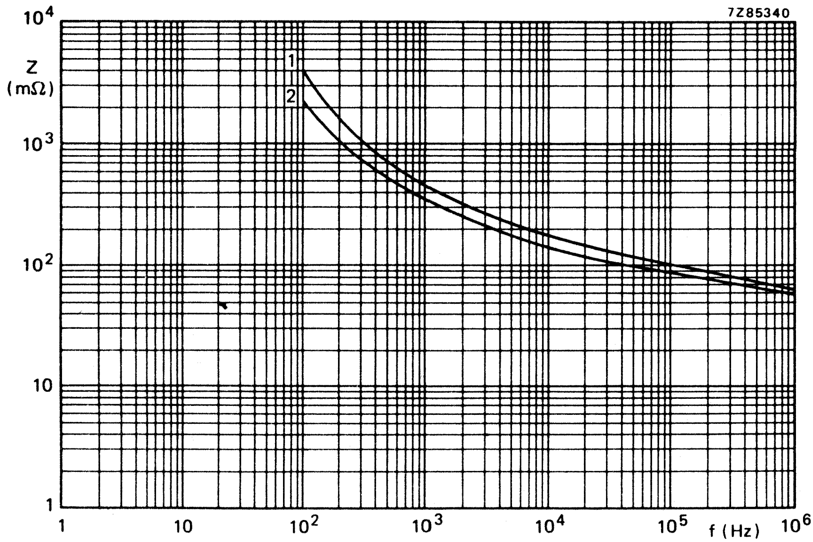


Fig. 21 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 12a:**
curve 1 = 330 μF, 385 V; curve 2 = 680 μF, 250 V.

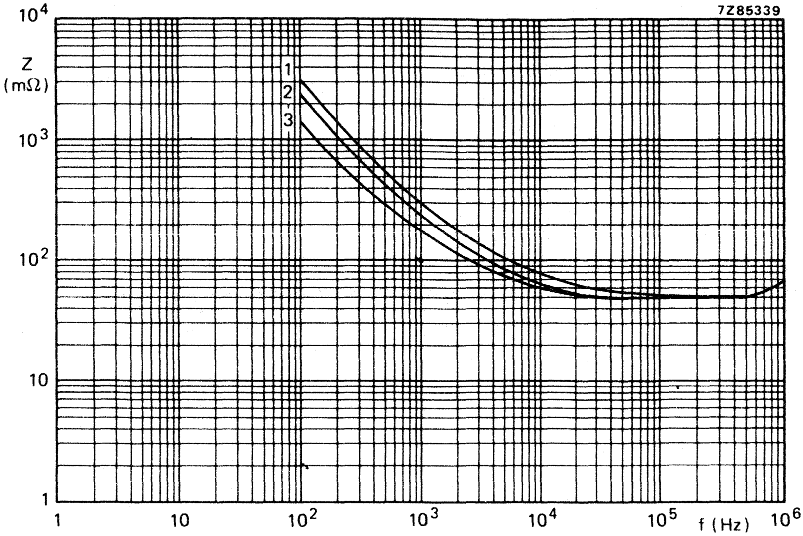


Fig. 22 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 14:**
curve 1 = 470 μF, 385 V; curve 2 = 680 μF, 350 V;
curve 3 = 1000 μF, 250 V.

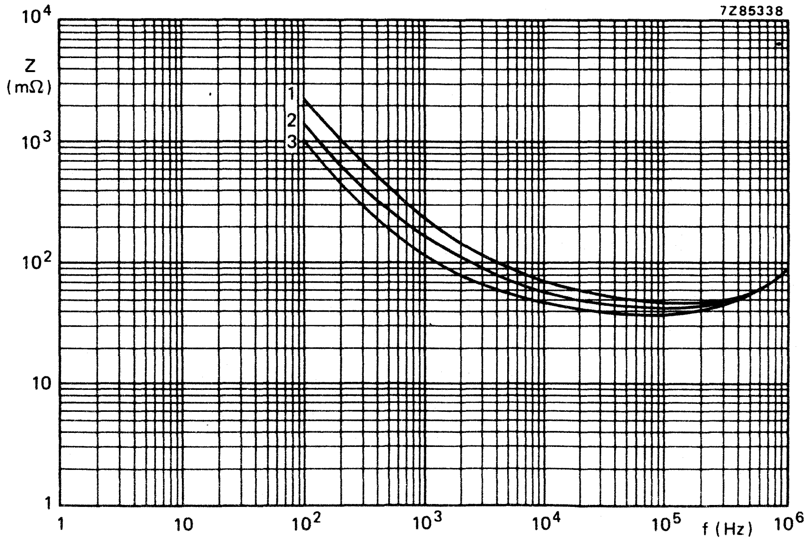


Fig. 23 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 15a:**
curve 1 = 680 μF, 385 V; curve 2 = 1000 μF, 350 V;
curve 3 = 1500 μF, 250 V.

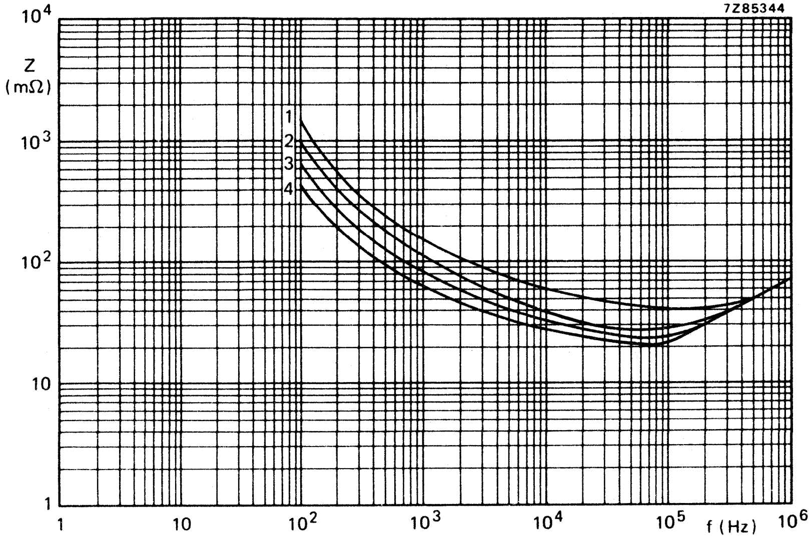


Fig. 24 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 16a:**
curve 1 = 1000 μF, 385 V; curve 2 = 1500 μF, 385 V;
curve 3 = 2200 μF, 250 V; curve 4 = 3300 μF, 250 V.

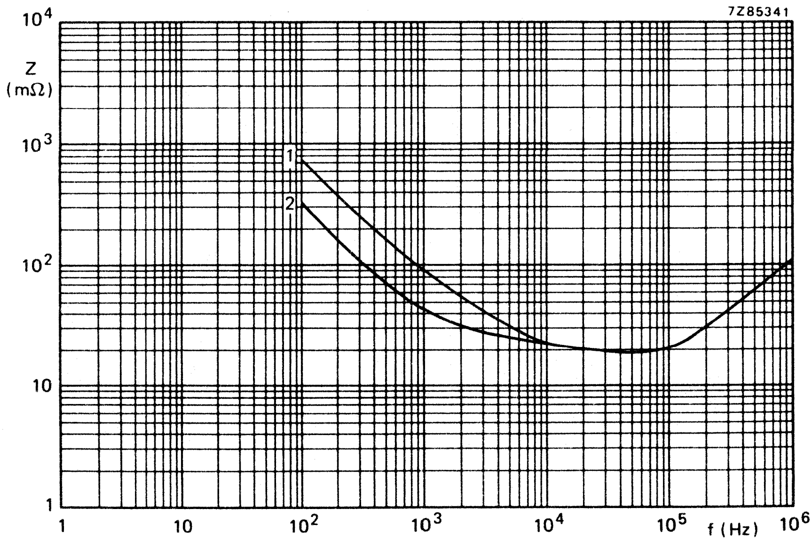


Fig. 25 Typical impedance as a function of frequency at T_{amb} = 20 °C; **case size 17:**
curve 1 = 2200 μF, 385 V; curve 2 = 4700 μF, 250 V.

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)**

Shelf life at 0 V and T_{amb} = 85 °C 500 h

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 Introduction, section 9, under aluminium electrolytic capacitors.

After *shelf life test, 500 h, 85 °C,* the capacitors meet the same requirements as after endurance test. The rated voltage shall be applied to the capacitors for minimum 30 min., at least 24 h and not more than 48 h before measurements.

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.

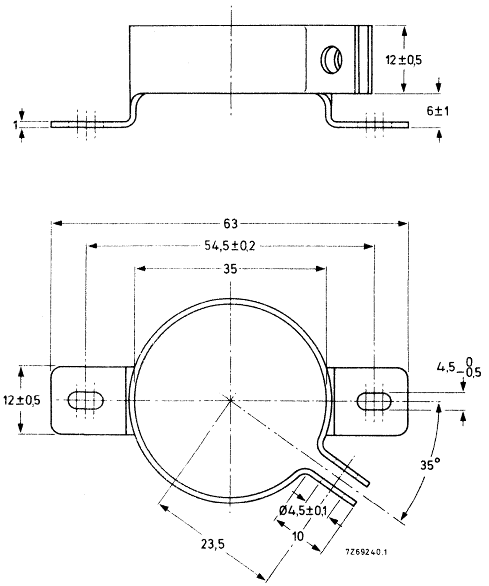


Fig. 26 Clamp for case diameter of 35 mm.
Catalogue number: 4322 043 04272.

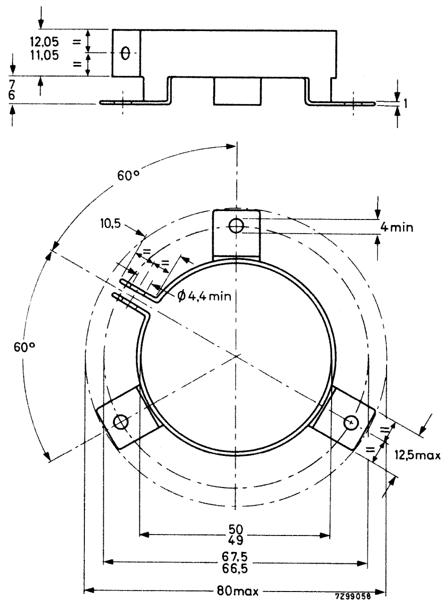
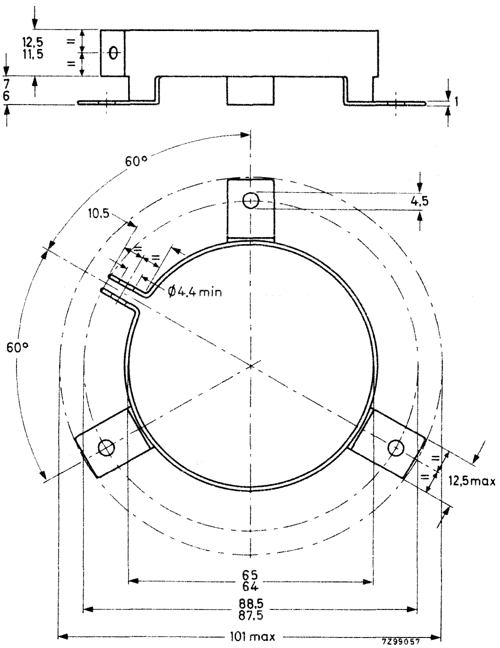


Fig. 27 Clamp for case diameter of 50 mm.
Catalogue number: 4322 043 04281.



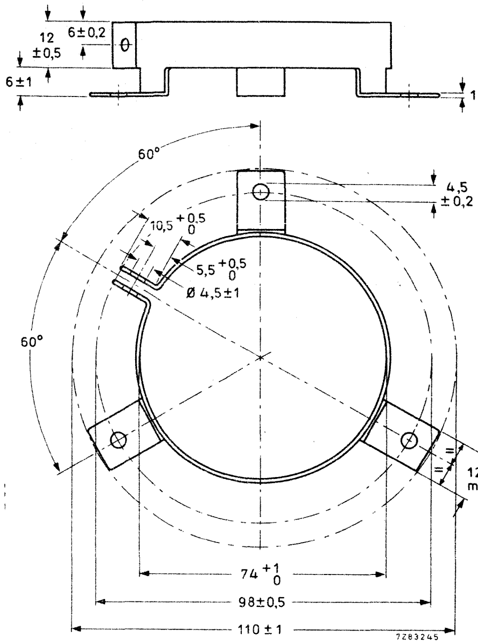


Fig. 28 Clamp for case diameter of 65 mm.
Catalogue number: 4322 043 04291.

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.

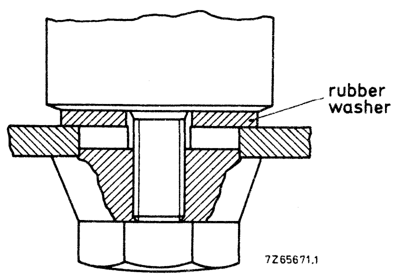


Fig. 30 Insulated mounting.

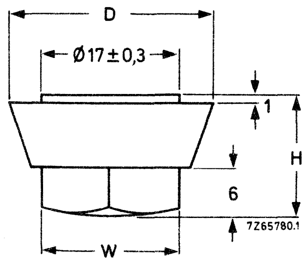
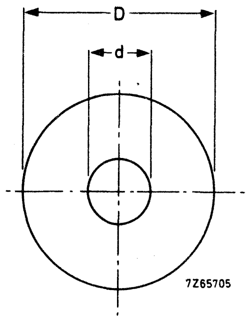


Fig. 31 Synthetic cap nut; see Table 6 for dimensions D, H and W.

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

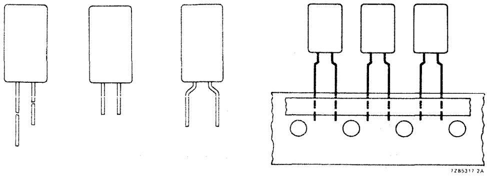
D	d	catalogue number
34	8,4	4322 043 05591
49	13	4322 043 05531
64	13	4322 043 05521
74	13	4322 043 13000

Fig. 32 Rubber washer; thickness 2 mm.

* W measured across flats.

ALUMINIUM ELECTROLYTIC CAPACITORS

- **High-temperature version of 2222 036 series**
- **Miniature type**
- **Single ended**
- **Long life**
- **Industrial applications**
- **High CU product per unit volume**



QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	0,47 to 470 μF
Tolerance on nominal capacitance	−20 to + 20%
Rated voltage range, U_R (R5 series)	6,3 to 50 V
Category temperature range	−55 to + 105 °C
Endurance test	1500 h at 105 °C/5000 h at 85 °C
Shelf life at 0 V	1500 h at 105 °C/5000 h at 85 °C
Basic specification	IEC 384-4, long-life grade DIN 41332/DIN 41259
Climatic category	
IEC 68	55/105/56
DIN 40040	FPF

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

C_{nom} μF	U_R (V)					
	6,3	10	16	25	35	50
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
15						11
22						11
33					11	13
47				11		13
68			11			13
100		11			13	
150	11			13		
220			13			
330		13				
470	13					

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

APPLICATION

These capacitors with extremely high CU product to volume ratio are mainly used for smoothing, coupling and decoupling purposes in industrial applications, where high reliability and/or a wide temperature range is required. Other applications are timing and delay circuits. The taped versions are suitable for automatic insertion and for cutting and forming equipment.

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 all-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.

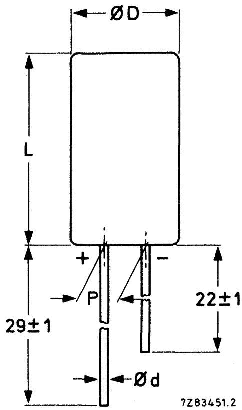


Fig. 1. Style 1; see Table 1 for dimensions d, D, L and P.

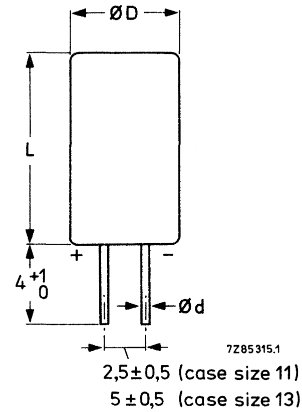


Fig. 2 Style 2; non preferred, see Table 1 for dimensions d, D and L.

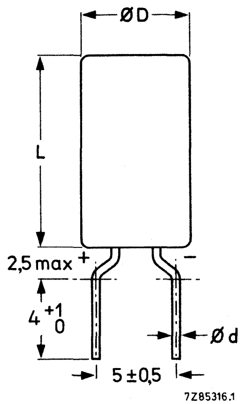
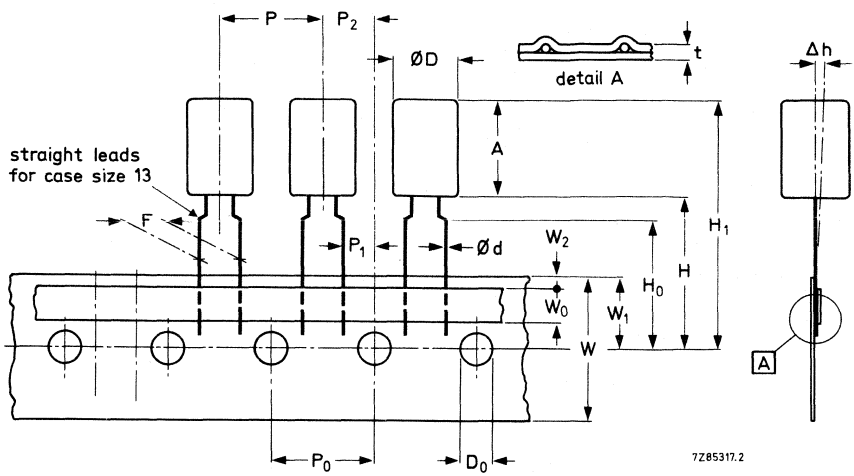


Fig. 3 Style 3; case size 11 only; non preferred, see Table 1 for dimensions d, D and L.

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 consideratuin.



→ direction of tape transport

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

DEVELOPMENT SAMPLE DATA

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	6,0	6,0	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	32,0	32,0	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.

Marking

The capacitors are marked as follows:

on the top

- nominal capacitance;
- code letter for tolerance on nominal capacitance, according to IEC 62;
- rated voltage;
- polarity identification.

on the circumference

- name of manufacturer;
- group number (116); code for long-life grade (LL);
- code letter of manufacturer;
- date code (year and month) according to IEC 62.

Minimum atmospheric pressure 8,5 kPa

WARNING

Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled; caution is necessary should the outer case be fractured.

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%.

DEVELOPMENT SAMPLE DATA

Table 3

U_R V	nom. cap. µF	max. r.m.s. ripple current mA at T_{amb} = 85 °C	max. r.m.s. ripple current mA at T_{amb} = 105 °C	max. leakage current at U_R after 1 min µA	max. tan δ	case size*	catalogue number 2222 116 followed by style 1	style 2	style 3	on reel style 4	in ammopack style 5
6,3	150	81	47	8,7	0,25	11	53151	83151	63151	23151	33151
	470	190	110	21	0,25	13	53471	63471		23471	33471
10	100	74	43	9	0,2	11	54101	84101	64101	24101	34101
	330	180	105	23	0,2	13	54331	64331		24331	34331
16	68	69	40	9,5	0,16	11	55689	85689	65689	25689	35689
	220	165	95	24	0,16	13	55221	65221		25221	35221
25	47	61	35	10	0,14	11	56479	86479	66479	26479	36479
	150	145	83	26	0,14	13	56151	66151		26151	36151
35	33	55	32	9,9	0,12	11	50339	80339	60339	20339	30339
	100	130	74	24	0,12	13	50101	60101		20101	30101
50	0,47	7,6	4,4	3,1	0,09	11	51477	81477	61477	21477	31477
	0,68	9,1	5,3	3,2	0,09	11	51687	81687	61687	21687	31687
	1	11	6,4	3,3	0,09	11	51108	81108	61108	21108	31108
	1,5	13,5	7,8	3,5	0,09	11	51158	81158	61158	21158	31158
	2,2	16,5	9,5	3,7	0,09	11	51228	81228	61228	21228	31228
	3,3	20	11,5	4	0,09	11	51338	81338	61338	21338	31338
	4,7	24	14	4,4	0,09	11	51478	81478	61478	21478	31478
	6,8	29	16,5	5	0,09	11	51688	81688	61688	21688	31688
	10	35	20	6	0,09	11	51109	81109	61109	21109	31109
	15	43	25	7,5	0,09	11	51159	81159	61159	21159	31159
	22	52	30	9,6	0,09	11	51229	81229	61229	21229	31229
	33	85	49	13	0,09	13	51339	61339		21339	31339
	47	100	58	17	0,09	13	51479	61479		21479	31479
	68	120	70	23	0,09	13	51689	61689		21689	31689

* Case size 11: ϕ 5 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%

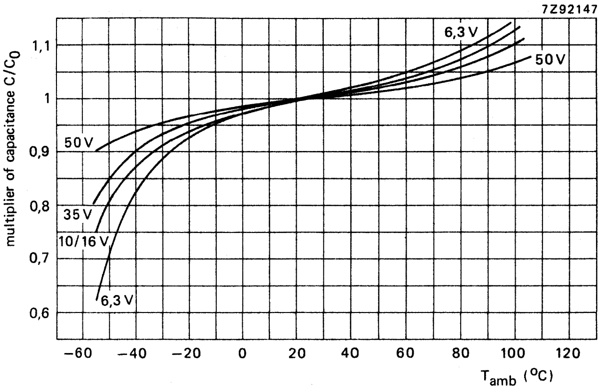


Fig. 5 Typical multiplier of capacitance as a function of ambient temperature; C_0 = capacitance at 20 °C, 100 Hz.

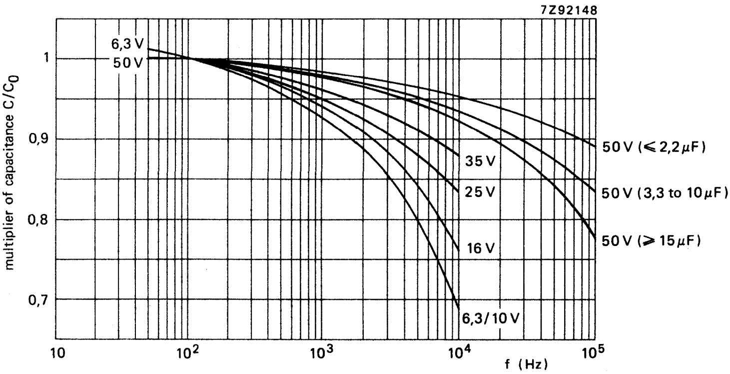


Fig. 6 Typical multiplier of capacitance as a function of frequency; C_0 = capacitance at 20 °C, 100 Hz.

Voltage

	< 85 °C	85 to 105 °C
Rated voltage = max. permissible voltage	1,3 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	1,3 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	1,5 x U_R	1,3 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 and 105 °C — see Table 3

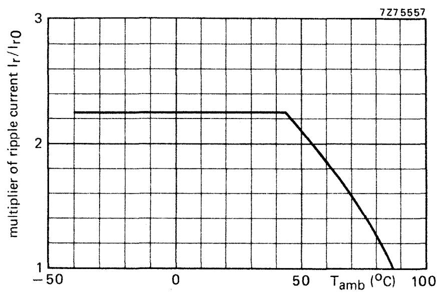


Fig. 7 Typical multiplier of ripple current as a function of ambient temperature; I_{r0} = ripple current at 85 °C, 100 Hz.

DEVELOPMENT SAMPLE DATA

* 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.

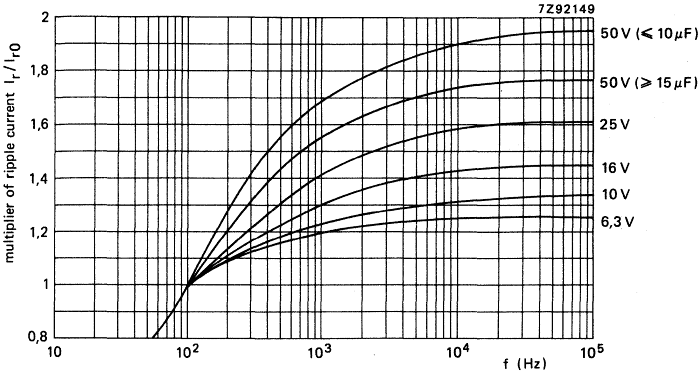


Fig. 8 Typical multiplier of ripple current as a function of frequency;
I_{r0} = ripple current at 85 °C, 100 Hz.

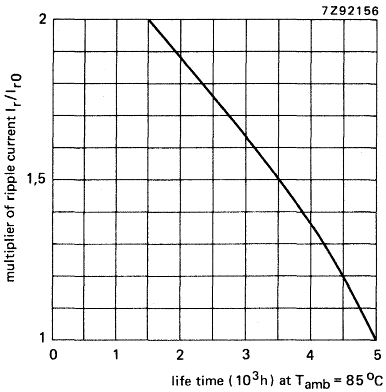


Fig. 9 Typical multiplier of ripple current as a function of life time at 85 °C;
I_{r0} = ripple current at 85 °C, 100 Hz.

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

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} = 20 °C	see Table 3 (0,006 CU + 3 μA)
Leakage current during continuous operation at U_R, at T_{amb} = 25 °C	approx. 0,05 x value stated in Table 3
at T_{amb} = 85 °C	≤ 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 2.

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

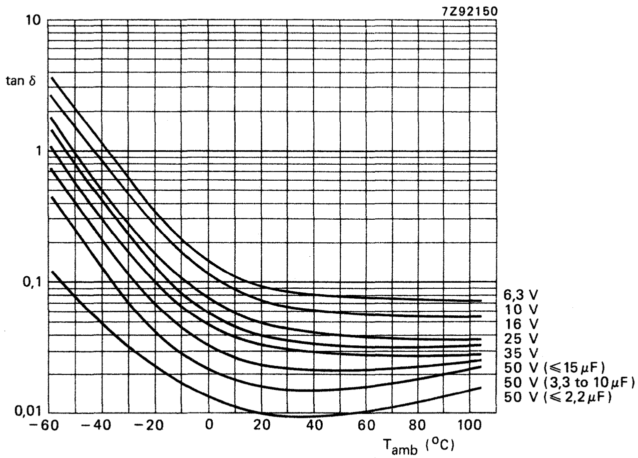


Fig. 10 Typical tan δ at 100 Hz as a function of ambient temperature.

DEVELOPMENT SAMPLE DATA

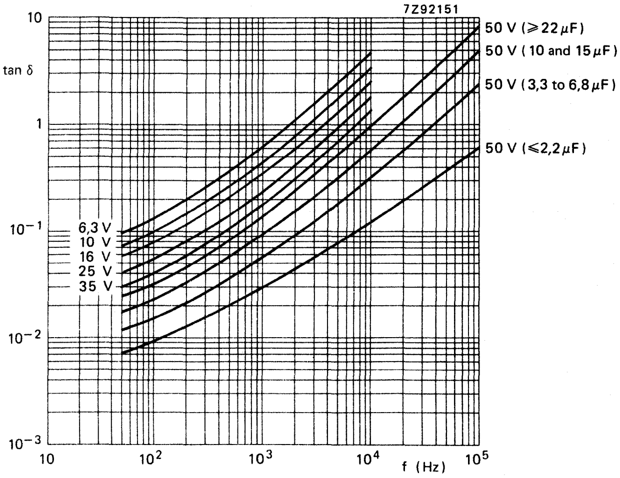


Fig. 11 Typical tan δ as a function of frequency at T_{amb} = 20 °C.

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

Equivalent series inductance (ESL)

Case size 11	typ. 13 nH
Case size 13	typ. 16 nH

Impedance (Z)

Maximum impedance at T_{amb} = 20 °C, −25 °C and −40 °C and 10 kHz, measured by a four-terminal circuit (Thomson circuit)	see Table 4
Maximum ratio between impedances at T_{amb} = −25 °C and + 20 °C, at T_{amb} = −40 °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 4

Table 4

U_R V	nom. cap. µF	case size*	max. impedance at 10 kHz T_{amb} = 20 °C Ω	T_{amb} = −25 °C Ω	T_{amb} = −40 °C Ω	maximum impedance ratio at U_R and 100 Hz $\frac{Z \text{ at } -25\,^{o}C}{Z \text{ at } +20\,^{o}C}$	$\frac{Z \text{ at } -40\,^{o}C}{Z \text{ at } +20\,^{o}C}$	$\frac{Z \text{ at } -55\,^{o}C}{Z \text{ at } +20\,^{o}C}$
6,3	150	11	2	12	32	2	3	8
	470	13	0,64	3,8	10	2	3	8
10	100	11	2	12	32	1,5	2	6
	330	13	0,61	3,6	9,7	1,5	2	6
16	68	11	2,4	11	29	1,5	2	5
	220	13	0,73	3,4	9,1	1,5	2	5
25	47	11	2,6	12	32	1,5	2	4
	150	13	0,8	3,7	10	1,5	2	4
35	33	11	2,7	12	33	1,5	2	3
	100	13	0,9	4	11	1,5	2	3
50	0,47	11	150	640	1900	1,3	1,5	2
	0,68	11	105	440	1300	1,3	1,5	2
	1	11	70	300	900	1,3	1,5	2
	1,5	11	47	200	600	1,3	1,5	2
	2,2	11	32	135	410	1,3	1,5	2
	3,3	11	21	91	270	1,5	2	3
	4,7	11	15	64	190	1,5	2	3
	6,8	11	10,5	44	130	1,5	2	3
	10	11	7	30	90	1,5	2	3
	15	11	4,7	20	60	1,5	2	3
	22	11	3,2	13,5	41	1,5	2	3
	33	13	2,1	9,1	27	1,5	2	3
	47	13	1,5	6,4	19	1,5	2	3
	68	13	1,05	4,4	13	1,5	2	3

DEVELOPMENT SAMPLE DATA

* Case size 11: ϕ 5 mm x 11 mm; case size 13: ϕ 8,2 x 11 mm (nominal dimensions).

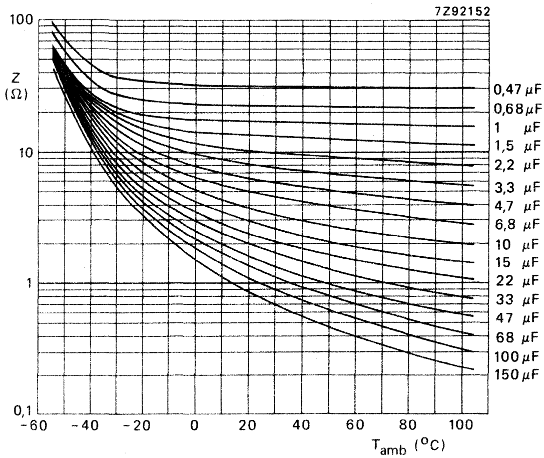


Fig. 12 Typical impedance at 10 kHz as a function of ambient temperature, case size 11.

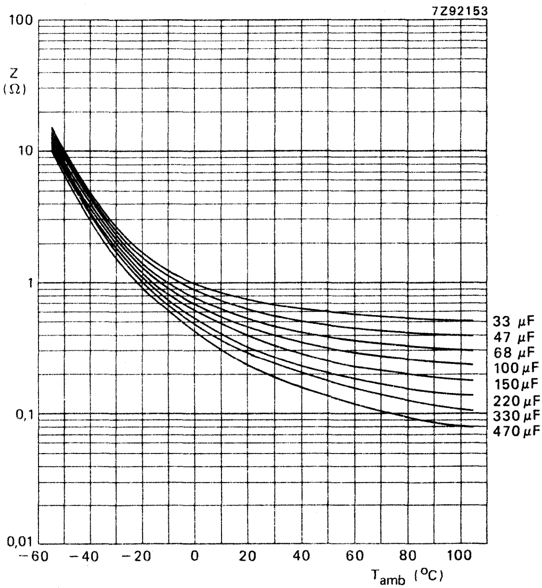


Fig. 13 Typical impedance at 10 kHz as a function of ambient temperature, case size 13.

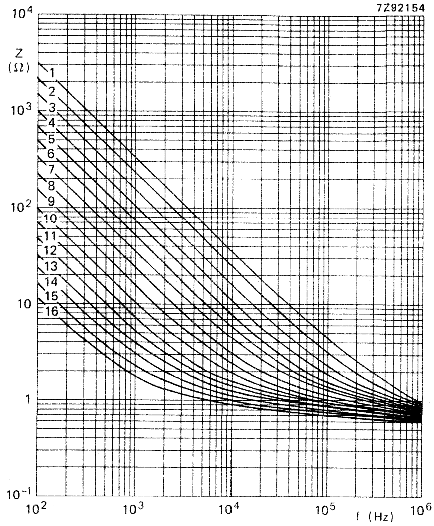


Fig. 14 Typical impedance as a function of frequency at T_{amb} = 20 °C, **case size 11:**
curve 1 = 0,47 μF;
curve 2 = 0,68 μF;
curve 3 = 1 μF;
curve 4 = 1,5 μF;
curve 5 = 2,2 μF;
curve 6 = 3,3 μF;
curve 7 = 4,7 μF;
curve 8 = 6,8 μF;
curve 9 = 10 μF;
curve 10 = 15 μF;
curve 11 = 22 μF;
curve 12 = 33 μF;
curve 13 = 47 μF;
curve 14 = 68 μF;
curve 15 = 100 μF;
curve 16 = 150 μF.

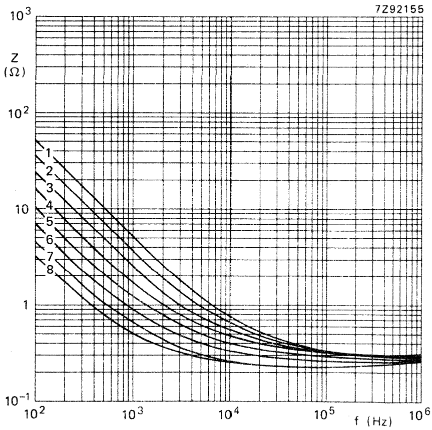


Fig. 15 Typical impedance as a function of frequency at T_{amb} = 20 °C, **case size 13:**
curve 1 = 33 μF;
curve 2 = 47 μF;
curve 3 = 68 μF;
curve 4 = 100 μF;
curve 5 = 150 μF;
curve 6 = 220 μF;
curve 7 = 330 μF;
curve 8 = 470 μF.

DEVELOPMENT SAMPLE DATA

OPERATIONAL DATA

Category temperature range	−55 to + 105 °C
→ Typical life time	
at T_{amb} = 40 °C	120 000 h
at T_{amb} = 85 °C	6000 h
at T_{amb} = 105 °C	2000 h
→ Shelf life at 0 V	
at T_{amb} = 85 °C	5000 h
at T_{amb} = 105 °C	1500 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 5.

Table 5

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

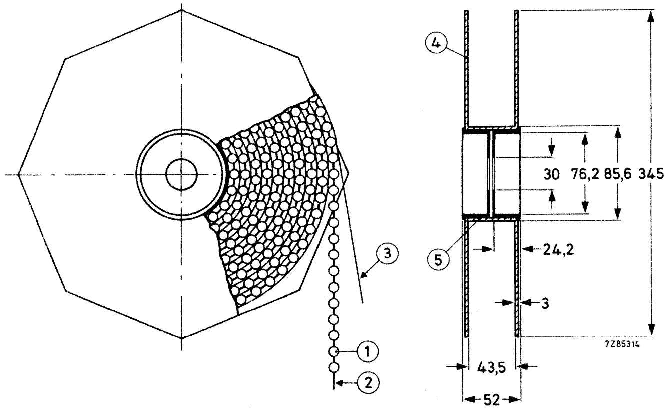


Fig. 16 Capacitors (style 4) on tape on reel.
1 = capacitor
2 = tape
3 = paper
4 = flange
5 = cylinder

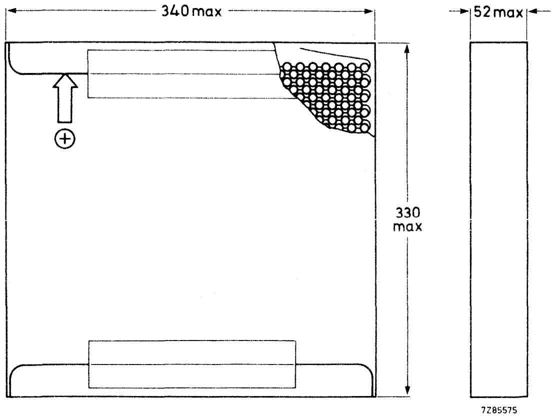


Fig. 17 Capacitors (style 5) on tape in ammunition pack.

DEVELOPMENT SAMPLE DATA

TESTS AND REQUIREMENTS

See Introduction, section 9, under aluminium electrolytic capacitors, with the following addition.

After *endurance test, at U_R, 1500 h, 105 °C or 5000 h, 85 °C,* the capacitors meet the following requirements:

$\Delta C/C \leqslant \pm$ 20%, for U_R = 10 to 50 V;

$\Delta C/C \leqslant +$ 20%, −30% for U_R = 6,3 V;

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

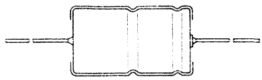
leakage current $\leqslant$ specified value.

After *shelf life test, at 0 V,* the capacitors meet the same requirements, except for leakage current: $\leqslant$ 200% of specified value. The rated voltage shall be applied to the capacitors for minimum 30 min, at least 24 h and not more than 48 h before measurements.

Note: Capacitors 2222 116 are miniature, long-life grade.

ALUMINIUM ELECTROLYTIC CAPACITORS

- Miniature and small types
- Axial leads
- Long life
- Industrial applications



QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	1 to 4700 μF
Tolerance on nominal capacitance	−10 to +50%
Rated voltage, U_R (R5 series)	10 to 350 V
Category temperature range	
case sizes 4 to 7	−40 to +85 °C
case sizes 00 to 05 ($U_R \leqslant$ 100 V)	−55 to +85 °C
case sizes 00 to 05 ($U_R \geqslant$ 160 V)	−40 to +85 °C
Endurance test at 85 °C	
case sizes 4 and 5	6000 h
case sizes 6 to 05	8000 h
Shelf life at 0 V, 85 °C (case sizes 5 to 05)	500 h
Basic specifications	IEC 384-4, long life grade DIN 41257 UTE C031/C033 (case sizes 00 to 05)

Climatic category	IEC 68	DIN 40040
case sizes 4 to 7	40/085/56	GPF
case sizes 00 to 05 ($U_R \leqslant$ 100 V)	55/085/56	FPF
case sizes 00 to 05 ($U_R \geqslant$ 160 V)	40/085/56	GPF

See next page for selection chart for C_{nom}-U_R and relevant case sizes.

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

C_{nom} µF	U_R (V) 10	16	25	40	63	100	160	250	350
1						4			
1,5						4			
2,2						4			
3,3						4			
4,7					4	4			
6,8					4	5			
10					4	5			01
15				4	5	6			
22			4		5	6	00	01	02
33			4	5	6	7			
47		4		5	6	7/00	02	03	04
68		4	5	6	7/00	01			
100		5		6	00	02	03	05	
150		5	6	7/01	02	03			
220		6	7/01	01	02	04	05		
330		7/01	01	02	03	04			
470	01	7/01	01	02	04	05			
680	01	02	03	03	05				
1000	02	02	03	04	05				
1500	03	03	04	05					
2200	03	04	05	05					
3300	04	05							
4700	05	05							

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

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 telephony equipment.

They are mainly used for energy storage, smoothing, coupling and decoupling purposes, as well as for timing and delay circuits. The bandoliered version is extremely suitable for automatic insertion and for cutting and forming equipment.

DESCRIPTION

The capacitors have etched and oxidized 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 capacitors are housed in an aluminium case with axial soldered-copper 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

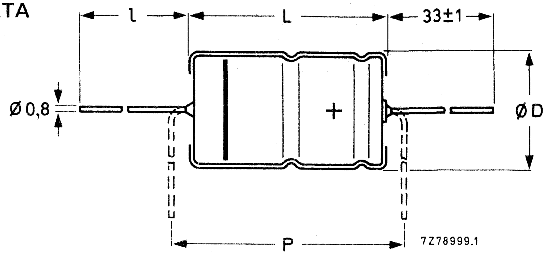


Fig. 1 See Table 1 for dimensions D, L, l and P.

Table 1

case size	l	D_{nom}	L_{nom}	D_{max}	L_{max}	P_{min}	mass approx. g
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	4,3
01	55 ± 1	12,5	30,0	13,0	30,5	35,0	6,6
02	55 ± 1	15,0	30,0	15,5	30,5	35,0	8,5
03	55 ± 1	18,0	30,0	18,5	30,5	35,0	11,2
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).

DEVELOPMENT SAMPLE DATA

Marking

The capacitors are marked with:
- nominal capacitance;
- tolerance on nominal capacitance according to IEC 62;
- rated voltage;
- group number 132 or 133;
- maximum temperature; grade reference LL;
- name of manufacturer; code of origin;
- date code (year and month) according to IEC 62;
- band to identify the negative terminal;
- + signs to identify the 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

WARNING

Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled. Caution is necessary should the outer case be fractured.

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 86 to 106 kPa and a relative humidity of 45 to 75%.

U_R	nom. cap.	max. r.m.s. ripple current at T_{amb} = 85 °C	max. leakage current at U_R after 5 min	max. tan δ	max. ESR	max. impedance Ω		case size	catalogue number* 2222 followed by
						at 10 kHz	at 100 kHz		
V	μF	mA	μA		Ω				
10	470	350	9,4	0,18	0,77	0,26	0,60	01	132 14471
	680	460	13,6	0,18	0,53	0,20	0,40	01	132 14681
	1000	640	20	0,18	0,36	0,12		02	132 14102
	1500	800	30	0,22	0,29	0,10		03	132 14152
	2200	1100	44	0,22	0,20	0,09		03	132 14222
	3300	1300	66	0,27	0,16	0,05		04	132 14332
	4700	1800	94	0,27	0,12	0,05		05	132 14472
16	47	95	5,5	0,14		2,6		4	132 . 5479
	68	110	6,2	0,14		1,8		4	132 . 5689
	100	150	7,2	0,14		1,2		5	132 . 5101
	150	190	8,8	0,14		0,80		5	132 . 5151
	220	250	11	0,14		0,55		6	132 . 5221
	330	320	14,6	0,14		0,36		7	**
	330	320	10,6	0,14	0,80	0,36	0,60	01	132 15331
	470	450	19	0,14	0,55	0,26		7	**
	470	450	15	0,14	0,55	0,26	0,40	01	132 15471
	680	550	22	0,14	0,39	0,14		02	132 15681
	1000	780	32	0,14	0,26	0,12		02	132 15102
	1500	950	48	0,15	0,19	0,10		03	132 15152
	2200	1300	70	0,15	0,12	0,06		04	132 15222
	3300	1600	106	0,15	0,09	0,05		05	132 15332
	4700	2300	150	0,15	0,08	0,05		05	132 15472
25	22	60	5,1	0,11		4,1		4	132 . 6229
	33	80	5,7	0,11		2,7		4	132 . 6339
	68	140	7,4	0,11		1,3		5	132 . 6689
	150	230	11,5	0,11		0,60		6	132 . 6151
	220	340	15	0,11		0,40		7	**
	220	340	11	0,11	1,0	0,40	0,60	01	132 16221
	330	410	16,5	0,11	0,63	0,30	0,40	01	132 16331
	470	560	24	0,11	0,47	0,20		01	132 16471
	680	700	34	0,11	0,32	0,10		03	132 16681
	1000	1000	50	0,11	0,22	0,10		03	132 16102
	1500	1100	75	0,12	0,16	0,06		04	132 16152
	2200	1850	110	0,13	0,12	0,05		05	132 16222

* Replace dot in catalogue number by:
2 for case sizes 4 to 7, on bandoliers on reel;
3 for case sizes 4 to 7, on bandoliers in box.

** See Table 3.

DEVELOPMENT SAMPLE DATA

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	max. ESR Ω	max. impedance Ω at 10 kHz	max. impedance Ω at 100 kHz	case size	catalogue number* 2222 followed by
40	15	60	5,2	0,09		5		4	132 . 7159
	33	100	6,6	0,09		2,3		5	132 . 7339
	47	120	7,8	0,09		1,6		5	132 . 7479
	68	170	9,4	0,09		1,1		6	132 . 7689
	100	210	12	0,09		0,75		6	132 . 7101
	150	310	16	0,09		0,50		7	**
	150	310	12	0,09	1,27	0,50	0,60	01	132 17151
	220	410	17,5	0,09	0,86	0,34	0,40	01	132 17221
	330	550	26	0,09	0,58	0,20		02	132 17331
	470	700	38	0,09	0,40	0,16		02	132 17471
	680	900	54	0,09	0,28	0,10		03	132 17681
	1000	1200	80	0,09	0,19	0,08		04	132 17102
	1500	1500	120	0,10	0,14	0,06		05	132 17152
	2200	1900	176	0,10	0,10	0,05		05	132 17222
63	4,7	38	4,6	0,07		12		4	132 . 8478
	6,8	45	4,9	0,07		8,1		4	132 . 8688
	10	64	5,3	0,07		5,5		4	132 . 8109
	15	80	5,9	0,07		3,7		5	132 . 8159
	22	100	6,8	0,07		2,5		5	132 . 8229
	33	140	8,2	0,07		1,7		6	132 . 8339
	47	170	9,9	0,07		1,2		6	132 . 8479
	68	210	12,6	0,07		0,81		7	**
	68	210	8,6	0,07	1,9	0,80	0,60	00	132 18689
	100	300	12,6	0,07	1,3	0,60	0,40	00	132 18101
	150	350	19	0,07	0,87	0,37		02	132 18151
	220	520	28	0,07	0,58	0,25		02	132 18221
	330	600	42	0,07	0,40	0,15		03	132 18331
	470	970	59	0,07	0,27	0,12		04	132 18471
	680	1000	86	0,07	0,19	0,08		05	132 18681
	1000	1600	126	0,07	0,13	0,06		05	132 18102
100	1	20	4,2	0,06		45		4	132 . 9108
	1,5	25	4,3	0,06		30		4	132 . 9158
	2,2	30	4,4	0,06		20		4	132 . 9228
	3,3	37	4,7	0,06		14		4	132 . 9338
	4,7	48	4,9	0,06		9,6		4	132 . 9478
	6,8	60	5,4	0,06		6,6		5	132 . 9688
	10	73	6	0,06		4,5		5	132 . 9109
	15	100	7	0,06		3		6	132 . 9159
	22	130	8,4	0,06		2		6	132 . 9229
	33	170	10,6	0,06		1,4		7	132 . 9339
	47	220	13,4	0,06		1		7	**
	47	220	9,4	0,06	2,4	1	0,90	00	132 19479
	68	250	13,5	0,06	1,7	0,80		01	132 19689
	100	380	20	0,06	1,1	0,50		02	132 19101
	150	400	30	0,06	0,75	0,35		03	132 19151
	220	660	44	0,06	0,5	0,20		04	132 19221
	330	700	66	0,06	0,34	0,15		04	132 19331
	470	1200	94	0,06	0,24	0,10		05	132 19471

Table 2 (continued)

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	max. ESR Ω	max. impedance Ω at 10 kHz	at 100 kHz	case size	catalogue number* 2222 followed by
160	22	120	7	0,10	6,8	5,5	2,5	00	133 11229
	47	180	15	0,10	3,2	2,6		02	133 11479
	100	350	32	0,10	1,5	1,2		03	133 11101
	220	610	70	0,10	0,7	0,60		05	133 11221
250	22	130	11	0,10	6,8	5		01	133 13229
	47	200	24	0,10	3,2	2,3		03	133 13479
	100	370	50	0,10	1,5	1,1		05	133 13101
350	10	90	7	0,10	15	10		01	133 15109
	22	140	15,5	0,10	6,8	4,5		02	133 15229
	47	270	33	0,10	3,2	2,1		04	133 15479

Table 3

U_R V	nom. cap. μF	case size	catalogue number: capacitors on bandoliers on reel	catalogue number: capacitors on bandoliers in box
16	330	7	2222 132 90508	2222 132 90509
	470	7	90507	90502
25	220	7	90503	90504
40	150	7	90511	90512
63	68	7	90513	90514
100	47	7	90505	90506

Capacitance

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

Tolerance on nominal capacitance at 100 Hz — −10 to +50%

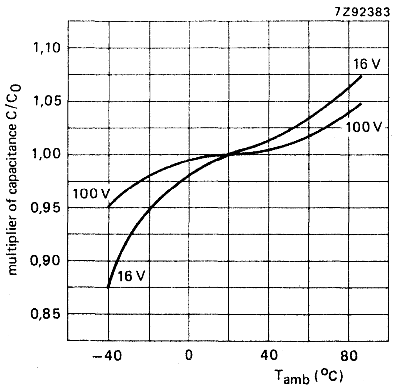


Fig. 2 Multiplier of capacitance as a function of ambient temperature, **case sizes 4 to 7;** C_0 = capacitance at 20 °C, 100 Hz.

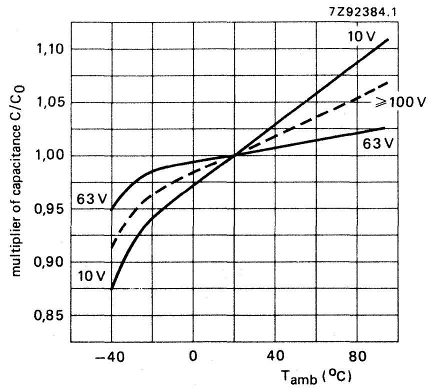


Fig. 3 Multiplier of capacitance as a function of ambient temperature, **case sizes 00 to 05;** C_0 = capacitance at 20 °C, 100 Hz.

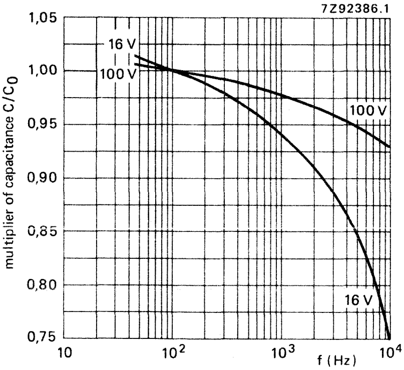


Fig. 4 Multiplier of capacitance as a function of frequency, **case sizes 4 to 7**; C_0 = capacitance at 20 °C, 100 Hz.

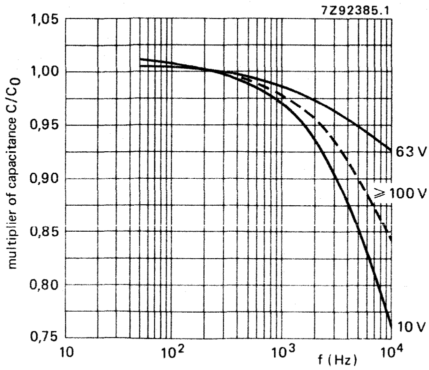


Fig. 5 Multiplier of capacitance as a function of frequency, **case sizes 00 to 05**; C_0 = capacitance at 20 °C, 100 Hz.

DEVELOPMENT SAMPLE DATA

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 without d.c. voltage applied	1 V
	c. momentary value of applied voltage	between 1,1 x U_R and −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

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

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

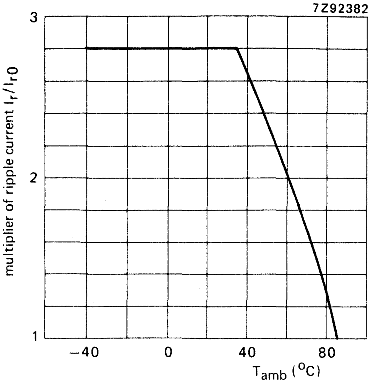


Fig. 6 Multiplier of ripple current as a function of ambient temperature, **case sizes 4 to 7;** I_{r0} = ripple current at 85 °C and 100 Hz.

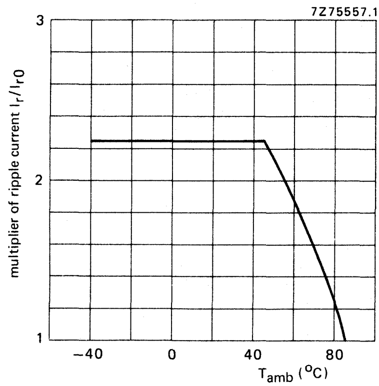


Fig. 7 Multiplier of ripple current as a function of ambient temperature, **case sizes 00 to 05;** I_{r0} = ripple current at 85 °C and 100 Hz.

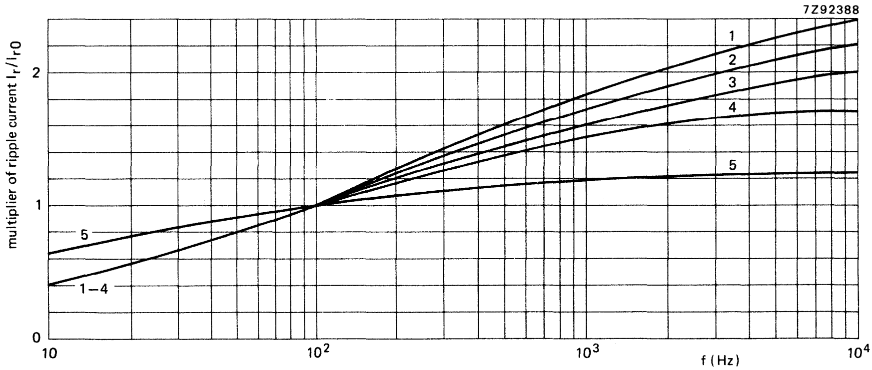


Fig. 8 Multiplier of ripple current as a function of frequency, **case sizes 4 to 7;** I_{r0} = ripple current at 85 °C and 100 Hz.

Curve 1 = 1 μF, 100 V; curve 2 = 1,5 μF, 100 V; curve 3 = 2,2 μF, 100 V;
curve 4 = $\geqslant$ 3,3 μF, 100 V; curve 5 = 16 V.

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;
$\sqrt{r_n} = I_r/I_{r0}$ = 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.

Leakage current

Case sizes 4 to 7

Maximum leakage current 1 min after application of U_R at T_{amb} = 20 °C	0,01 CU + 3 μA
Maximum leakage current 5 min after application of U_R at T_{amb} = 20 °C	see Table 2 (0,002 CU + 4 μA)
Leakage current during continuous operation at U_R	
at T_{amb} = 20 °C	0,001 CU + 1 μA
at T_{amb} = 85 °C	0,002 CU + 4 μA

Case sizes 00 to 05

Maximum leakage current 1 min after application of U_R at T_{amb} = 20 °C	0,006 CU + 4 μA
Maximum leakage current 5 min after application of U_R at T_{amb} = 20 °C	see Table 2 (0,002 CU)
Leakage current during continuous operation at U_R	
at T_{amb} = 20 °C	$<$ 0,0005 CU
at T_{amb} = 85 °C	0,002 CU

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.

DEVELOPMENT SAMPLE DATA

Tan δ (dissipation factor)

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

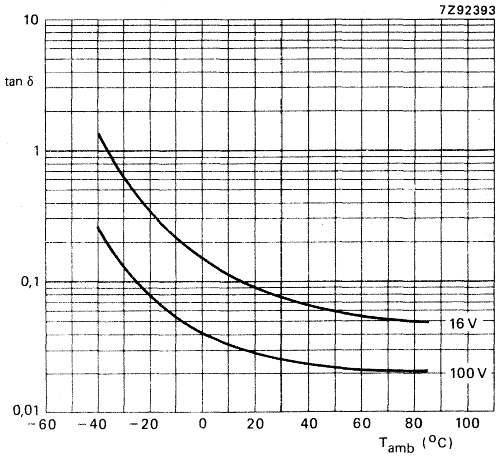


Fig. 9 Typical tan δ as a function of ambient temperature at 100 Hz, **case sizes 4 to 7.**

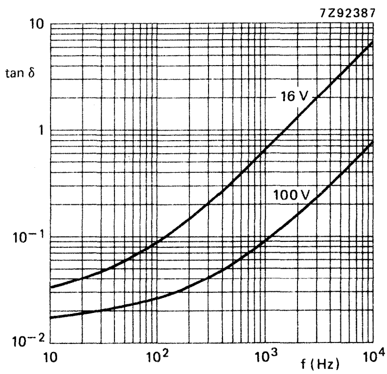


Fig. 10 Typical tan δ as a function of frequency at 20 °C, **case sizes 4 to 7.**

Impedance (Z)

Maximum impedance at T_{amb} = 20 °C and 10 kHz or 100 kHz, measured by a four-terminal circuit (Thomson circuit) — see Table 2

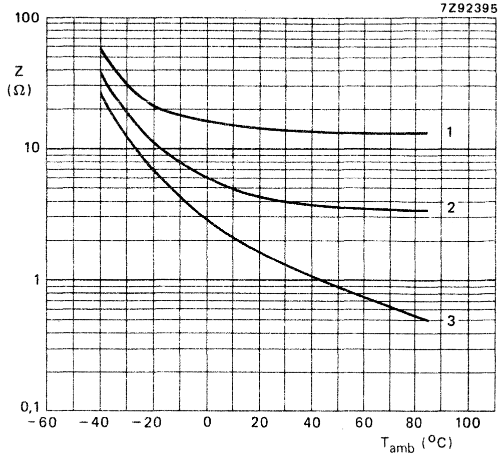


Fig. 11 Typical impedance as a function of ambient temperature at 10 kHz, **case size 4.**
Curve 1 = 1 μF, 100 V; curve 2 = 4,7 μF, 100 V; curve 3 = 47 μF, 16 V.

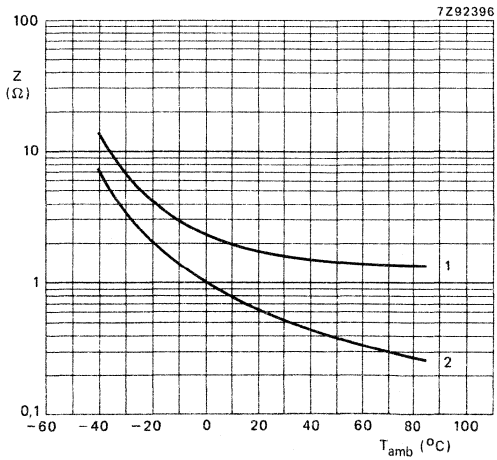


Fig. 12 Typical impedance as a function of ambient temperature at 10 kHz, **case size 5.**
Curve 1 = 10 μF, 100 V; curve 2 = 150 μF, 16 V.

DEVELOPMENT SAMPLE DATA

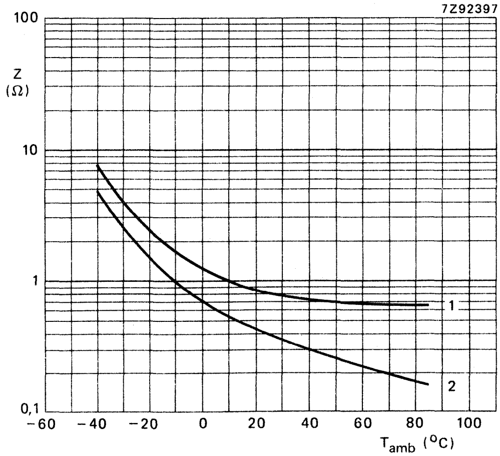


Fig. 13 Typical impedance as a function of ambient temperature at 10 kHz, **case size 6.**
Curve 1 = 22 μF, 100 V; curve 2 = 220 μF, 16 V.

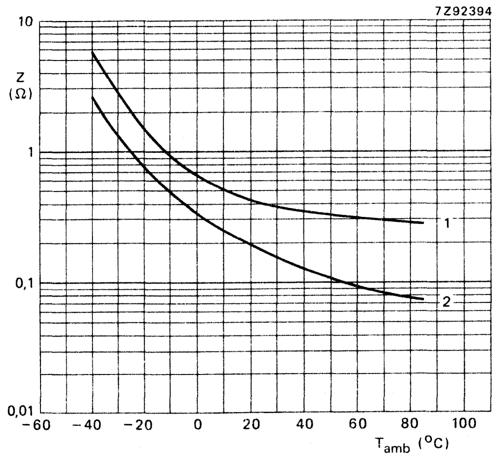


Fig. 14 Typical impedance as a function of ambient temperature at 10 kHz, **case size 7.**
Curve 1 = 47 μF, 100 V; curve 2 = 470 μF, 16 V.

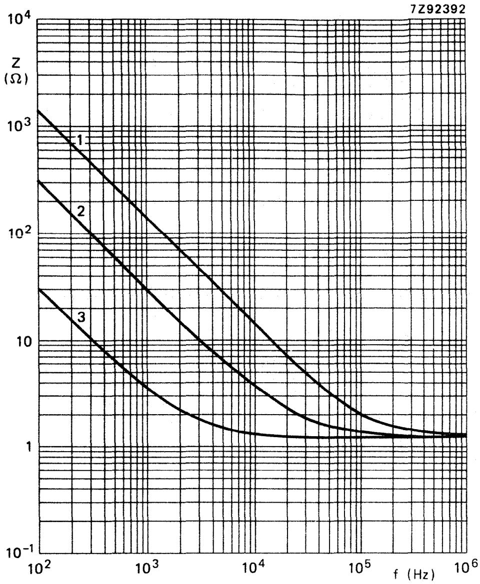


Fig. 15 Typical impedance as a function of frequency at 20 °C, **case size 4.**
Curve 1 = 1 μF, 100 V; curve 2 = 4,7 μF, 100 V; curve 3 = 47 μF, 16 V.

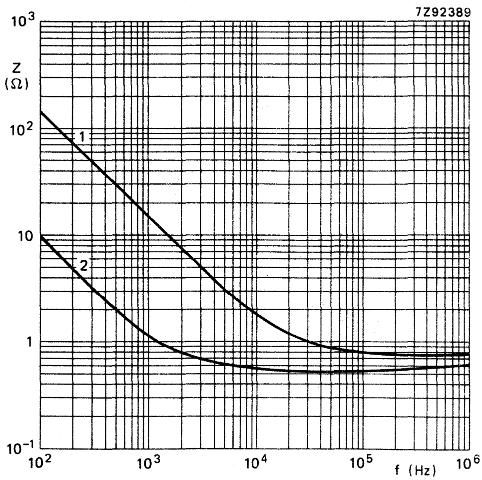


Fig. 16 Typical impedance as a function of frequency at 20 °C, **case size 5.**
Curve 1 = 10 μF, 100 V; curve 2 = 150 μF, 16 V.

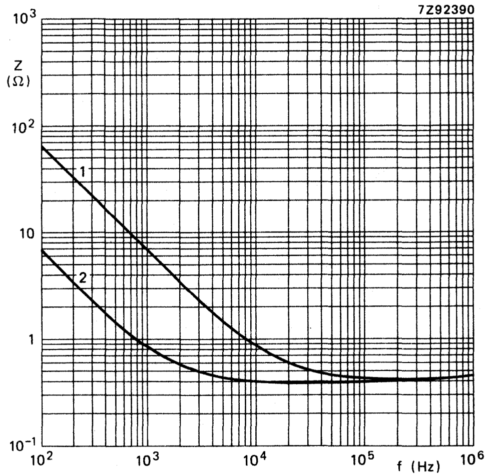


Fig. 17 Typical impedance as a function of frequency at 20 °C, **case size 6.**
Curve 1 = 22 μF, 100 V; curve 2 = 220 μF, 16 V.

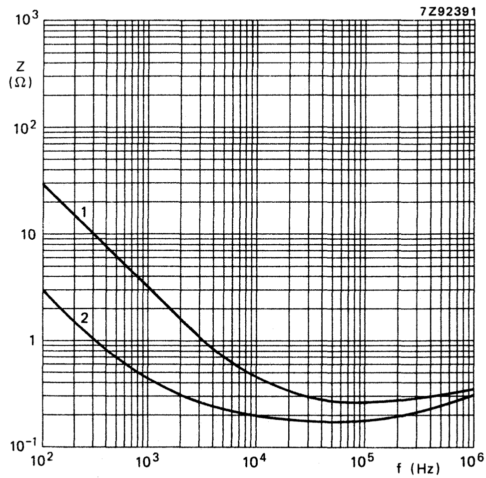


Fig. 18 Typical impedance as a function of frequency at 20 °C, **case size 7.**
Curve 1 = 47 μF, 100 V; curve 2 = 470 μF, 16 V.

DEVELOPMENT SAMPLE DATA

Equivalent series resistance (ESR)

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

Equivalent series inductance (ESL)

Case size 4	typ. 25 nH
Case size 5	typ. 40 nH
Case sizes 6, 7, 00 and 01	typ. 50 nH
Case size 02	typ. 55 nH
Case sizes 03, 04 and 05	typ. 60 nH

OPERATIONAL DATA

Category temperature range

case sizes 4 to 7	−40 to +85 °C
case sizes 00 to 05, $U_R \leqslant 100$ V	−55 to +85 °C
case sizes 00 to 05, $U_R \geqslant 160$ V	−40 to +85 °C

Typical life time

	T_{amb} = 85 °C	T_{amb} = 40 °C
case sizes 4 and 5	⩾ 10 000 h	⩾ 200 000 h
case sizes 6 to 05	⩾ 15 000 h	⩾ 300 000 h (approx. 40 years)

Shelf life at 0 V and T_{amb} = 85 °C — 500 h

PACKING

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

Table 4

case size	number of capacitors per box or per reel
4	1000
5	500
6	500
7	500
00	200
01	200
02	200
03	200
04	100
05	100

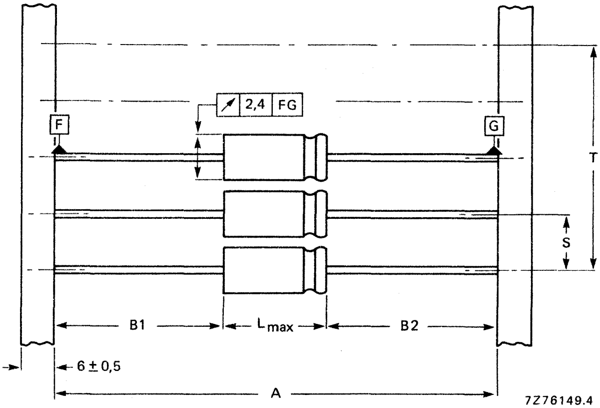


Fig. 19 Capacitors (case sizes 4 to 7) on bandoliers; the bandolier to which the negative capacitor terminals are connected is blue. See Table 5 for dimensions A, S, T and L_{max}.
$|B1 - B2| = 1,4 + (L_{max} - L)$ mm max.

Table 5

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

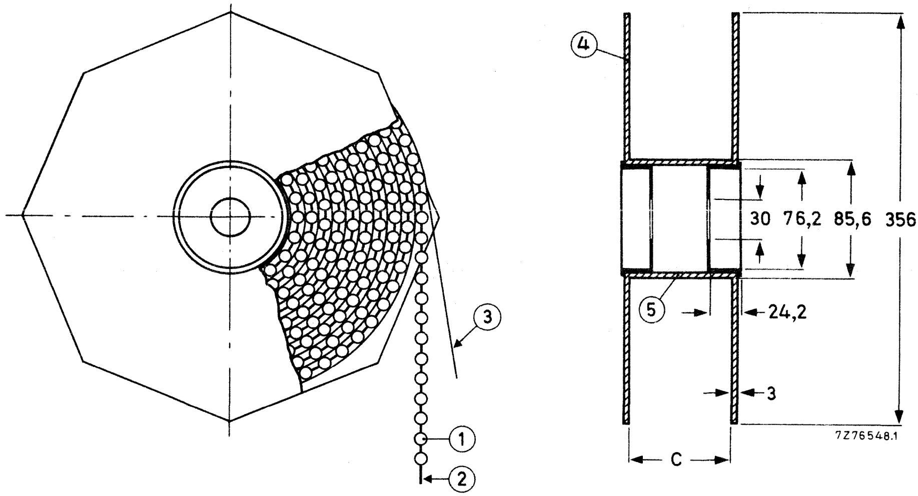


Fig. 20 Capacitors (case sizes 4 to 7) on bandoliers on reel; dimensions C is 88,5 mm; the overall width of the reel is 99,5 mm.

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

TESTS AND REQUIREMENTS

See Introduction, section 9, under aluminium electrolytic capacitors, with the exception of IEC 384-4 subclause 9.14, for which the following is valid.
IEC 384-4 subclause 9.14.
IEC 68-2 test method: no reference.
Name of test: Endurance.
Procedure: 6000 h at U_R and 85 °C for case sizes 4 and 5;
8000 h at U_R and 85 °C for case sizes 6 to 05.

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 10 kHz $\leqslant$ 2 x stated limit, $\Delta C/C \leqslant 15\%$.

After *shelf life test, 500 h, 85 °C,* the capacitors meet the same requirements as after endurance test. The rated voltage shall be applied to the capacitors for minimum 30 min, at least 24 h and not more than 48 h before measurements.

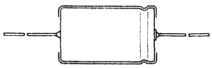
Note

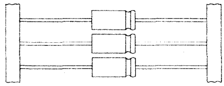
Capacitors 2222 132 and 2222 133 are miniature and small types, long-life grade.

SOLID ALUMINIUM CAPACITORS

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 50 V
Category temperature range	−55 to + 125 °C
Usable temperature range	−80 to + 175 °C
Endurance test at 125 °C	5000 h
Basic specification	IEC 384-4, long-life grade
Climatic category, IEC 68; 6,3 V to 40 V ranges	55/125/56
Climatic category, IEC 68; 50 V range	
at 50 V	55/085/56
at 40 V	55/125/56
Approvals; 6,3 V to 40 V ranges	CECC 30 302-001
	U.K. Post Office
	FOA/FTL (Sweden)
	Ministry of Defence DEF 59-44
	SCC Arcao AR C121 (Ariane)

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

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

case size	nominal dimensions (mm)
1	Ø 6,5 x 15
2A	Ø 7,5 x 20
4	Ø 9 x 23
5	Ø 10 x 31,5
6	Ø 12,5 x 31,5

APPLICATION

These capacitors utilize advanced technology to achieve long life, high stability, excellent reliability, very 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 capacitors have etched aluminium foil electrodes separated by a layer of semiconductive material. The electrolyte is pyrolitically formed manganese dioxide. The capacitors are housed in an aluminium case with axial leads and are sealed by a ceramic disc. The cathode lead is welded to the case, which is insulated with a blue transparent plastic sleeve.

The capacitors are available in 2 styles:
  style 1: axial leads, case sizes 1 to 6, in boxes;
  style 2: axial leads, case sizes 1 to 6, on bandoliers on reel.

Note: A special version is available, which is partly epoxy-filled, withstanding severe shock and vibration tests; see also "Tests and requirements".

MECHANICAL DATA

Dimensions in mm

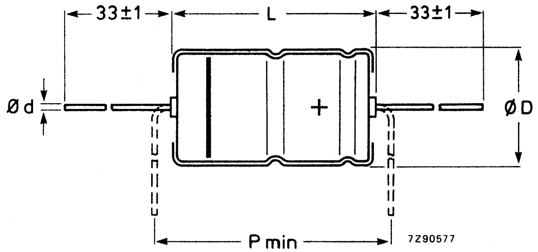


Fig. 1 Style 1; for dimensions d, D, L and P, see Table 1a.

Table 1a

case size	d	D_{nom}	L_{nom}	D_{max}	L_{max}	P_{min}	mass** approx. g
1	0,6 (0,8)*	6,5	15	6,7	15,3 (17,5)*	17,5 (20)*	1,2
2A	0,6 (0,8)*	7,5	20	7,6	20,4 (23,3)*	22,5 (25)*	2,4
4	0,6 (0,8)*	9	23	9,3 (10,3)*	23,3	25	3,3
5	0,8	10	31,5	10,3	32	35	4,5
6	0,8	12,5	31,5	12,9	32	35	6,3

* Dimension between brackets is valid until the middle of 1984.
** Add 10% for epoxy-filled version.

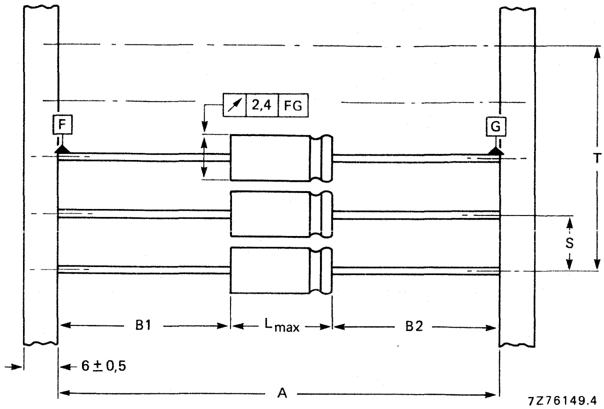


Fig. 2 Style 2 capacitors on bandoliers; the bandolier to which the negative capacitor terminals are connected is blue. See Table 1b for dimensions A, S, T and L_{max}.
$|B1-B2| = 1,4 + (L_{max}-L)$ mm max.

Table 1b

case size	A	S	T for number (n) of capacitors		L_{max}
			n < 50	50 < n < 100	
1	73 ± 1,6	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	15,3 (17,5)*
2A	73 ± 1,6	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	20,4 (23,3)*
4	73 ± 1,6	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	23,3
5	73 ± 1,6	15 ± 0,75	10 (n-1) ± 2	10 (n-1) ± 4	32
6	73 ± 1,6	15 ± 0,75	10 (n-1) ± 2	10 (n-1) ± 4	32

Marking

The capacitors are marked with: group number (121), capacitance, tolerance, rated and derated voltages at corresponding maximum temperatures, date code, a band to identify the negative terminal, "+" signs for the positive terminal and name of manufacturer.

Mounting

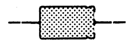
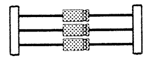
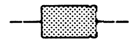
No special provisions are required for soldering to the tinned leads. (2 mm of the anode lead nearest the body are not solderable).

* Dimension between brackets is valid until the middle of 1984.

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 86 to 106 kPa and a relative humidity of 45 to 75%.
See also the corresponding paragraphs.

Table 2

U_R	nom. cap.	max. r.m.s. ripple current at T_{amb} = 125 °C	max. leakage current at U_R after 1 min*	max. tan δ	max. ESR	max. impedance at 100 kHz*	case size	catalogue number 2222 121 followed by		
								 style 1	 style 2	 epoxy-filled version**
V	μF	mA	μA		Ω	Ω				
6,3	22	60	12,5	0,18	16,5	1,2	1	13229	23229	63229
	47	100	25	0,18	7,6	1,0	2A	13479	23479	63479
	68	130	40	0,18	5,3	0,75	2A	13689	23689	63689
	150	220	70	0,18	2,4	0,4	4	13151	23151	63151
	220	320	125	0,18	1,6	0,3	5	13221	23221	63221
	330	430	150	0,18	1,1	0,2	6	13331	23331	63331
10	15	50	15	0,16	21,5	2,5	1	14159	24159	64159
	33	85	30	0,16	9,6	1,25	2A	14339	24339	64339
	47	115	47	0,16	6,8	0,75	2A	14479	24479	64479
	100	190	80	0,16	3,2	0,5	4	14101	24101	64101
	150	280	150	0,16	2,1	0,4	5	14151	24151	64151
	220	380	200	0,16	1,4	0,4	6	14221	24221	64221
16	10	45	16	0,14	28	2,5	1	15109	25109	65109
	15	60	24	0,14	19	1,25	2A	15159	25159	65159
	33	105	53	0,14	8,4	0,75	2A	15339	25339	65339
	47	140	75	0,14	5,9	0,5	4	15479	25479	65479
	68	200	109	0,14	4,1	0,4	5	15689	25689	65689
	100	270	160	0,14	2,8	0,4	6	15101	25101	65101

* Capacitors with lower values of max. leakage current or max. impedance are available to special order.
** Withstands severe shock and vibration.

Table 2 (continued)

U_R	nom. cap.	max. r.m.s. ripple current at T_{amb} = 125 °C	max. leakage current at U_R after 1 min*	max. tan δ	max. ESR	max. impedance at 100 kHz*	case size	catalogue number 2222 121 followed by		
								style 1	style 2	epoxy-filled version**
V	μF	mA	μA		Ω	Ω				
25	4,7	30	12	0,14	60	5	1	16478	26478	66478
	10	50	25	0,14	28	2,5	2A	16109	26109	66109
	22	85	55	0,14	13	1,5	2A	16229	26229	66229
	33	120	83	0,14	8,4	1	4	16339	26339	66339
	47	160	118	0,14	5,9	0,8	5	16479	26479	66479
	68	220	170	0,14	4,1	0,5	6	16689	26689	66689
40	2,2	20	9	0,12	109	5	1	17228	27228	67228
	3,3	30	13	0,12	73	5	1	17338	27338	67338
	4,7	35	19	0,12	51	2,5	2A	17478	27478	67478
	6,8	45	27	0,12	35	2,5	2A	17688	27688	67688
	10	60	40	0,12	24	1,5	2A	17109	27109	67109
	22	100	88	0,12	11	1	4	17229	27229	67229
	33	150	132	0,12	7,3	0,8	5	17339	27339	67339
	47	200	188	0,12	5,1	0,5	6	17479	27479	67479
50	2,2	15	11	0,25	230	20	1	18228	28228	68228
	4,7	25	24	0,25	106	10	2A	18478	28478	68478
	6,8	35	34	0,25	74	6	2A	18688	28688	68688
	15	60	75	0,25	34	4	4	18159	28159	68159
	22	85	110	0,25	23	3,2	5	18229	28229	68229
	33	110	165	0,25	15,5	2	6	18339	28339	68339

* Capacitors with lower values of max. leakage current or max. impedance are available to special order.
** Withstands severe shock and vibration.

Capacitance

Nominal capacitance values at 100 Hz and T_{amb} = 25 °C	see Table 2
Tolerance on nominal capacitance at 100 Hz	± 20%

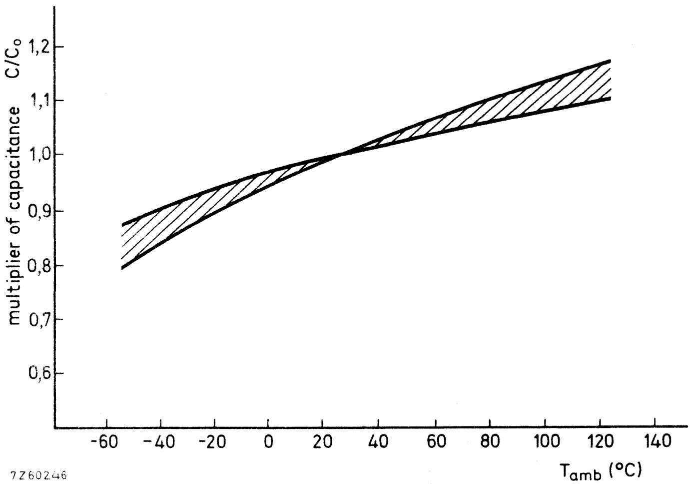


Fig. 3 Typical capacitance as a function of ambient temperature.
C_0 = capacitance at T_{amb} = 25 °C, 100 Hz.

Voltage

Rated voltage

6,3 V to 40 V ranges	= max. permissible voltage at $T_{amb} \leqslant 125$ °C	U_R
50 V range	= max. permissible voltage at $T_{amb} \leqslant 85$ °C	U_R*

Derated voltage

6,3 V to 40 V ranges	= max. permissible voltage at T_{amb} from 125 °C to 175 °C	0,63 x U_R
50 V range	= max. permissible voltage at T_{amb} from 85 °C to 125 °C	40 V

Ripple voltage

Max. permissible a.c. voltage providing the following four conditions are met:

a) Max. a.c. voltage, with negative d.c. voltage applied — 2 V

* 63 V is permissible for max. 500 h at T_{amb} = 85 °C.

b) Max. peak a.c. voltage, without d.c. voltage applied

	$T_{amb} \leq 85$ °C	85 °C $< T_{amb} \leq 125$ °C*
at $f \leq 0{,}1$ Hz	0,30 x U_R	0,15 x U_R
at 0,1 Hz $< f \leq 1$ Hz	0,45 x U_R	0,22 x U_R
at 1 Hz $< f \leq 10$ Hz	0,60 x U_R	0,30 x U_R
at 10 Hz $< f \leq 50$ Hz	0,65 x U_R	0,32 x U_R
at $f > 50$ Hz	0,80 x U_R	0,40 x U_R

c) Momentary value of applied voltage, with positive d.c. voltage applied: between U_R (in the positive half wave) and the limits mentioned under b) (in the negative half wave)

d) Ripple voltage limits are not applicable if the maximum ripple current is exceeded. In that case the ripple current is decisive. Whichever is in practice decisive, depends on the actual impedance of the capacitor. Table 3 should be considered as an aid only in establishing whether the ripple voltage or the ripple current is decisive.

Table 3

frequency	decisive factor	
	at $T_{amb} \leq 85$ °C	$T_{amb} > 85$ °C
$f \leq 50$ Hz	voltage	voltage, if actual capacitor impedance is high; current, if actual capacitor impedance is low
50 Hz $< f \leq 1$ kHz	voltage, if actual capacitor impedance is high; current, if actual capacitor impedance is low	current
$f > 1$ kHz	current	current

Surge voltage

		$T_{amb} \leq 85$ °C	85 °C $< T_{amb} \leq 125$ °C
6,3 V to 40 V ranges	= max. permissible voltage for short periods (see also "Tests and requirements")	1,15 x U_R	
50 V range	= max. permissible voltage for max. 500 h	63 V	45 V

* For 50 V range, $U_R = 40$ V.

Reverse voltage		$T_{amb} \leqslant 85\ ^oC$	$85\ ^oC < T_{amb} \leqslant 125\ ^oC$
6,3 V to 40 V ranges	= max. d.c. voltage continuously (2000 h) applied in the reverse polarity,		
	at $T_{amb} \leqslant 85\ ^oC$	$0,30 \times U_R$	
	at $85\ ^oC < T_{amb} \leqslant 125\ ^oC$	$0,15 \times U_R$	
50 V range	= max. d.c. voltage applied in the reverse polarity at the maximum category temperature for short periods (see also "Tests and requirements")	7,5 V	6 V

Ripple current

Maximum permissible r.m.s. ripple current at 100 Hz and $T_{amb} = 125\ ^oC$ — see Table 2

Maximum permissible r.m.s. ripple current at other frequencies, temperatures and conditions — see Table 4 to 6, and Fig. 4

Table 4 Temperature multiplier of ripple current ($\sqrt{k}$), at 100 Hz

T_{amb} ^oC	$\sqrt{k}$
25	2,6
35	2,5
45	2,4
55	2,25
65	2,2
70	2,15
75	2,1
80	2,05
85	2,0
90	1,9
95	1,8
100	1,7
105	1,6
110	1,45
115	1,35
120	1,2
125	1,0

Table 5 Frequency multiplier of ripple current ($\sqrt{r}$) at 25 ^oC

frequency kHz	$\sqrt{r}$
0,05	0,8
0,1	1,0
0,2	1,2
0,5	1,4
1	1,55
2	1,70
5	1,80
10	1,95
20	2,05
50	2,15
100	2,20
200	2,25
500	2,30
1000	2,35

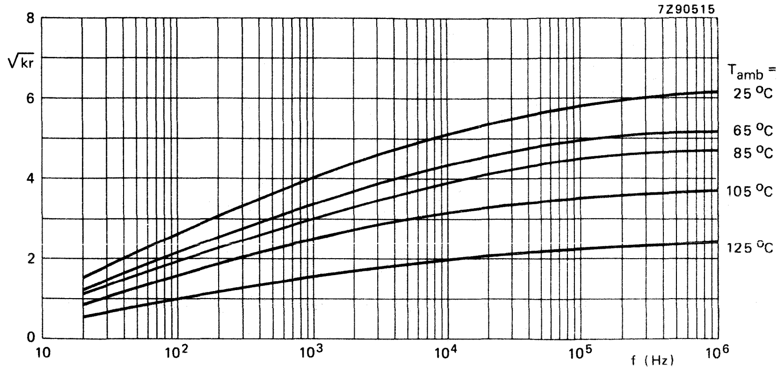


Fig. 4 Combined temperature/frequency multiplier of ripple current ($\sqrt{kr}$) as a function of frequency. $I_{r\,max} = I_{r0}\sqrt{kr}$.

Table 6 Multiplier of ripple current for various application conditions

condition	multiplier
A. Capacitor insulated with a blue sleeve, mounted horizontally on a thermally non-conducting printed-circuit board, in free flowing air and in a surrounding that allows the absorption of radiation heat.	1,0
B. As under A but capacitor is not insulated	0,9
C. As under A but capacitor is mounted vertically.	0,7
D. As under A but capacitor is mounted on a good thermally conducting printed-circuit board.	1,25
E. As under A but the surrounding walls etc. have a temperature higher than 125 °C and therefore prevent the absorption of heat by radiation.	0,6
F. Capacitor has an ESR value lower than the maximum ESR.	$\sqrt{\frac{ESR_{max}}{ESR_{actual}}}$
G. As under A but capacitor is epoxy-filled (for severe shock and vibration resistance).	1,05
H. As under G but capacitor is mounted on a good thermally conducting printed-circuit board.	1,5

Note: Neither the maximum permissible ripple current nor the maximum permissible ripple voltage values are to be exceeded. Refer to Table 3 to find whichever factor will be decisive.

Calculation of ripple currents

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 and 125 °C (see Table 2);

$\sqrt{k}$ = temperature multiplier (neglecting the frequency dependence) = $\sqrt{P_{max}/P_{125}}$;

$\sqrt{r}$ = frequency multiplier (neglecting the temperature dependence) = $\sqrt{ESR_{100}/ESR_{max}}$;

(for $\sqrt{k}$ and $\sqrt{r}$, see Tables 4 and 5, for $\sqrt{kr}$, see Fig. 4);

while P_{max} = max. permissible power dissipation, temperature dependent;

P_{125} = max. permissible power dissipation at 125 °C = $I^2_{r0}\ ESR_{100}$;

ESR_{max} = max. equivalent series resistance, frequency dependent;

ESR_{100} = max. equivalent series resistance at 100 Hz.

The formula is derived for any temperature and frequency as follows:

$$I^2_{r\,max} = P_{max}/ESR_{max}$$
$$= kr\ P_{125}/ESR_{100}$$
$$= kr\ I^2_{r0}\ ESR_{100}/ESR_{100}$$

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

The values of the temperature multiplier $\sqrt{k}$ and of P125 have been calculated allowing a capacitor temperature of 138 °C and assuming the values of ESR_{max} at 138 °C to be 0,8 times the ESR_{max} at 25 °C at all frequencies.

The values of the frequency multiplier $\sqrt{r}$ have been measured at 25 °C assuming it to be the same at all temperatures.

The power dissipation (P_{max}) has been calculated assuming it to be governed by the simplified relation:

$P_{max} = \beta \times S \times \Delta T$,

where β = heat transfer coefficient, taken as 9,0 W/m^2K;

S = capacitor outer surface;

ΔT = temperature difference between capacitor surface and the ambient atmosphere, taken as 13 °C at T_{amb} = 125 °C.

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 1 min after application of U_R, at T_{amb} = 25 °C	see Table 2 (max. 0,1 CU)
Leakage current during continuous operation at U_R,	
at T_{amb} = 25 °C	approx. 0,5 x value stated in Table 2
at T_{amb} = 85 °C	approx. 2 x value stated in Table 2
at T_{amb} = 125 °C	approx. 7 x value stated in Table 2
Leakage current during continuous operation at 40 V, T_{amb} = 125 °C (only applicable to 50 V range)	approx. 2 x value stated in Table 2

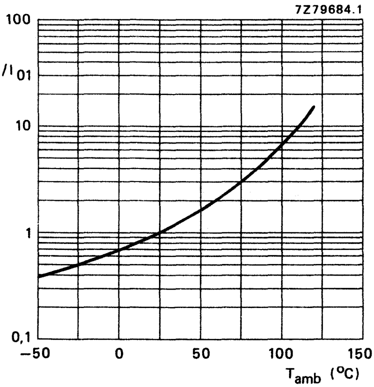


Fig. 5 Multiplier I/I_{01} as a function of temperature. I_{01} = leakage current during continuous operation at U_R, T_{amb} = 25 °C.

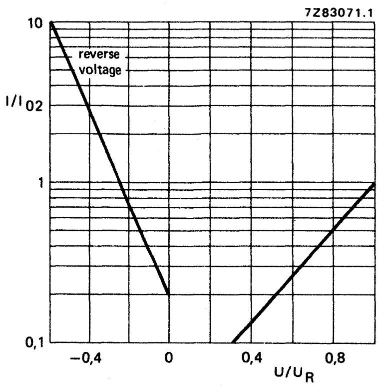


Fig. 6 Multiplier I/I_{02} as a function of U/U_R. I_{02} = leakage current at U_R at a discrete constant temperature.

Tan δ (dissipation factor)

Maximum tan δ at 100 Hz and T_{amb} = 25 °C, measured by means of a four-terminal circuit (Thomson circuit)	see Table 2
Typical tan δ at 100 Hz and T_{amb} = 25 °C	approx. 0,6 x value stated in Table 2

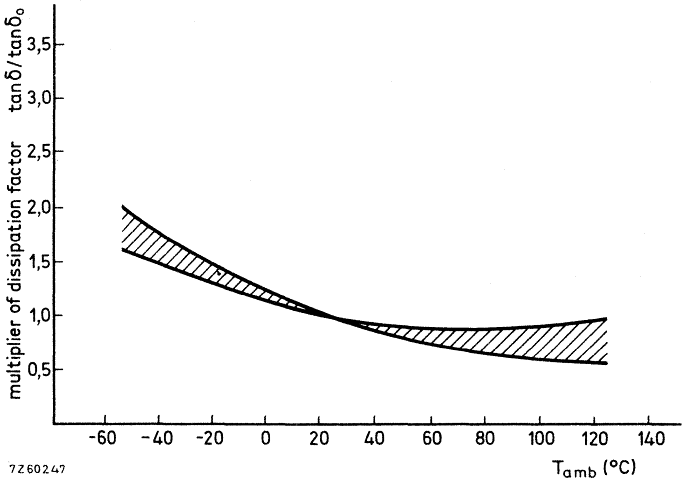


Fig. 7 Multiplier of dissipation factor as a function of ambient temperature; tan δ_0 = dissipation factor at 25 °C, 100 Hz.

Equivalent series resistance (ESR = tan δ/ωC)

Maximum ESR at 100 Hz and T_{amb} = 25 °C (calculated from maximum tan δ and 0,8 x nominal capacitance)	see Table 2

Impedance

Maximum impedance at 100 kHz, and T_{amb} = 25 °C, measured by means of a four-terminal circuit (Thomson circuit)	see Table 2
Typical impedance at 100 kHz, and T_{amb} = 25 °C	approx. 0,5 x value stated in Table 2

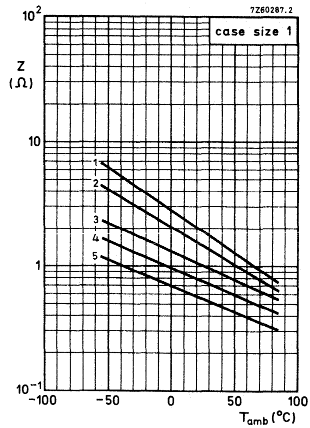


Fig. 8 Typical impedance as a function of temperature at 100 kHz.

Curve 1 = 2,2 μF, 40 V;
curve 2 = 4,7 μF, 25 V;
curve 3 = 10 μF, 16 V;
curve 4 = 15 μF, 10 V;
curve 5 = 22 μF, 6,3 V.

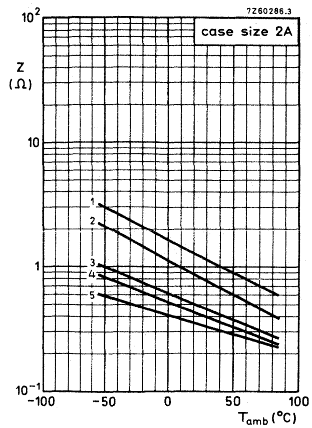


Fig. 9 Typical impedance as a function of temperature at 100 kHz.

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

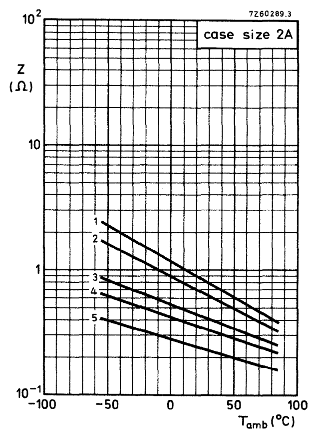


Fig. 10 Typical impedance as a function of temperature at 100 kHz.

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

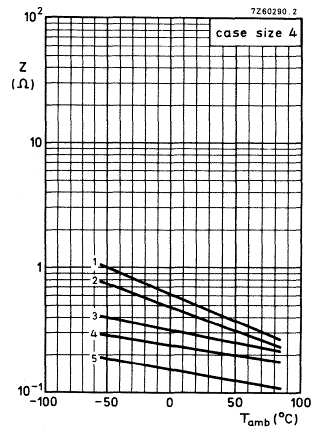


Fig. 11 Typical impedance as a function of temperature at 100 kHz.

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

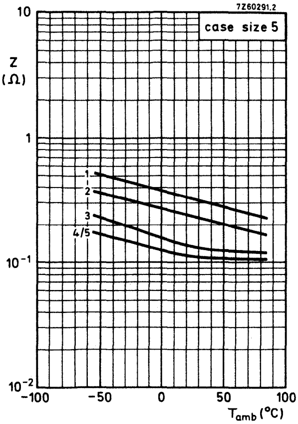


Fig. 12 Typical impedance as a function of temperature at 100 kHz.

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

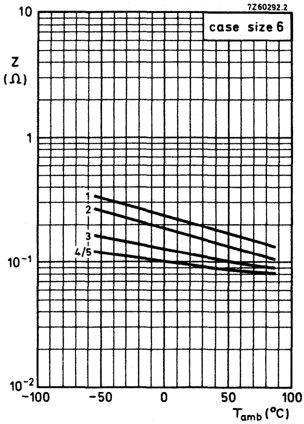


Fig. 13 Typical impedance as a function of temperature at 100 kHz.

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

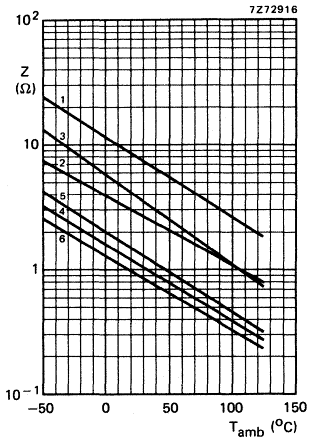


Fig. 14 Typical impedance as a function of temperature at 100 kHz.

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

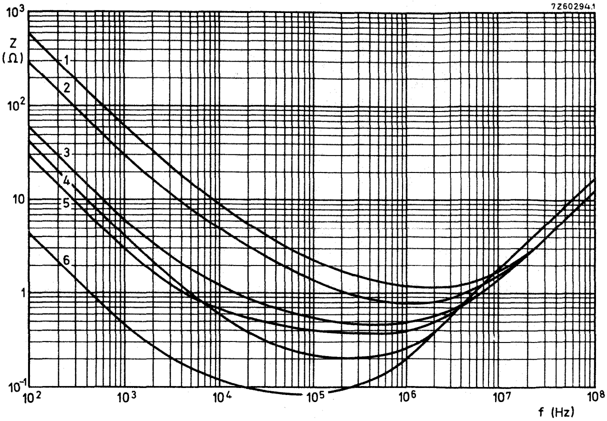


Fig. 15 Typical impedance as a function of frequency at T_{amb} = 25 °C.

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

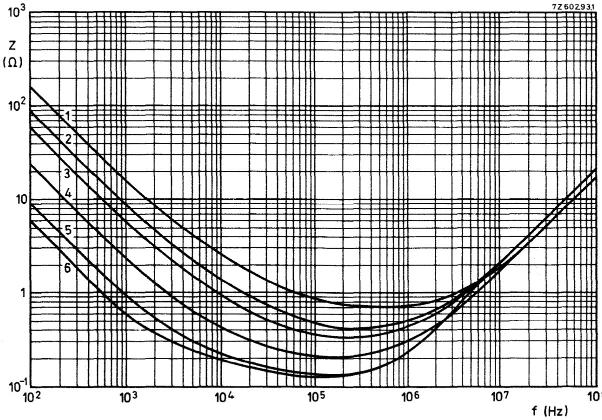


Fig. 16 Typical impedance as a function of frequency at T_{amb} = 25 °C.

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

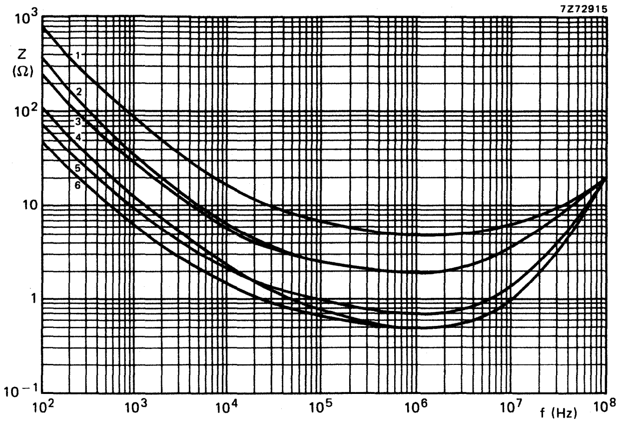


Fig. 17 Typical impedance as a function of frequency at T_{amb} = 25 °C.
Curve 1 = 2,2 μF, 50 V; curve 2 = 4,7 μF, 50 V; curve 3 = 6,8 μF, 50 V; curve 4 = 15 μF, 50 V; curve 5 = 22 μF, 50 V; curve 6 = 33 μF, 50 V.

Equivalent series inductance (ESL)

Equivalent series inductance, measured by means of a four-terminal circuit (Thomson circuit), at 10 MHz; the capacitor leads bent to the pitch as indicated

	pitch	max. ESL	typ. ESL
case size 1	20,3 mm	35 nH	18 to 28 nH
case size 2A	25,4 mm	35 nH	18 to 28 nH
case size 4	27,9 mm	40 nH	23 to 33 nH
case size 5	35,6 mm	40 nH	24 to 34 nH
case size 6	35,6 mm	55 nH	37 to 47 nH

OPERATIONAL DATA

Category temperature range, 6,3 V to 40 V ranges	–55 to + 125 °C
Category temperature range, 50 V range	
for rated voltage	–55 to + 85 °C
for derated voltage (40 V)	–55 to + 125 °C
Usable temperature range	–80 to + 175 °C
Typical life time, 6,3 V to 40 V ranges	
at T_{amb} = 125 °C and U_R	> 20 000 h
at T_{amb} = 150 °C and U_R	> 5 000 h
at T_{amb} = 175 °C and U_R	> 2 000 h
Typical life time, 50 V range	
at T_{amb} = 85 °C and U_R	> 10 000 h
at T_{amb} = 125 °C and derated voltage (40 V)	> 10 000 h
Field failure rate	< 1×10^{-9}/h

PACKING

Capacitors of style 1 are supplied in boxes, those of style 2 are on bandoliers on reels.
The number of capacitors per box or per reel is shown in Table 7.

Table 7

case size	number of capacitors	
	style 1 per box	style 2 per reel
1	100	1000
2A	100	1000
4	100	500
5	100	500
6	100	400

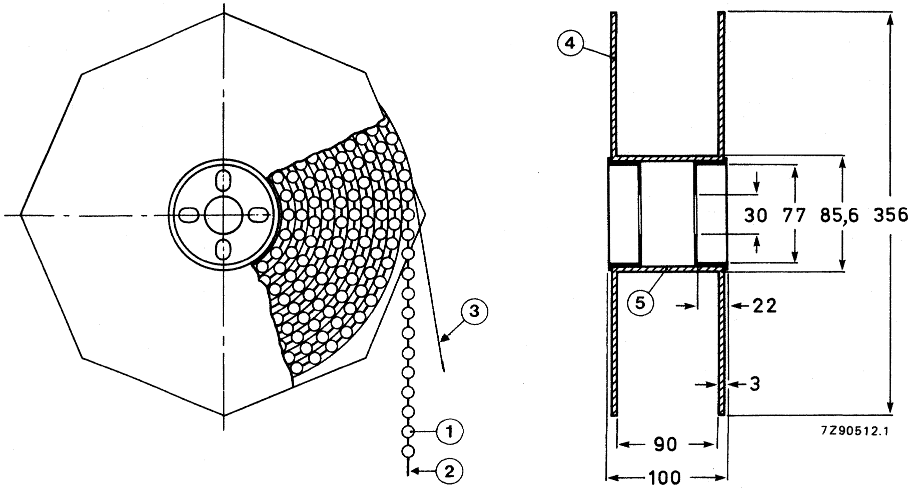


Fig. 18 Style 2 capacitors on banboliers on reel.

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

TESTS AND REQUIREMENTS

See Introduction, section 9, under solid aluminium capacitors, with the addition of the following tests.

Severe rapid change of temperature test: 100 cycles of 15 min at −40 °C and + 125 °C.

Requirements: leakage current ⩽ stated limit,
tan δ ⩽ 1,6 x stated limit,
impedance ⩽ 1,6 x stated limit,
ΔC/C ⩽ 10%.

Severe shock test (for expoxy-filled version only): 10 000g, 0,1 ms.

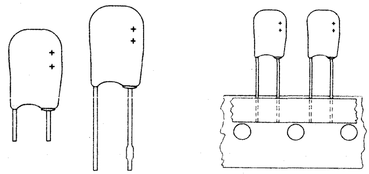
Requirements: leakage current ⩽ stated limit,
tan δ ⩽ 1,2 x stated limit,
ΔC/C ⩽ 10%,
typical capability ⩾ 100 000g.

Severe vibration test (for epoxy-filled version only): 50 to 2000 Hz, 50g, 125 °C, 1 octave/min, 2 directions (longitudinal and transversal), 3 sweeps per direction.

Requirements: leakage current ⩽ stated limit,
tan δ ⩽ 1,2 x stated limit,
ΔC/C ⩽ 10%,
typical capability: up to 80g (also at 125 °C).

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% to special order)
Rated voltage range, U_R (R5 series)	6,3 to 40 V
Category temperature range	−55 to + 125 °C
Usable temperature range	−55 to + 175 °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	
4,7		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 three styles:
style 1: with short wires,
style 2: with long wires of which the anode wire has a flattened area at the end,
style 3: with long wires (without flattened area) on tape on reel, positive leading.

MECHANICAL DATA

Dimensions in mm

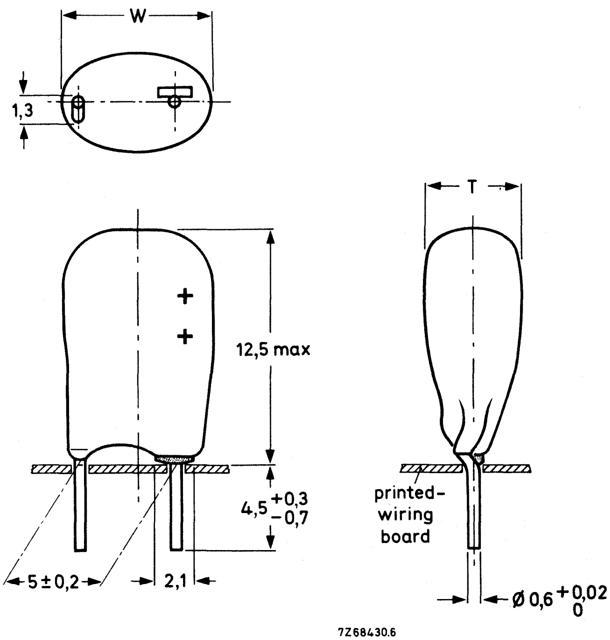


Fig. 1 Style 1; see Table 1a for dimensions T and W.

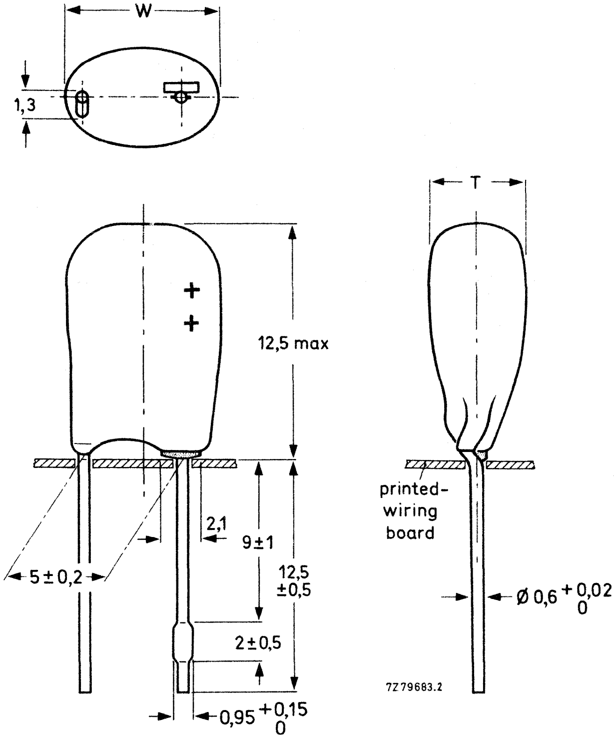


Fig. 2 Style 2; see Table 1a for dimensions T and W.

Table 1a

case size	T_{max}	W_{max}	mass g
1	3,5	8	0,30
2	4,5	8	0,35
3	5	8	0,50
4	6	8	0,60

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).

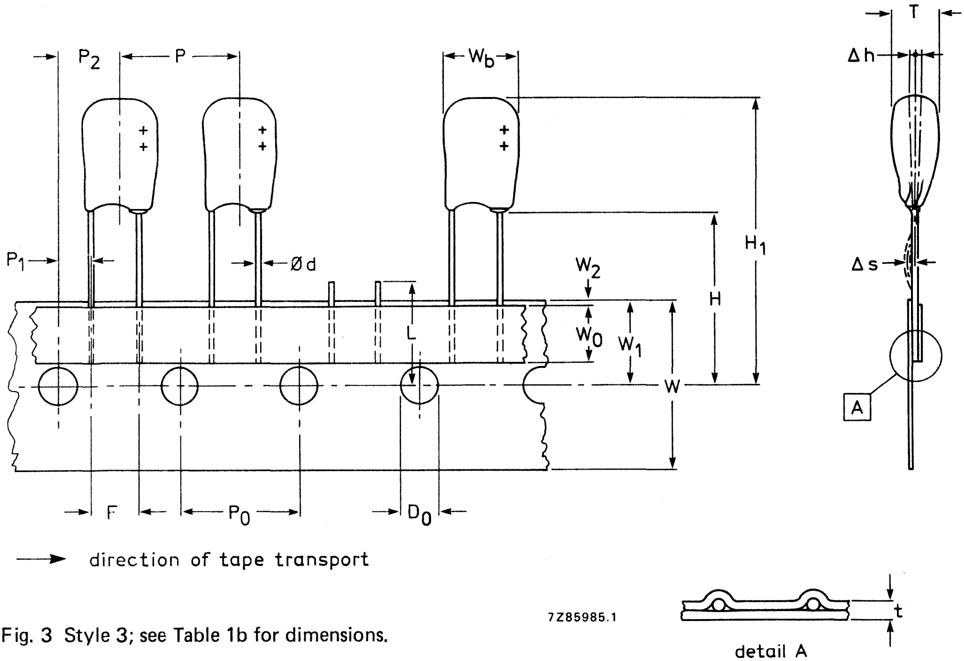


Fig. 3 Style 3; see Table 1b for dimensions.

Table 1b

	symbol	value	tolerance	remarks
Body thickness	T	3,5-4,5-5-6	max.	for case sizes 1, 2, 3 and 4 respectively
Body width	W_b	8	max.	
Component alignment	Δh	0	± 1	
Lead-wire diameter	d	0,6	+ 0,02/—0	
Lead straightness	Δs	0	± 0,5	
Length of snipped leads	L	11	max.	
Lead-to-lead distance	F	5	+ 0,4/—0,2	
Pitch of components	P	12,7	± 1	
Feed-hole pitch	P_0	12,7	± 0,2	*
Feed-hole centre to lead	P_1	3,85	± 0,5	
Feed-hole centre to component centre	P_2	6,35	± 1	
Feed-hole diameter	D_0	4	± 0,2	
Height of component from tape centre	H	18,5	± 0,5	
Component height	H_1	32	max.	
Tape width	W	18	± 0,5	
Hold-down tape width	W_0	6	± 0,5	Feed hole shall be free
Hole position	W_1	9	+ 0,5/—0,2	
Hold-down tape position	W_2	0,5	+ 0,5/—0,2	
Total tape thickness	t	0,9	max.	

* Cumulative pitch error: ± 0,5 mm/4 pitches, and ± 1 mm/20 pitches.

Marking

The capacitors are marked with: 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

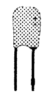
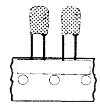
The diameter of the mounting holes in the printed-wiring board is 0,8 ± 0,1 mm, except that of the hole for the anode lead of style 2 capacitors: 1,3–0,2 mm.

When bending, cutting or straightening the leads, ensure that the capacitor body is relieved of stress.

ELECTRICAL DATA

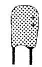
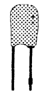
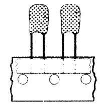
Unless otherwise specified all electrical values in Table 2 apply at an ambient temperature of 20 to 25 °C, a frequency of 100 Hz, an atmospheric pressure of 93 to 106 kPa and a relative humidity of 45 to 75%.
See also the corresponding paragraphs.

Table 2

U_R	nom. cap.	max. r.m.s. ripple current at T_{amb} = 125 °C*	max. leakage current (μA)** at U_R after		max. tan δ	max. ESR	max. impedance at 100 kHz**	case size	catalogue number 2222 122 followed by		
											
V	μF	mA	15 s	1 min		Ω	Ω		style 1	style 2	style 3
6,3	10	40	1,6	0,6	0,15	30	5	1	53109	73109	23109
	15	50	2,4	0,9	0,15	20	3	2	53159	73159	23159
	22	60	3,5	1,4	0,15	14	1,3	2	53229	73229	23229
	33	75	5,2	2,1	0,15	9	0,9	3	53339	73339	23339
	47	95	7,4	3,0	0,15	6,4	0,7	4	53479	73479	23479
	68	115	10,7	4,3	0,15	4,4	0,5	4	53689	73689	23689
10	4,7	30	1,2	0,5	0,15	64	7	1	54478	74478	24478
	6,8	35	1,7	0,7	0,15	44	5	1	54688	74688	24688
	10	40	2,5	1,0	0,15	30	1,5	2	54109	74109	24109
	15	50	3,8	1,5	0,15	20	1	2	54159	74159	24159
	22	60	5,5	2,2	0,15	14	0,7	3	54229	74229	24229
	33	80	8,3	3,3	0,15	9	0,5	4	54339	74339	24339
16	2,2	25	1,0	0,4	0,10	91	10	1	55228	75228	25228
	3,3	30	1,3	0,5	0,10	61	7	1	55338	75338	25338
	4,7	35	1,9	0,8	0,10	43	2	2	55478	75478	25478
	6,8	40	2,7	1,1	0,10	29,5	1,5	2	55688	75688	25688
	10	50	4,0	1,6	0,10	20	1	3	55109	75109	25109
	15	65	6,0	2,4	0,10	13,5	0,7	4	55159	75159	25159

* For calculation of the max. ripple current at these and other frequencies and temperatures, see paragraphs "Voltage" and "Ripple current".
** Versions with lower values of max. leakage current or max. impedance are available to special order.

Table 2 (continued)

U_R	nom. cap.	max. r.m.s. ripple current at T_{amb} = 125 °C*	max. leakage current (μA)** at U_R after		max. tan δ	max. ESR	max. impedance at 100 kHz**	case size	catalogue number 2222 122 followed by		
											
V	μF	mA	15 s	1 min		Ω	Ω		style 1	style 2	style 3
25	0,68	14	1,0	0,4	0,10	295	30	1	56687	76687	26687
	1,0	16	1,0	0,4	0,10	200	20	1	56108	76108	26108
	1,5	20	1,0	0,4	0,10	135	15	1	56158	76158	26158
	2,2	25	1,4	0,6	0,10	91	10	2	56228	76228	26228
	3,3	30	2,1	0,8	0,10	61	7	2	56338	76338	26338
	4,7	35	2,9	1,2	0,10	43	5	3	56478	76478	26478
	6,8	45	4,2	1,7	0,10	29,5	3	4	56688	76688	26688
	10▲	55	6,2	2,5	0,10	20	2	4			
40▲▲	0,1	5	1,0	0,4	0,10	1990	70	1	57107	77107	27107
	0,15	6	1,0	0,4	0,10	1330	50	1	57157	77157	27157
	0,22	8	1,0	0,4	0,10	910	30	1	57227	77227	27227
	0,33	10	1,0	0,4	0,10	610	30	1	57337	77337	27337
	0,47	12	1,0	0,4	0,10	430	20	2	57477	77477	27477
	0,68	14	1,0	0,4	0,10	295	15	2	57687	77687	27687
	1,0	16	1,0	0,4	0,10	200	10	3	57108	77108	27108
	1,5	20	1,5	0,6	0,10	135	7	4	57158	77158	27158
	2,2	25	2,2	0,9	0,10	91	5	4	57228	77228	27228

* For calculation of the max. ripple current at these and other frequencies and temperatures, see paragraphs "Voltage" and "Ripple current".
** Versions with lower values of max. leakage current or max. impedance are available to special order.
▲ Available to special order.
▲▲ Up to 85 °C; from 85 to 125 °C this value is 25 V.

Capacitance

Nominal capacitance values at 100 Hz and T_{amb} = 25 °C	see Table 2
Tolerance on nominal capacitance at 100 Hz	± 20% (± 10% to special order)

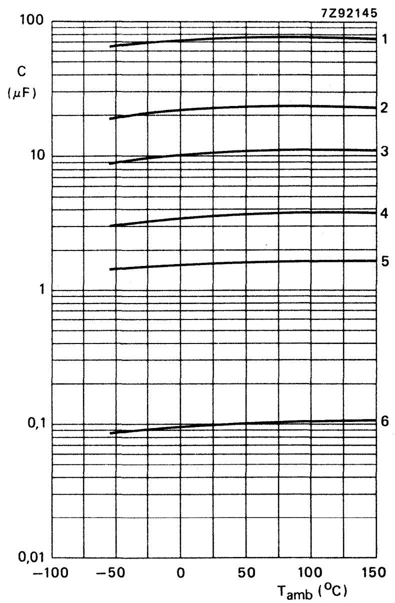


Fig. 4 Typical capacitance as a function of ambient temperature.

Curve 1 = 68 μF, 6,3 V;
curve 2 = 22 μF, 10 V;
curve 3 = 10 μF, 6,3 V;
curve 4 = 3,3 μF, 25 V;
curve 5 = 1,5 μF, 40 V;
curve 6 = 0,1 μF, 40 V.

Voltage

Rated voltage

6,3 V to 25 V ranges	= max. permissible voltage at $T_{amb} \leqslant$ 125 °C	U_R
40 V range	= max. permissible voltage at $T_{amb} \leqslant$ 85 °C	U_R

Derated voltage

6,3 V to 25 V ranges	= max. permissible voltage at T_{amb} from 125 °C to 175 °C	0,63 x U_R
40 V range	= max. permissible voltage at T_{amb} from 85 °C to 175 °C	0,63 x U_R

Ripple voltage

Max. permissible a.c. voltage providing the following four conditions are met:

a) Max. a.c. voltage, with negative d.c. voltage applied — 2 V

b) Max. peak a.c. voltage, without d.c. voltage applied

	$T_{amb} \leq 85\ ^oC$	$85\ ^oC < T_{amb} \leq 125\ ^oC$
at $f \leq 0,1$ Hz	$0,30 \times U_R$	$0,15 \times U_R$
at $0,1\ Hz < f \leq 1$ Hz	$0,45 \times U_R$	$0,22 \times U_R$
at $1\ Hz < f \leq 10$ Hz	$0,60 \times U_R$	$0,30 \times U_R$
at $10\ Hz < f \leq 50$ Hz	$0,65 \times U_R$	$0,32 \times U_R$
at $f > 50$ Hz	$0,80 \times U_R$	$0,40 \times U_R$

c) Momentary value of applied voltage, with positive d.c. voltage applied — between U_R (in the positive half wave) and the limits mentioned under b) (in the negative half wave)

d) Ripple voltage limits are not applicable if the maximum ripple current is exceeded. In that case the ripple current is decisive. Whichever is in practice decisive, depends on the actual impedance of the capacitor. Table 3 should be considered as an aid only in establishing whether the ripple voltage or the ripple current is decisive.

Table 3

frequency	decisive factor	
	$T_{amb} \leq 85\ ^oC$	$T_{amb} > 85\ ^oC$
$f \leq 100$ Hz	voltage	voltage, if actual capacitor impedance is high; current, if actual capacitor impedance is low
$100\ Hz < f \leq 1$ kHz	voltage, if actual capacitor impedance is high; current, if actual capacitor impedance is low	current
$f > 1$ kHz	current	current

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 (see also Tests and requirements) — $0,30 \times U_R$

Ripple current

Maximum permissible r.m.s. ripple current at 100 Hz and T_{amb} = 125 °C	see Table 2
Maximum permissible r.m.s. ripple current at other frequencies and temperatures	see Tables 4 and 5, and Fig. 5
Maximum permissible r.m.s. ripple current at 100 Hz and T_{amb} = 125 °C for capacitors with lower ESR value than the maximum ESR	$\sqrt{ESR_{max}/ESR_{actual}}$ x value stated in Table 2

Table 4 Temperature multiplier of ripple current ($\sqrt{k}$), at 100 Hz

T_{amb} °C	$\sqrt{k}$
25	2,6
35	2,5
45	2,4
55	2,25
65	2,2
70	2,15
75	2,1
80	2,05
85	2,0
90	1,9
95	1,8
100	1,7
105	1,6
110	1,45
115	1,35
120	1,2
125	1,0

Table 5 Frequency multiplier of ripple current ($\sqrt{r}$) at 25 °C

frequency kHz	$\sqrt{r}$
0,05	0,8
0,1	1,0
0,2	1,2
0,5	1,4
1	1,55
2	1,70
5	1,80
10	1,95
20	2,05
50	2,15
100	2,20
200	2,25
500	2,30
1000	2,35

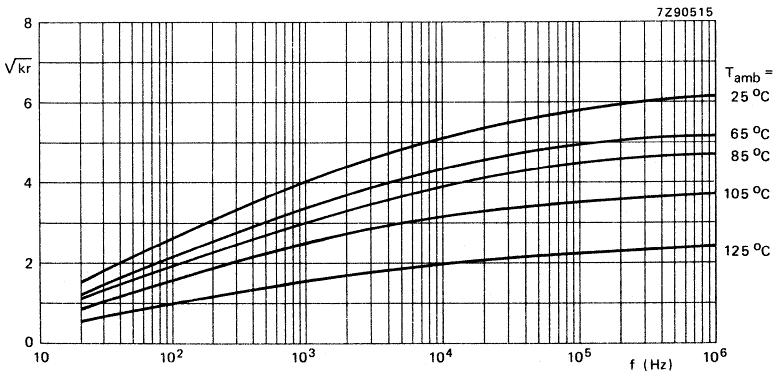


Fig. 5 Combined temperature/frequency multiplier of ripple current ($\sqrt{kr}$) as a function of frequency. $I_{r\,max} = I_{r0}\sqrt{kr}$.

Note: Neither the maximum permissible ripple current nor the maximum permissible ripple voltage values are to be exceeded. Refer to Table 3 (paragraph "Voltage") to find whichever factor will be decisive.

Calculation of ripple currents

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 and 125 °C (see Table 2);

$\sqrt{k}$ = temperature multiplier (neglecting the frequency dependence) = $\sqrt{P_{max}/P_{125}}$;

$\sqrt{r}$ = frequency multiplier (neglecting the temperature dependence) = $\sqrt{ESR_{100}/ESR_{max}}$;

(for $\sqrt{k}$ and $\sqrt{r}$, see Tables 4 and 5, for $\sqrt{kr}$, see Fig. 5);

while P_{max} = max. permissible power dissipation, temperature dependent;

P_{125} = max. permissible power dissipation at 125 °C = $I^2_{r0}\ ESR_{100}$;

ESR_{max} = max. equivalent series resistance, frequency dependent;

ESR_{100} = max. equivalent series resistance at 100 Hz.

The formula is derived for any temperature and frequency as follows:

$$I^2_{r\ max} = P_{max}/ESR_{max}$$
$$= kr\ P_{125}/ESR_{100}$$
$$= kr\ I^2_{r0}\ ESR_{100}/ESR_{100}$$

Thus $I_{r\ max} = I_{r0}\sqrt{kr}$.

The values of the temperature multiplier $\sqrt{k}$ and of P_{125} have been calculated allowing a capacitor temperature of 138 °C and assuming the values of ESR_{max} at 138 °C to be 0,8 x or 1,05 x the ESR_{max} at 25 °C at all frequencies for case sizes 1 to 3 or case size 4 respectively.
The values of the frequency multiplier $\sqrt{r}$ have been measured at 25 °C assuming it to be the same at all temperatures.
The power dissipation (P_{max}) has been calculated assuming it to be governed by the simplified relation:

$P_{max} = \beta \times S \times \Delta T$,

where β = heat transfer coefficient, taken as 18 W/m²K (capacitor mounted on a thermally well-conducting printed-circuit board, in free flowing air, the board being in vertical position);

S = capacitor outer surface;

ΔT = temperature difference between capacitor surface and the ambient atmosphere, taken as 13 °C at T_{amb} = 125 °C.

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 15 s after application of U_R, at T_{amb} = 25 °C	see Table 2 (0,025 CU or 1 μA whichever is greater)
Maximum leakage current 1 min after application of U_R, at T_{amb} = 25 °C	see Table 2 (0,01 CU or 0,4 μA whichever is greater)
Leakage current during continuous operation at U_R	
at T_{amb} = 25 °C	approx. 0,05 x 15 s-value stated in Table 2
at T_{amb} = 85 °C	approx. 0,25 x 15 s-value stated in Table 2

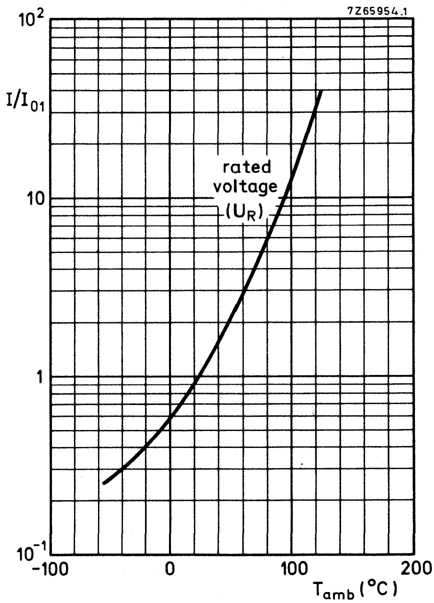


Fig. 6 Multiplier I/I_{01} as a function of ambient temperature; I_{01} = leakage current during continuous operation at U_R, T_{amb} = 25 °C.

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

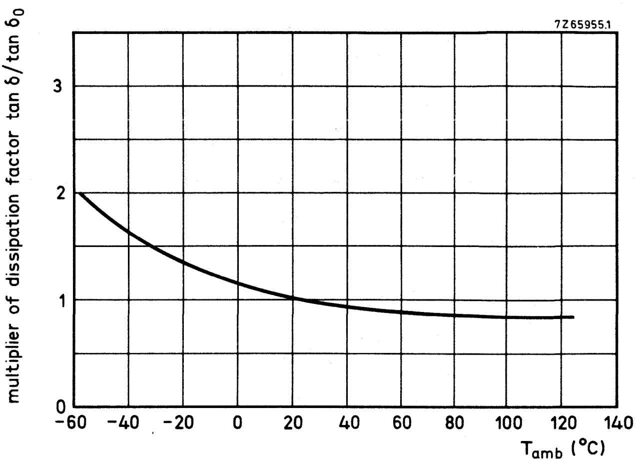


Fig. 7 Typical multiplier of dissipation factor as a function of temperature; tan δ_0 = dissipation factor at T_{amb} = 25 °C, 100 Hz.

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

Maximum ESR at 100 Hz and T_{amb} = 25 °C (calculated from maximum tan δ and 0,8 x nominal capacitance) see Table 2

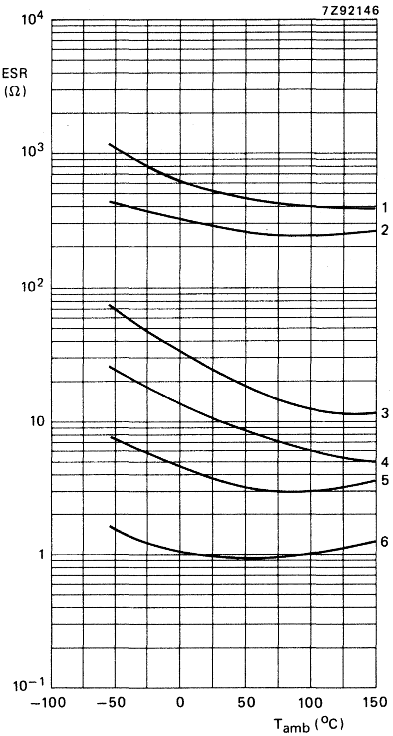


Fig. 8 Typical ESR as a function of ambient temperature at 100 Hz.

Curve 1 = 0,1 μF, 40 V;
curve 2 = 1,5 μF, 40 V;
curve 3 = 3,3 μF, 25 V;
curve 4 = 10 μF, 6,3 V;
curve 5 = 22 μF, 10 V;
curve 6 = 68 μF, 6,3 V.

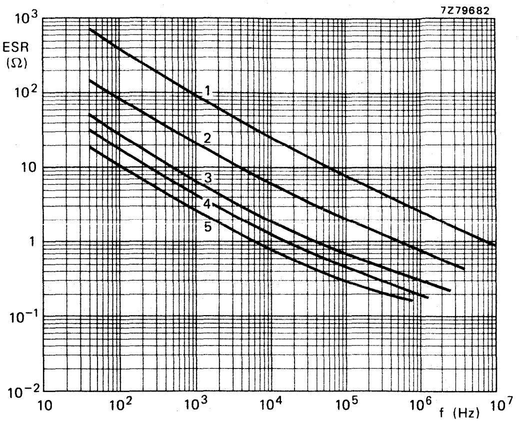


Fig. 9 Typical ESR as a function of frequency at T_{amb} = 25 °C; **case size 1.**

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.

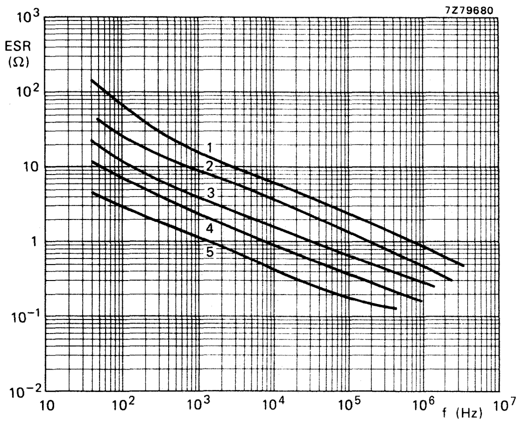


Fig. 10 Typical ESR as a function of frequency at T_{amb} = 25 °C; **case size 2.**

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.

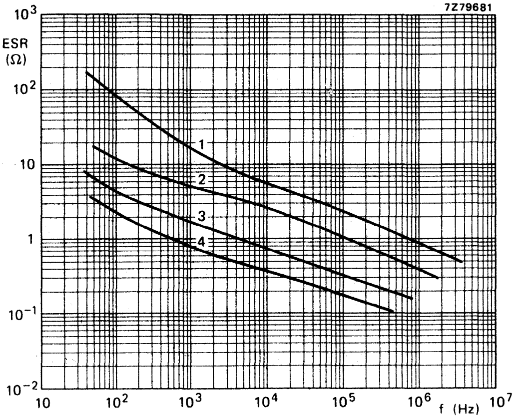


Fig. 11 Typical ESR as a function of frequency at T_{amb} = 25 °C; **case size 3.**

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.

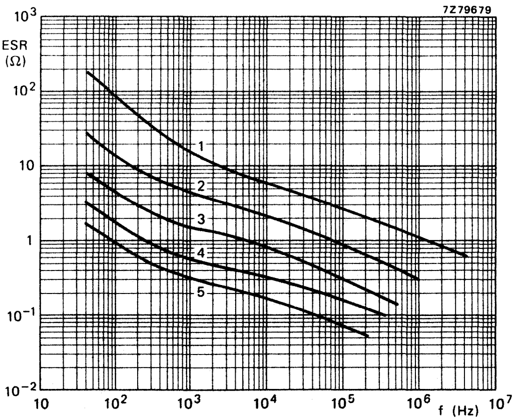


Fig. 12 Typical ESR as a function of frequency at T_{amb} = 25 °C; **case size 4.**

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.

Impedance

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

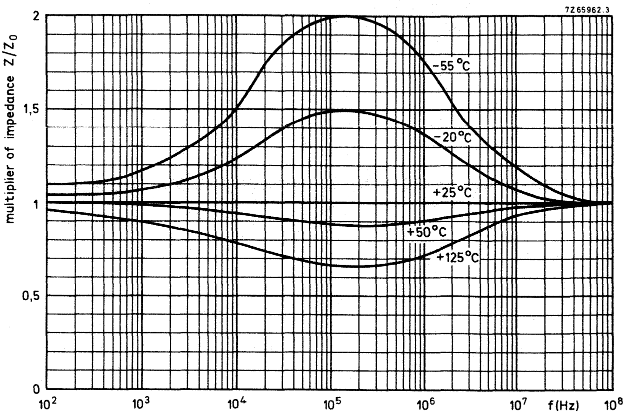


Fig. 13 Typical multiplier of impedance Z/Z_0 as a function of frequency at different temperatures; Z_0 = impedance initial value at T_{amb} = 25 °C.

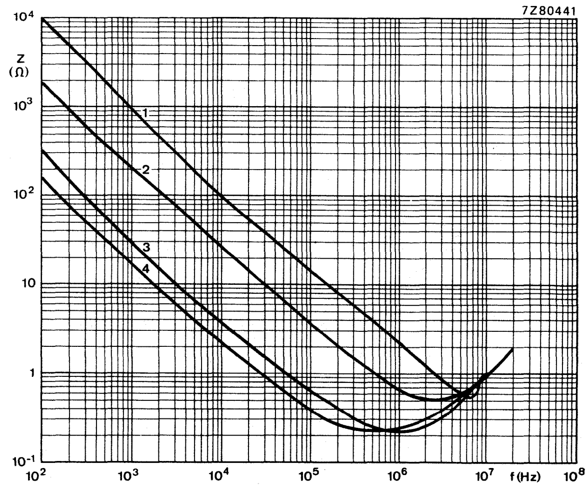


Fig. 14 Typical impedance as a function of frequency at T_{amb} = 25 °C; **case size 1.**

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.

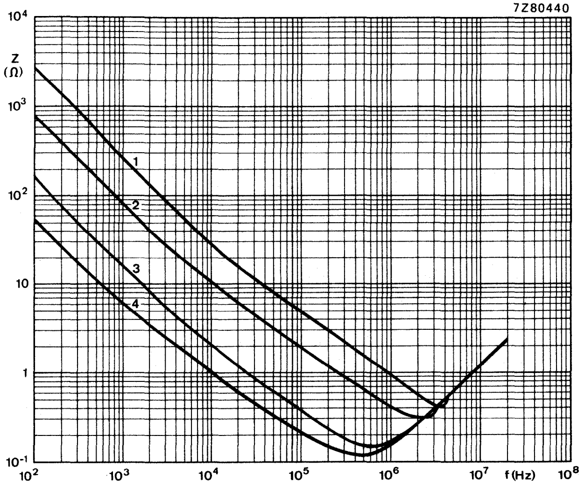


Fig. 15 Typical impedance as a function of frequency at T_{amb} = 25 °C; **case size 2.**

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.

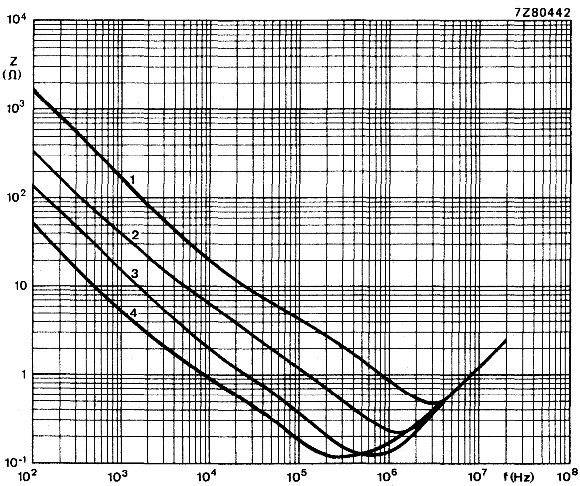


Fig. 16 Typical impedance as a function of frequency at T_{amb} = 25 °C; **case size 3.**

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.

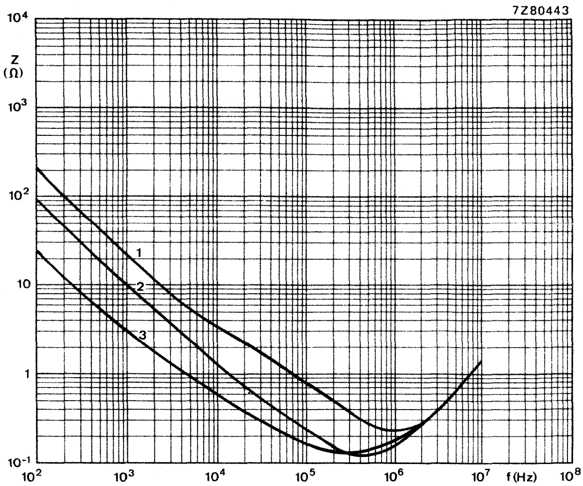


Fig. 17 Typical impedance as a function of frequency at T_{amb} = 25 °C; **case size 4.**
Curve 1 = 6,8 μF, 25 V;
curve 2 = 15 μF, 16 V;
curve 3 = 68 μF, 6,3 V.

Equivalent series inductance (ESL)

Equivalent series inductance, measured by means of a four-terminal circuit (Thomson circuit), at 10 MHz	
case sizes 1 and 2	max. 20 nH; typ. 9 to 14 nH
case sizes 3 and 4	max. 20 nH; typ. 11 to 16 nH

OPERATIONAL DATA

Category temperature range

for rated voltage, 6,3 V to 25 V range	−55 to + 125 °C
for rated voltage, 40 V range	−55 to + 85 °C
for derated voltage, 40 V range	−55 to + 125 °C

Usable temperature range	−55 to + 175 °C

Typical life time

at T_{amb} = 85 °C	> 20 000 h
at T_{amb} = 125 °C	> 10 000 h
at T_{amb} = 175 °C	> 2 000 h

Field failure rate	< 1 x 10^{-8}/h

PACKING

Capacitors of styles 1 and 2 are supplied in boxes, those of style 3 on tape on reel. The number of capacitors per box or per reel is:

style 1, all case sizes	: 1000 capacitors per box; 200 per plastic bag, 5 bags per box;
style 2, case sizes 1, 2 and 3	: 1000 capacitors per box; 200 per plastic bag, 5 bags per box;
style 2, case size 4	: 800 capacitors per box; 200 per plastic bag, 4 bags per box;
style 3, all case sizes	: 1000 capacitors per reel.

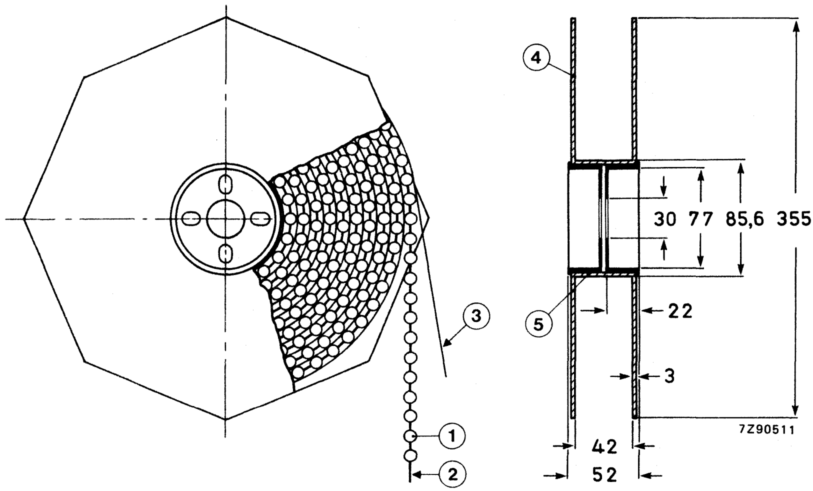


Fig. 18 Style 3 capacitors on tape on reel.

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

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 °C);
- calgonite solution (20 g/l, 70 ± 5 °C);
- mixture of 4,5% 2-butoxyethanol, 4,5% 2-amino-ethanol, and 91% water (70 ± 5 °C);
- 1.1.1. trichloro-ethane;
- mixtures of 1.1.2-trichloro-1.2.2-trifluoro-ethane (fluorocarbon 113) and the following solvents in the respective mass percentage ratios of these solvents to fluorocarbon:
  - 2-propanol (isopropanol), 25%: 75% (Arklone K*); up to the ratio 35%: 65%;
  - dichloromethane (methylene chloride), 49,5%: 50,5% (Freon TMC**);
  - ethanol, 4,5%: 95,5% (e.g. Arklone A*, Freon TE**);
  - methanol and nitromethane, 5,7%: 0,3%: 94% (Freon TMS**).

Requirement: visual appearance not affected.

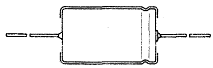
Note: Tests are carried out using non-contaminated solvents.

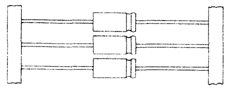
* Trade mark of I.C.I.

** Trade mark of Dupont de Nemours.

SOLID ALUMINIUM CAPACITORS

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





QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	2,2 to 2200 μF
Tolerance on nominal capacitance	± 20% (± 10% to special order)
Rated voltage range, U_R	4 to 40 V
Category temperature range	−55 to + 125 °C
Usable temperature range	−80 to + 175 °C
Endurance test at 125 °C	2000 h
Basic specification	IEC 384-4, long-life grade
Climatic category, IEC 68	55/125/56
Approval	Liste LNZ 44-04 COSC, gam-t-1 (France)

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

C_{nom}	U_R (V)							
μF	4	6,3	10	16	20	25	35	40
2,2							1	1
3,3							1	1
4,7							1	1
6,8							1	1
10				1	1	1	2A	2A
15				1	1	1*	2A	2A
22				1		2A	4/2A**	4
33			1	2A		2A	4	4
47		1	1	2A	2A		4	5/4**
68	1*		2A	2A		4	5	5
100			2A	4	4	4	6	6
150		2A	4	4	5	5	6*	
220	2A*		4	5	5	6		
330		4	5	5	6			
470	4*		5	6	6*			
680		5	6	6*				
1000	5*	6	6*					
1500	6*	6*						
2200	6*							

case size	nominal dimensions (mm)
1	Ø 6,5 x 15
2A	Ø 7,5 x 20
4	Ø 9 x 23
5	Ø 10 x 31,5
6	Ø 12,5 x 31,5

* Available from the middle of 1984.

** Under consideration.

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

The capacitors are available in 2 styles:
- style 1: axial leads, case sizes 1 to 6, in boxes;
- style 2: axial leads, case sizes 1 to 6, on bandoliers on reel.

Note: A special version is available, which is partly epoxy-filled, withstanding severe shock and vibration tests; see also paragraph "Tests and requirements".

MECHANICAL DATA

Dimensions in mm

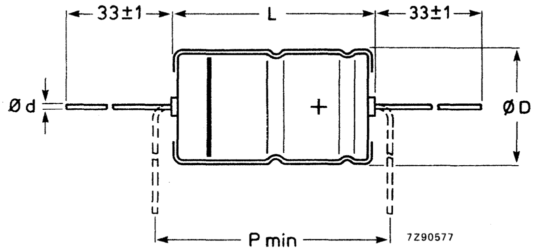


Fig. 1 Style 1; for dimensions d, D, L and P, see Table 1a.

Table 1a

case size	d	D_{nom}	L_{nom}	D_{max}	L_{max}	P_{min}	mass** approx. g
1	0,6 (0,8)*	6,5	15	6,7	15,3 (17,5)*	17,5	1,2
2A	0,6 (0,8)*	7,5	20	7,6	20,4 (23,3)*	22,5	2,4
4	0,6 (0,8)*	9	23	9,3 (10,3)*	23,3	25	3,3
5	0,8	10	31,5	10,3	32	35	4,5
6	0,8	12,5	31,5	12,9	32	35	6,3

* Dimension between brackets is valid until the middle of 1984.

** Add 10% for epoxy-filled version.

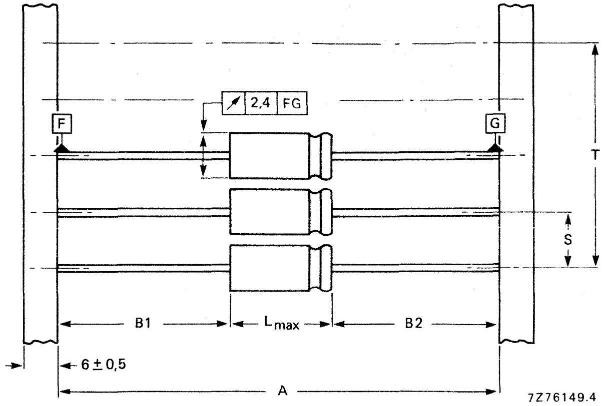


Fig. 2 Style 2 capacitors on bandoliers; the bandolier to which the negative capacitor terminals are connected is blue. See Table 1b for dimensions A, S, T and L_{max}.
$|B1-B2| = 1{,}4 + (L_{max}-L)$ mm max.

Table 1b

Dimensions in mm

case size	A	S	T for number (n) of capacitors		L_{max}
			n < 50	50 < n < 100	
1	73 ± 1,6	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	15,3 (17,5)*
2A	73 ± 1,6	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	20,4 (23,3)*
4	73 ± 1,6	10 ± 0,4	10 (n-1) ± 2	10 (n-1) ± 4	23,3
5	73 ± 1,6	15 ± 0,75	10 (n-1) ± 2	10 (n-1) ± 4	32
6	73 ± 1,6	15 ± 0,75	10 (n-1) ± 2	10 (n-1) ± 4	32

Marking

The capacitors are marked with: group number (123), capacitance, tolerance, rated voltage at corresponding maximum temperature, date code, a band to identify the negative terminal, "+" signs for the positive terminal and name of manufacturer.

Mounting

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

* Dimension between brackets is valid until the middle of 1984.

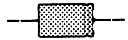
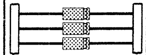
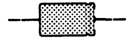
ELECTRICAL DATA

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 86 to 106 kPa and a relative humidity of 45 to 75%.
See also the corresponding paragraphs.

Table 2

U_R	nom. cap.	max. r.m.s. ripple current at T_{amb} = 125 °C	max. leakage current at U_R after 1 min*	max. tan δ	max. ESR	max. impedance at 100 kHz*	case size	catalogue number 2222 123 followed by		
V	μF	mA	μA		Ω	Ω		style 1	style 2	version with severe shock and vibration resistance
4	68**	90	22	0,25	7,3	1,2	1	12689	22689	62689
	220**	190	70	0,25	2,3	1,0	2A	12221	22221	62221
	470**	310	150	0,25	1,1	0,4	4	12471	22471	62471
	1000**	540	320	0,25	0,50	0,3	5	12102	22102	62102
	1500**	800	480	0,25	0,33	0,2	6	12152	22152	62152
	2200**	960	700	0,25	0,23	0,2	6	12222	22222	62222
6,3	47	90	25	0,18	7,6	1,2	1	13479	23479	63479
	150	190	70	0,18	2,4	1,0	2A	13151	23151	63151
	330	310	150	0,18	1,1	0,4	4	13331	23331	63331
	680	520	350	0,18	0,55	0,3	5	13681	23681	63681
	1000	760	650	0,18	0,36	0,2	6	13102	23102	63102
	1500**	940	760	0,18	0,24	0,2	6	13152	23152	63152
10	33	75	30	0,18	11	1,2	1	14339	24339	64339
	47	90	45	0,18	7,6	1,2	1	14479	24479	64479
	68	120	70	0,18	5,3	1,0	2A	14689	24689	64689
	100	150	80	0,18	3,6	1,0	2A	14101	24101	64101
	150	210	150	0,18	2,4	0,4	4	14151	24151	64151
	220	250	200	0,18	1,7	0,4	4	14221	24221	64221
	330	360	330	0,18	1,1	0,3	5	14331	24331	64331
	470	420	380	0,18	0,8	0,3	5	14471	24471	64471
	680	630	550	0,18	0,55	0,2	6	14681	24681	64681
	1000**	760	800	0,18	0,36	0,2	6	14102	24102	64102

Table 2 (continued)

U_R	nom. cap.	max. r.m.s. ripple current at T_{amb} = 125 °C	max. leakage current at U_R after 1 min*	max. tan δ	max. ESR	max. impedance at 100 kHz*	case size	catalogue number 2222 123 followed by		
								 style 1	 style 2	 version with severe shock and vibration resistance
V	μF	mA	μA		Ω	Ω				
16	10	45	16	0,14	28	2,5	1	15109	25109	65109
	15	55	24	0,14	19	2,5	1	15159	25159	65159
	22	70	35	0,14	13	2,5	1	15229	25229	65229
	33	95	55	0,14	8,4	2,0	2A	15339	25339	65339
	47	120	75	0,14	5,9	2,0	2A	15479	25479	65479
	68	140	110	0,14	4,1	2,0	2A	15689	25689	65689
	100	200	160	0,14	2,8	0,8	4	15101	25101	65101
	150	220	240	0,16	2,1	0,8	4	15151	25151	65151
	220	310	350	0,16	1,5	0,6	5	15221	25221	65221
	330	380	500	0,16	1,0	0,6	5	15331	25331	65331
	470	550	750	0,16	0,7	0,4	6	15471	25471	65471
	680**	650	870	0,16	0,5	0,4	6	15681	25681	65681
20	10	45	20	0,14	28	2,5	1	90037	90057	90077
	15	55	30	0,14	19	2,5	1	90038	90058	90078
	47	115	95	0,14	5,9	2,0	2A	90042	90062	90082
	100	200	200	0,14	2,8	0,8	4	90044	90064	90084
	150	260	300	0,16	2,1	0,6	5	90045	90065	90085
	220	310	440	0,16	1,5	0,6	5	90046	90066	90086
	330	460	660	0,16	1,0	0,4	6	90047	90067	90087
	470**	550	940	0,16	0,7	0,4	6	90048	90068	90088
25	10	45	25	0,14	28	5	1	16109	26109	66109
	22	75	55	0,14	13	2,5	2A	16229	26229	66229
	33	100	85	0,14	8,4	2,5	2A	16339	26339	66339
	68	160	170	0,14	4,1	1,0	4	16689	26689	66689
	100	200	250	0,16	3,2	1,0	4	16101	26101	66101
	150	260	400	0,16	2,1	0,8	5	16151	26151	66151
	220	370	550	0,16	1,5	0,6	6	16221	26221	66221

* Capacitors with lower values of max. leakage current or max. impedance are available to special order.

** Available from the middle of 1984.

Table 2 (continued)

U_R	nom. cap.	max. r.m.s. ripple current at T_{amb} = 125 °C	max. leakage current at U_R after 1 min*	max. tan δ	max. ESR	max. impedance at 100 kHz*	case size	catalogue number 2222 123 followed by		
								style 1	style 2	version with severe shock and vibration resistance
V	μF	mA	μA		Ω	Ω				
35	2,2	20	5	0,12	109	5	1	97228	20228	60228
	3,3	30	7	0,12	73	5	1	97338	20338	60338
	4,7	35	10	0,12	51	5	1	97478	20478	60478
	6,8	40	15	0,12	35	5	1	97688	20688	60688
	10	55	20	0,12	24	2,5	2A	97109	20109	60109
	15	65	30	0,12	16	2,5	2A	97159	20159	60159
	22	90	45	0,12	11	1,5	4	97229	20229	60229
	33	120	65	0,12	7,2	1,0	4	97339	20339	60339
	47	150	95	0,12	5,1	1,0	4	97479	20479	60479
	68	180	135	0,16	4,7	0,8	5	97689	20689	60689
	100	250	200	0,16	3,2	0,6	6	97101	20101	60101
	150**	310	300	0,16	2,1	0,6	6	97151	20151	60151
40	2,2	20	9	0,12	109	5	1	17228	27228	67228
	3,3	30	13	0,12	73	5	1	17338	27338	67338
	4,7	35	19	0,12	51	5	1	17478	27478	67478
	6,8	40	27	0,12	35	5	1	17688	27688	67688
	10	55	40	0,12	24	2,5	2A	17109	27109	67109
	15	65	60	0,12	16	2,5	2A	17159	27159	67159
	22	90	90	0,12	11	1,5	4	17229	27229	67229
	33	125	130	0,12	7,2	1,0	4	17339	27339	67339
	47	160	190	0,12	5,1	1,0	5	17479	27479	67479
	68	170	270	0,16	4,7	0,8	5	17689	27689	67689
	100	250	400	0,16	3,2	0,6	6	17101	27101	67101

* Capacitors with lower values of max. leakage current or max. impedance are available to special order.
** Available from the middle of 1984.

Capacitance

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

Tolerance on nominal capacitance at 100 Hz — ± 20% (± 10% to special order)

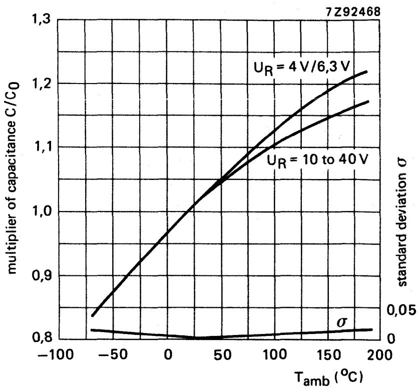


Fig. 3 Typical capacitance as a function of ambient temperature.
C_0 = capacitance at 25 °C, 100 Hz.

Voltage

Rated voltage = max. permissible voltage — U_R

Derated voltage = max. permissible voltage at T_{amb} from 125 °C to 175 °C — $0,63 \times U_R$

Ripple voltage = max. permissible a.c. voltage providing the following four conditions are met:

a) Max. a.c. voltage, with negative d.c. voltage applied — 2 V

b) Max. peak a.c. voltage, without d.c. voltage applied

	$T_{amb} \leqslant 85$ °C	85 °C $< T_{amb} \leqslant 125$ °C
at $f \leqslant 0,1$ Hz	$0,30 \times U_R$	$0,15 \times U_R$
at 0,1 Hz $< f \leqslant 1$ Hz	$0,45 \times U_R$	$0,22 \times U_R$
at 1 Hz $< f \leqslant 10$ Hz	$0,60 \times U_R$	$0,30 \times U_R$
at 10 Hz $< f \leqslant 50$ Hz	$0,65 \times U_R$	$0,32 \times U_R$
at $f > 50$ Hz	$0,80 \times U_R$	$0,40 \times U_R$

c) Momentary value of applied voltage, with positive d.c. voltage applied — between U_R (in the positive half wave) and the limits mentioned under b) (in the negative half wave)

d) Ripple voltage limits are not applicable if the maximum ripple current is exceeded. In that case the ripple current is decisive. Whichever is in practice decisive, depends on the actual impedance of the capacitor. Table 3 should be considered as an aid only in establishing whether the ripple voltage or the ripple current is decisive.

Table 3

frequency	decisive factor	
	at $T_{amb} \leqslant 85\ ^oC$	$T_{amb} > 85\ ^oC$
$f \leqslant 50$ Hz	voltage	voltage, if actual capacitor impedance is high; current, if actual capacitor impedance is low
50 Hz $< f \leqslant 1$ kHz	voltage, if actual capacitor impedance is high; current, if actual capacitor impedance is low	current
$f > 1$ kHz	current	current

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 $T_{amb} \leqslant 85\ ^oC$ — $0{,}30 \times U_R$
at $85\ ^oC < T_{amb} \leqslant 125\ ^oC$ — $0{,}15 \times U_R$

Ripple current

Maximum permissible r.m.s. ripple current at 100 Hz and T_{amb} = 125 °C — see Table 2

Maximum permissible r.m.s. ripple current at other frequencies, temperatures and conditions — see Tables 4 to 6, and Fig. 4.

Table 4 Temperature multiplier of ripple current ($\sqrt{k}$), at 100 Hz

T_{amb} °C	$\sqrt{k}$
25	2,6
35	2,5
45	2,4
55	2,25
65	2,2
70	2,15
75	2,1
80	2,05
85	2,0
90	1,9
95	1,8
100	1,7
105	1,6
110	1,45
115	1,35
120	1,2
125	1,0

Table 5 Frequency multiplier of ripple current ($\sqrt{r}$) at 25 °C

frequency kHz	$\sqrt{r}$
0,05	0,8
0,1	1,0
0,2	1,2
0,5	1,4
1	1,55
2	1,70
5	1,80
10	1,95
20	2,05
50	2,15
100	2,20
200	2,25
500	2,30
1000	2,35

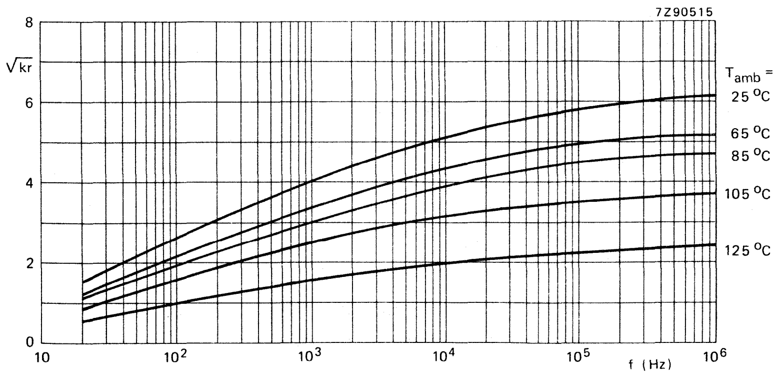


Fig. 4 Combined temperature/frequency multiplier of ripple current ($\sqrt{kr}$) as a function of frequency. $I_{r\,max} = I_{r0}\sqrt{kr}$.

Table 6 Multiplier of ripple current for various application conditions

condition	multiplier
A. Capacitor insulated with a blue sleeve, mounted horizontally on a thermally non-conducting printed-circuit board, in free flowing air and in a surrounding that allows the absorption of radiation heat.	1,0
B. As under A but capacitor is not insulated.	0,9
C. As under A but capacitor is mounted vertically	0,7
D. As under A but capacitor is mounted on a thermally well-conducting printed-circuit board.	1,25
E. As under A but the surrounding walls etc. have a temperature higher than 125 °C and therefore prevent the absorption of heat by radiation	0,6
F. Capacitor has an ESR value lower than the maximum ESR.	$\sqrt{\frac{ESR_{max}}{ESR_{actual}}}$
G. As under A but capacitor is epoxy-filled (for severe shock and vibration resistance).	1,05
H. As under G but capacitor is mounted on a thermally well-conducting printed-circuit board	1,5

Note: Neither the maximum permissible ripple current nor the maximum permissible ripple voltage values are to be exceeded. Refer to Table 3 (paragraph "Voltage") to find whichever factor will be decisive.

Calculation of ripple currents

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 and 125 °C (see Table 2);

$\sqrt{k}$ = temperature multiplier (neglecting the frequency dependence) = $\sqrt{P_{max}/P_{125}}$;

$\sqrt{r}$ = frequency multiplier (neglecting the temperature dependence) = $\sqrt{ESR_{100}/ESR_{max}}$;

(for $\sqrt{k}$ and $\sqrt{r}$, see Tables 4 and 5, for $\sqrt{kr}$, see Fig. 4);

while P_{max} = max. permissible power dissipation, temperature dependent;

P_{125} = max. permissible power dissipation at 125 °C = $I^2_{r0}\,ESR_{100}$;

ESR_{max} = max. equivalent series resistance, frequency dependent;

ESR_{100} = max. equivalent series resistance at 100 Hz.

The formula is derived for any temperature and frequency as follows:

$$I_{r\,max}{}^2 = P_{max}/ESR_{max}$$
$$= kr\,P_{125}/ESR_{100}$$
$$= kr\,I^2{}_{r0}\,ESR_{100}/ESR_{100}$$

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

The values of the temperature multiplier $\sqrt{k}$ and of P_{125} have been calculated allowing a capacitor temperature of 138 °C and assuming the values of ESR_{max} at 138 °C to be 0,8 times the ESR_{max} at 25 °C at all frequencies.

The values of the frequency multiplier $\sqrt{r}$ have been measured at 25 °C assuming it to be the same at all temperatures.

The power dissipation (P_{max}) has been calculated assuming it to be governed by the simplified relation:

$$P_{max} = \beta \times S \times \Delta T,$$

where β = heat transfer coefficient, taken as 9,0 W/m²K;

S = capacitor outer surface;

ΔT = temperature difference between capacitor surface and the ambient atmosphere, taken as 13 °C at T_{amb} = 125 °C.

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 1 min after application of U_R, at T_{amb} = 25 °C	see Table 2 (max. 0,1 CU)
Leakage current during continuous operation at U_R,	
at T_{amb} = 25 °C	approx. 0,5 x value stated in Table 2
at T_{amb} = 85 °C	approx. 2 x value stated in Table 2
at T_{amb} = 125 °C	approx. 7 x value stated in Table 2

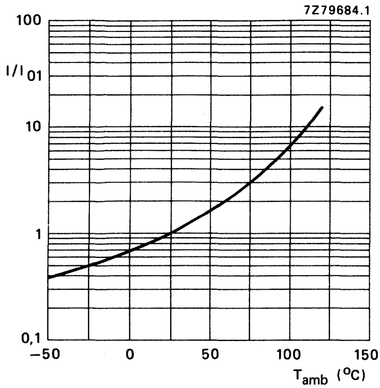


Fig. 5 Multiplier I/I_{01} as a function of temperature. I_{01} = leakage current during continuous operation at U_R, T_{amb} = 25 °C.

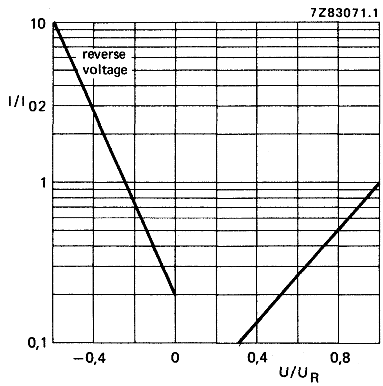


Fig. 6 Multiplier I/I_{02} as a function of U/U_R. I_{02} = leakage current at U_R at a discrete constant temperature.

Tan δ (dissipation factor)

Maximum tan δ at 100 Hz and T_{amb} = 25 °C, measured by means of a four-terminal circuit (Thomson circuit)	see Table 2
Typical tan δ at 100 Hz and T_{amb} = 25 °C	0,6 x value stated in Table 2

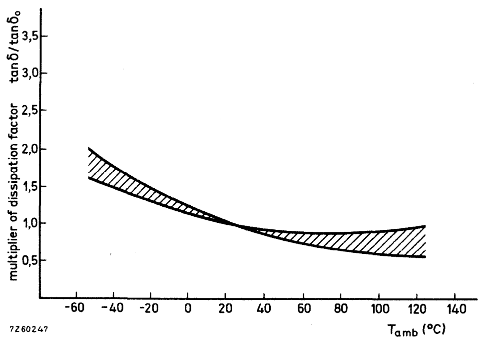


Fig. 7 Multiplier of dissipation factor as a function of ambient temperature; tan δ_0 = dissipation factor at 25 °C, 100 Hz.

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

Maximum ESR at 100 Hz and T_{amb} = 25 ^{o}C (calculated from maximum tan δ and 0,8 x nominal capacitance)	see Table 2
Maximum ESR at 100 kHz and T_{amb} = 25 ^{o}C	equal to values of max. impedance at 100 kHz, see Table 2

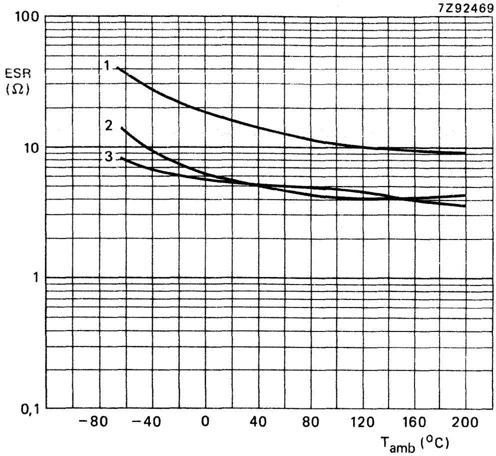


Fig. 8 Typical ESR as a function of ambient temperature at 100 Hz, **case size 1.**

Curve 1 = 6,8 μF, 40 V and 10 μF, 25 V;
curve 2 = 22 μF, 16 V;
curve 3 = 33 μF, 10 V.

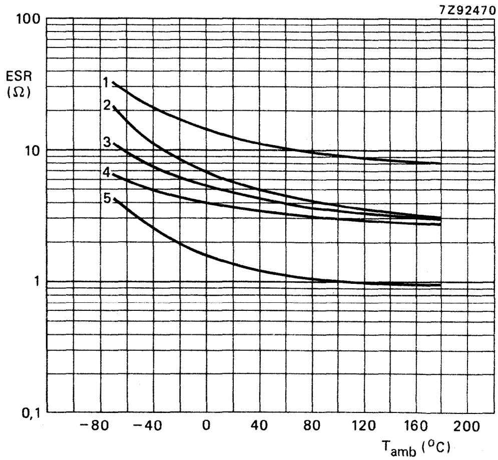


Fig. 9 Typical ESR as a function of ambient temperature at 100 Hz, **case size 2A.**

Curve 1 = 10 μF, 40 V;
curve 2 = 33 μF, 25 V;
curve 3 = 68 μF, 10 V;
curve 4 = 47 μF, 20 V;
curve 5 = 150 μF, 6,3 V.

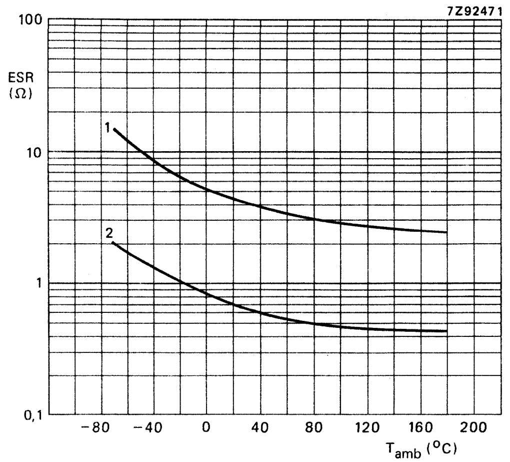


Fig. 10 Typical ESR as a function of ambient temperature at 100 Hz, **case size 4.**

Curve 1 = 33 μF, 40 V;
curve 2 = 220 μF, 10 V and 330 μF, 6,3 V.

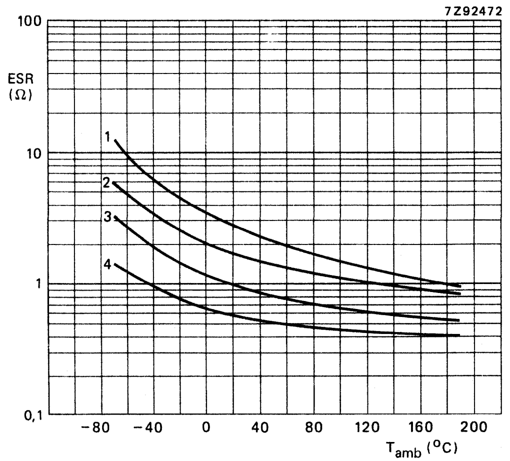


Fig. 11 Typical ESR as a function of ambient temperature at 100 Hz, **case size 5.**

Curve 1 = 68 μF, 40 V;
curve 2 = 100 μF, 25 V;
curve 3 = 150 μF, 25 V;
curve 4 = 330 μF, 10 V.

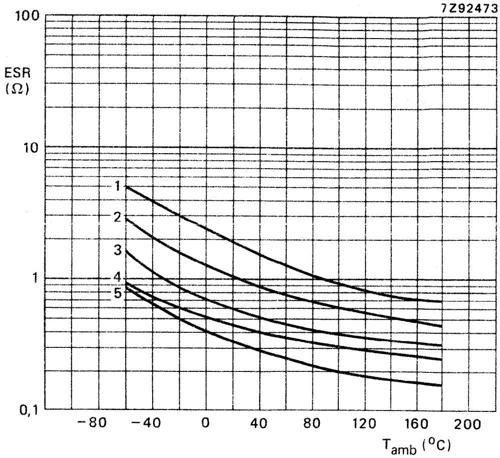


Fig. 12 Typical ESR as a function of ambient temperature at 100 Hz, **case size 6.**

Curve 1 = 100 μF, 40 V;
curve 2 = 150 μF, 35 V;
curve 3 = 220 μF, 25 V;
curve 4 = 470 μF, 16 V and 680 μF, 10 V;
curve 5 = 1000 μF, 6,3 V.

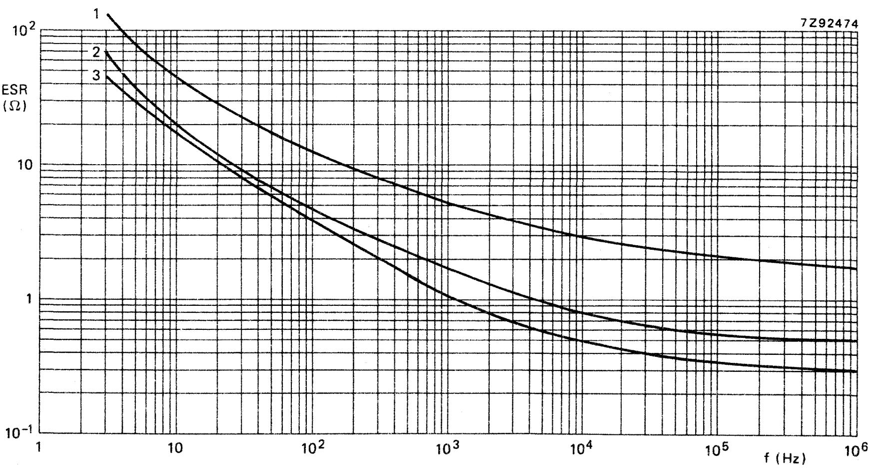


Fig. 13 Typical ESR as a function of frequency at T_{amb} = 25 °C, **case size 1.**

Curve 1 = 6,8 μF, 40 V and 10 μF, 25 V;
curve 2 = 22 μF, 16 V;
curve 3 = 33 μF, 10 V.

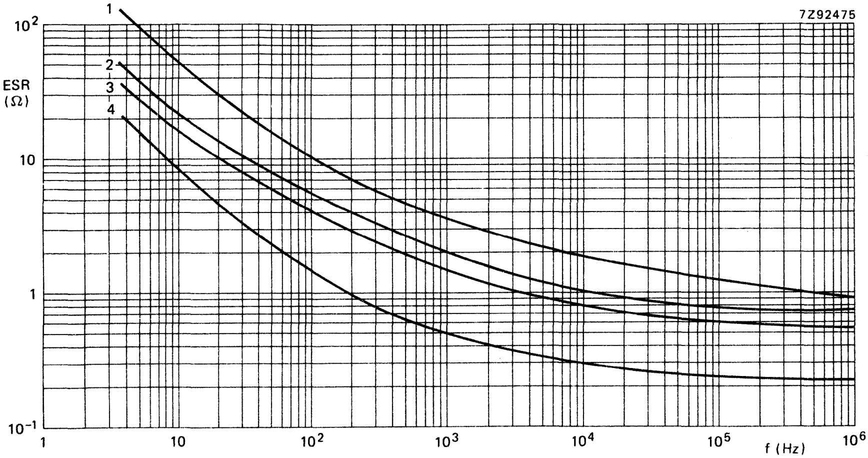


Fig. 14 Typical ESR as a function of frequency at T_{amb} = 25 °C, **case size 2A.**

Curve 1 = 10 μF, 40 V; curve 3 = 47 μF, 20 V and 68 μF, 10 V;
curve 2 = 33 μF, 25 V; curve 4 = 150 μF, 6,3 V.

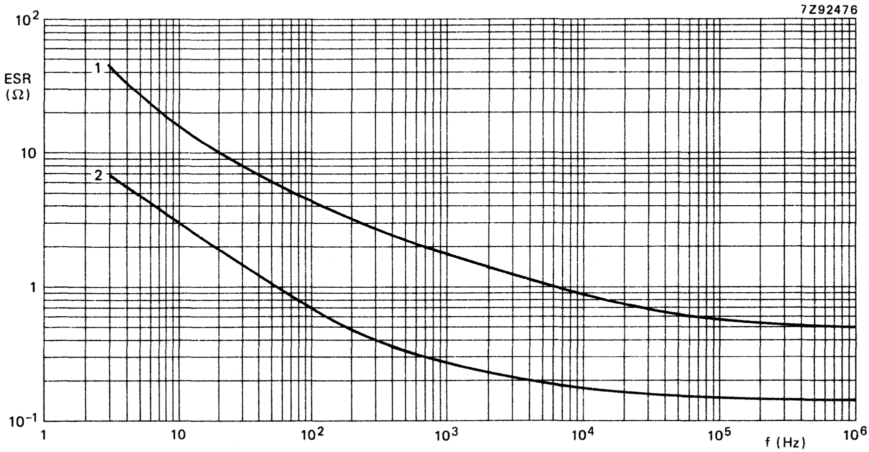


Fig. 15 Typical ESR as a function of frequency at T_{amb} = 25 °C, **case size 4.**

Curve 1 = 33 μF, 40 V; curve 2 = 220 μF, 10 V and 330 μF, 6,3 V.

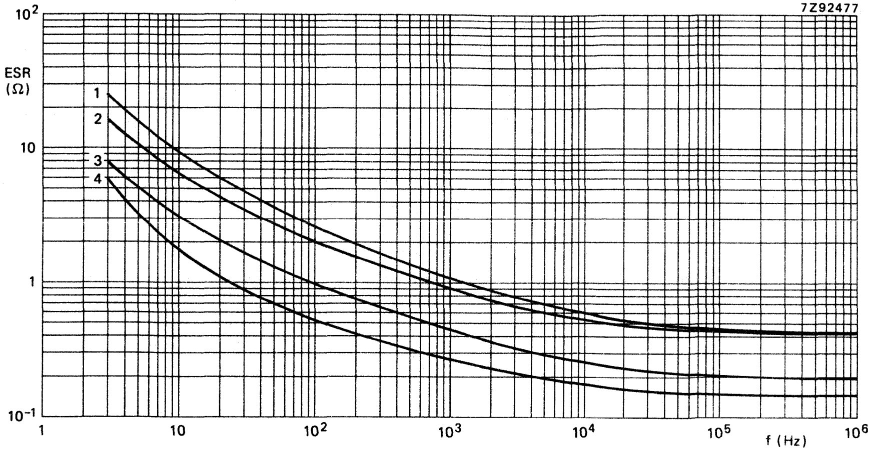


Fig. 16 Typical ESR as a function of frequency at T_{amb} = 25 °C, **case size 5.**

Curve 1 = 68 μF, 40 V;
curve 2 = 100 μF, 25 V;
curve 3 = 150 μF, 20 V;
curve 4 = 330 μF, 10 V and 470 μF, 10 V.

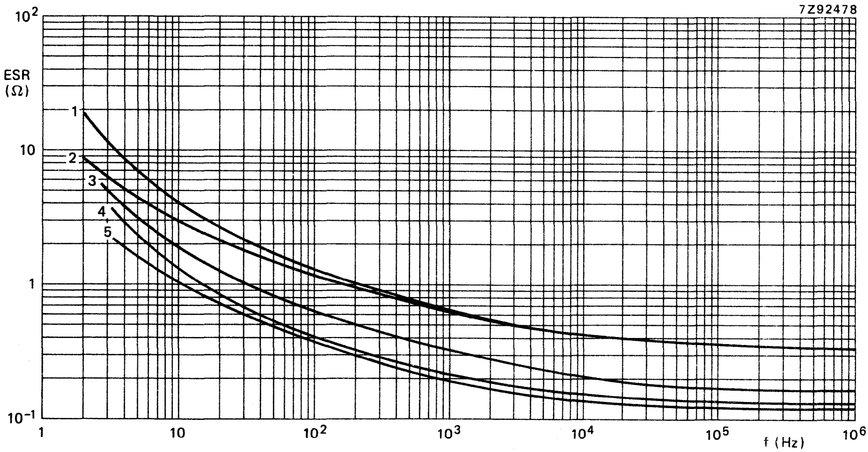


Fig. 17 Typical ESR as a function of frequency at T_{amb} = 25 °C, **case size 6.**

Curve 1 = 100 μF, 40 V;
curve 2 = 150 μF, 35 V;
curve 3 = 220 μF, 25 V;
curve 4 = 470 μF, 16 V and 680 μF, 10 V;
curve 5 = 1000 μF, 6,3 V.

Impedance

Maximum impedance at 100 kHz and T_{amb} = 25 °C, measured by means of a four-terminal circuit (Thomson circuit)	see Table 2
Typical impedance at 100 kHz, and T_{amb} = 25 °C	0,5 x value stated in Table 2

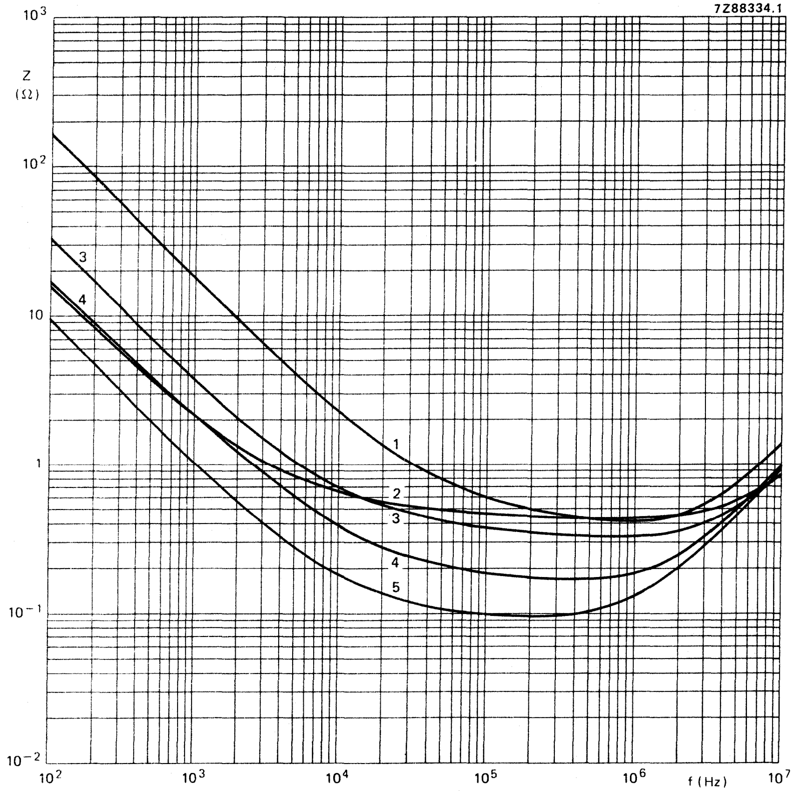


Fig. 18 Typical impedance as a function of frequency at T_{amb} = 25 °C.

Curve 1 = case size 1, 10 μF, 20 V;
curve 2 = case size 2A, 100 μF, 10 V;
curve 3 = case size 2A, 47 μF, 20 V;
curve 4 = case size 4, 100 μF, 20 V;
curve 5 = case size 5, 150 μF, 20 V and case size 6, 150 μF, 35 V.

Equivalent series inductance (ESL)

Equivalent series inductance, measured by means of a four-terminal circuit (Thomson circuit), at 10 MHz; the capacitor leads bent to the pitch as indicated

	pitch	max. ESL	typ. ESL
case size 1	20,3 mm	35 nH	18 to 28 nH
case size 2A	25,4 mm	35 nH	18 to 28 nH
case size 4	27,9 mm	40 nH	23 to 33 nH
case size 5	35,6 mm	40 nH	24 to 34 nH
case size 6	35,6 mm	55 nH	37 to 47 nH

OPERATIONAL DATA

Category temperature range	−55 to + 125 °C
Usable temperature range	−80 to + 175 °C
Typical life time at T_{amb} = 125 °C and U_R	> 20 000 h
Field failure rate	$< 1 \times 10^{-9}$/h

PACKING

Capacitors of style 1 are supplied in boxes, those of style 2 are on bandoliers on reels. The number of capacitors per box or per reel is shown in Table 7.

Table 7

case size	number of capacitors	
	style 1 per box	style 2 per reel
1	100	1000
2A	100	1000
4	100	500
5	100	500
6	100	400

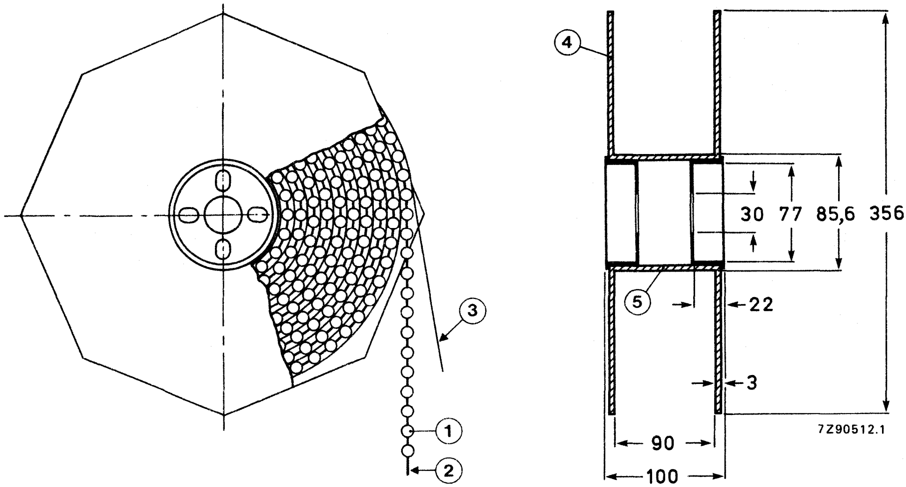


Fig. 19 Style 2 capacitors on bandoliers on reel.

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

TESTS AND REQUIREMENTS

See Introduction, section 9, under solid aluminium capacitors, with the addition of the following tests.

Severe rapid change of temperature test: 100 cycles of 15 min at −40 °C and + 125 °C.

Requirements: leakage current ⩽ stated limit,
tan δ ⩽ 1,6 x stated limit,
impedance ⩽ 1,6 x stated limit,
ΔC/C ⩽ 10%.

Severe shock test (for epoxy-filled version only): 10 000g, 0,1 ms.

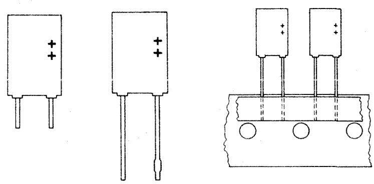
Requirements: leakage current ⩽ stated limit,
tan δ ⩽ 1,2 x stated limit,
ΔC/C ⩽ 10%,
typical capability ⩾ 100 000g.

Severe vibration test (for epoxy-filled version only): 50 to 2000 Hz, 50g, 125 °C, 1 octave/min, 2 directions (longitudinal and transversal), 3 sweeps per direction.

Requirements: leakage current ⩽ stated limit,
tan δ ⩽ 1,2 x stated limit,
ΔC/C ⩽ 10%,
typical capability: up to 80g (also at 125 °C).

SOLID ALUMINIUM CAPACITORS

- **Miniature type**
- **Single ended**
- **Epoxy potted**
- **Long life**
- **General and industrial applications**



QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	0,1 to 68 μF
Tolerance on nominal capacitance	± 20% (± 10% to special order)
Rated voltage range, U_R (R5 series)	6,3 to 40 V
Category temperature range	−55 to + 85 °C
Endurance test at 85 °C	5000 h
Basic specification	IEC 384-4, long-life grade
Climatic category, IEC 68	55/085/56

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					1
0,68					1
1				1	2
1,5				1	2
2,2				1	2
3,3				1	
4,7			1	2	
6,8			1	2	
10		1	2	2*	
15		1	2		
22	1	2			
33		2			
47	2				
68	2				

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

* Available to special order.

APPLICATION

These capacitors are for filtering, smoothing, coupling and decoupling purposes in general and industrial applications. They 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. Thanks to the potted execution they are particularly suited to withstand severe shock and vibration tests.

DESCRIPTION

The capacitor is of a construction with a highly etched aluminium plate anode, aluminium oxide as a dielectric and a solid cathode. The capacitor is potted with epoxy resin in a blue case.

The capacitor is available in three styles:

style 1 : with short wires;
style 2 : with long wires of which the anode wire has a flattened area at the end;
style 3*: with long wires (without flattened area) on tape on reel, positive leading.

MECHANICAL DATA

Dimensions in mm

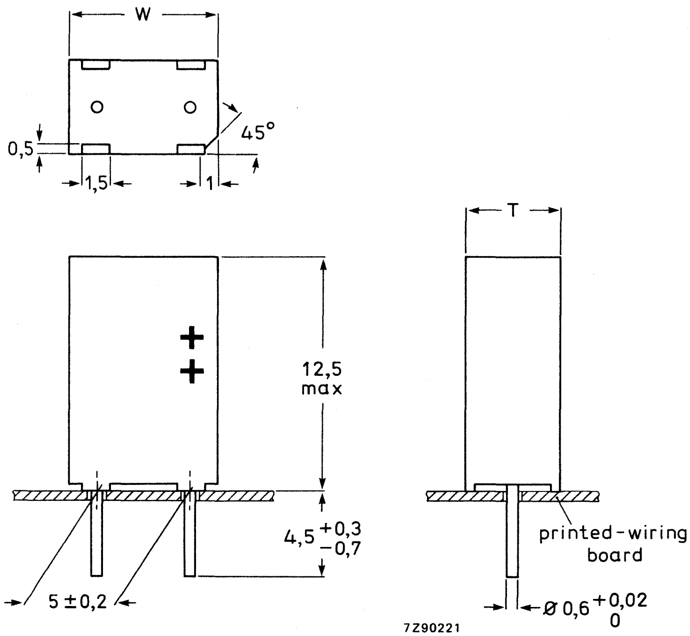


Fig. 1 Style 1; see Table 1a for dimensions T and W.

* Under consideration

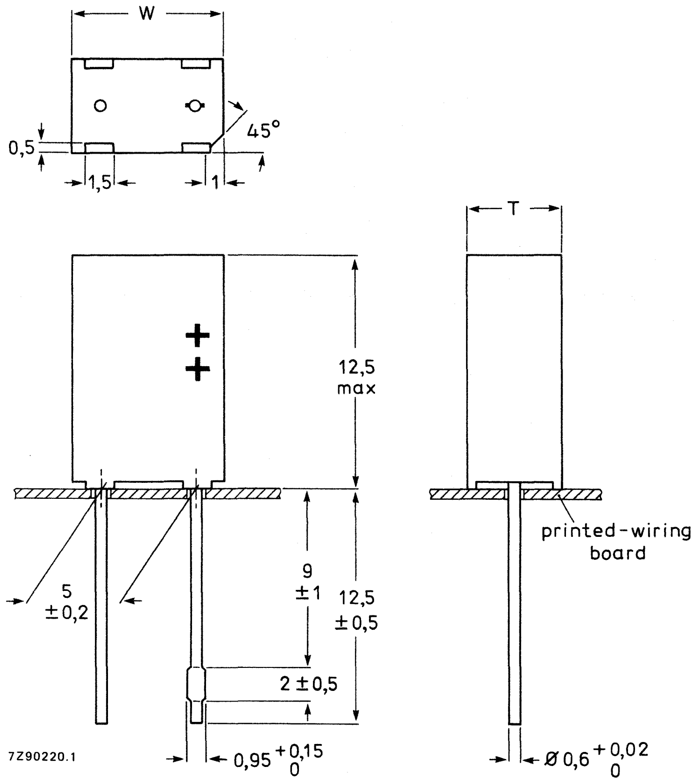
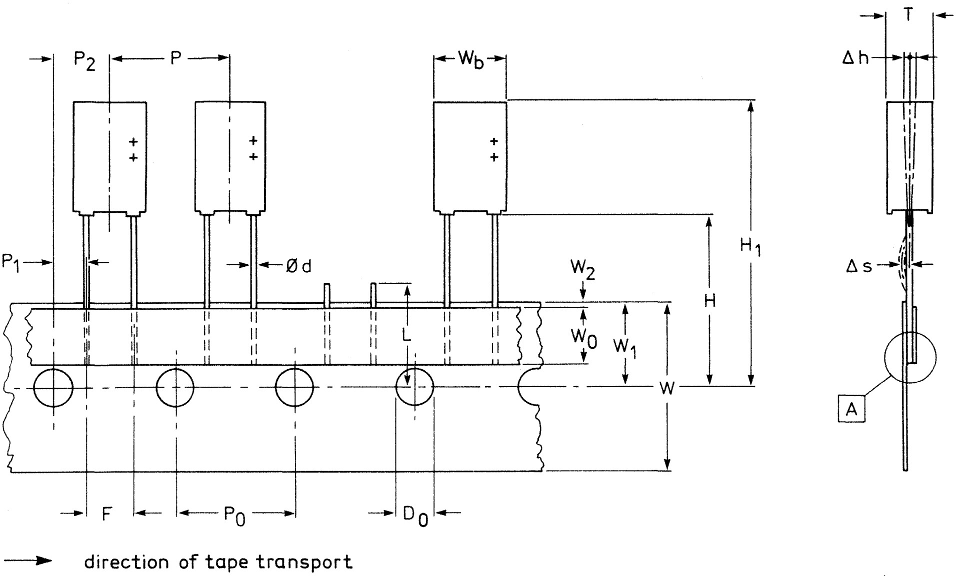


Fig. 2 Style 2; see Table 1a for dimensions T and W.

DEVELOPMENT SAMPLE DATA

Table 1a

case size	T_{max}	W_{max}	mass g
1	4,5	8,5	0,4
2	6	8,5	0,7



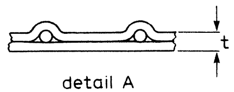


Fig. 3 Style 3*; see Table 1b for dimensions.

Table 1b

	symbol	value	tolerance	remarks
Body thickness	T	4,5-6	max.	for case sizes 1 and 2 resp.
Body width	W_b	8	max.	
Component alignment	Δh	0	± 1	
Lead-wire diameter	d	0,6	+ 0,02/–0	
Lead straightness	Δs	0	± 0,5	
Length of snipped leads	L	11	max.	
Lead-to-lead distance	F	5	+ 0,4/–0,2	
Pitch of components	P	12,7	± 1	
Feed-hole pitch	P_0	12,7	± 0,2	**
Feed-hole centre to lead	P_1	3,85	± 0,5	
Feed-hole centre to component centre	P_2	6,35	± 1	
Feed-hole diameter	D_0	4	± 0,2	
Height of component from tape centre	H	18,5	± 0,5	
Component height	H_1	32	max.	
Tape width	W	18	± 0,5	
Hold-down tape width	W_0	6	± 0,5	Feed hole shall be free
Hole position	W_1	9	+ 0,5/–0,2	
Hold-down tape position	W_2	0,5	+ 0,5/–0,2	
Total tape thickness	t	0,9	max.	

* Under consideration.

** Cumulative pitch error: ± 0,5 mm/4 pitches, and ± 1 mm/20 pitches.

Marking

The capacitors are marked with: 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.

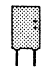
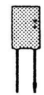
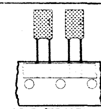
Mounting

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

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%. See also the corresponding paragraphs.

Table 2

U_R	nom. cap.	max. r.m.s. ripple current at T_{amb} = 85 °C*	max. leakage current (μA)** at U_R after		max. tan δ	max. ESR	max. impedance at 100 kHz**	case size	catalogue number 2222 124 followed by		
											
V	μF	mA	15 s	1 min		Ω	Ω		style 1	style 2	style 3▲
6,3	22	60	3,5	1,4	0,15	14	1,3	1	53229	73229	23229
	47	95	7,4	3,0	0,15	6,4	0,7	2	53479	73479	23479
	68	115	10,7	4,3	0,15	4,4	0,5	2	53689	73689	23689
10	10	40	2,5	1,0	0,15	30	1,5	1	54109	74109	24109
	15	50	3,8	1,5	0,15	20	1	1	54159	74159	24159
	22	60	5,5	2,2	0,15	14	0,7	2	54229	74229	24229
	33	80	8,3	3,3	0,15	9	0,5	2	54339	74339	24339
16	4,7	35	1,9	0,8	0,10	43	2	1	55478	75478	25478
	6,8	40	2,7	1,1	0,10	29,5	1,5	1	55688	75688	25688
	10	50	4,0	1,6	0,10	20	1	2	55109	75109	25109
	15	65	6,0	2,4	0,10	13,5	0,7	2	55159	75159	25159
25	1	16	1,0	0,4	0,10	200	20	1	56108	76108	26108
	1,5	20	1,0	0,4	0,10	135	15	1	56158	76158	26158
	2,2	25	1,4	0,6	0,10	91	10	1	56228	76228	26228
	3,3	30	2,1	0,8	0,10	61	7	1	56338	76338	26338
	4,7	35	2,9	1,2	0,10	43	5	2	56478	76478	26478
	6,8	45	4,2	1,7	0,10	29,5	3	2	56688	76688	26688
	10▲▲	55	6,3	2,5	0,10	20	2	2			

* For calculation of the max. ripple current at these and other frequencies and temperatures, see paragraphs "Voltage" and "Ripple current".

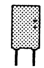
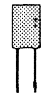
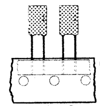
** Versions with lower values of max. leakage current or max. impedance are available to special order.

▲ Under consideration.

▲▲ Available to special order.

DEVELOPMENT SAMPLE DATA

Table 2 (continued)

U_R	nom. cap.	max. r.m.s. ripple current at T_{amb} = 85 °C*	max. leakage current (μA)** at U_R after		max. tan δ	max. ESR	max. impedance at 100 kHz**	case size	catalogue number 2222 124 followed by		
											
V	μF	mA	15 s	1 min		Ω	Ω		style 1	style 2	style 3▲
40	0,1	5	1,0	0,4	0,10	1990	70	1	57107	77107	27107
	0,15	6	1,0	0,4	0,10	1330	50	1	57157	77157	27157
	0,22	8	1,0	0,4	0,10	910	30	1	57227	77227	27227
	0,33	10	1,0	0,4	0,10	610	30	1	57337	77337	27337
	0,47	12	1,0	0,4	0,10	430	20	1	57477	77477	27477
	0,68	14	1,0	0,4	0,10	295	15	1	57687	77687	27687
	1,0	16	1,0	0,4	0,10	200	10	2	57108	77108	27108
	1,5	20	1,5	0,6	0,10	135	7	2	57158	77158	27158
	2,2	25	2,2	0,9	0,10	91	5	2	57228	77228	27228

* For calculation of the max. ripple current at these and other frequencies and temperatures, see paragraphs "Voltage" and "Ripple current".
** Versions with lower values of max. leakage current or max. impedance are available to special order.
▲ Under consideration.

Capacitance

Nominal capacitance values at 100 Hz and T_{amb} = 25 °C	see Table 2
Tolerance on nominal capacitance at 100 Hz	± 20% (± 10% to special order)

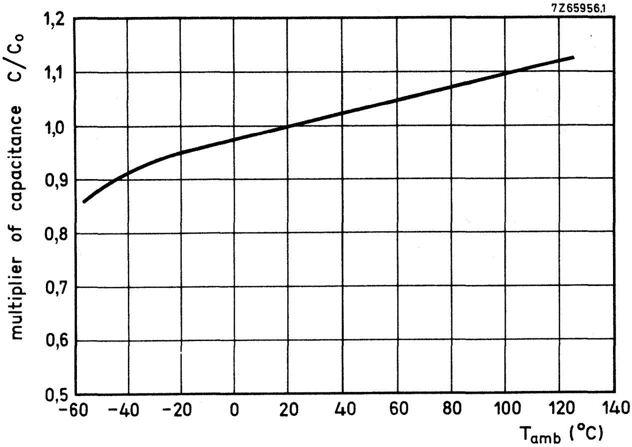


Fig. 4 Multiplier of capacitance as a function of temperature; C_o = capacitance at T_{amb} = 25 °C, 100 Hz.

Voltage

Rated voltage = max. permissible voltage at $T_{amb} \leqslant 85$ °C	U_R
Ripple voltage = max. permissible a.c. voltage providing the following four conditions are met:	
a) Max. a.c. voltage, with negative d.c. voltage applied	2 V
b) Max. peak a.c. voltage, without d.c. voltage applied	
at $f \leqslant 0{,}1$ Hz	0,30 x U_R
at 0,1 Hz $< f \leqslant$ 1 Hz	0,45 x U_R
at 1 Hz $< f \leqslant$ 10 Hz	0,60 x U_R
at 10 Hz $< f \leqslant$ 50 Hz	0,65 x U_R
at $f >$ 50 Hz	0,80 x U_R
c) Momentary value of applied voltage, with positive d.c. voltage applied	between U_R (in the positive half wave) and the limits mentioned under b) (in the negative half wave)

d) Ripple voltage limits are not applicable if the maximum ripple current is exceeded. In that case the ripple current is decisive. Whichever is in practice decisive, depends on the actual impedance of the capacitor. Table 3 should be considered as an aid only in establishing whether the ripple voltage or the ripple current is decisive.

Table 3

frequency	decisive factor
$f \leq 100$ Hz	voltage
100 Hz $< f \leq 1$ kHz	voltage, if actual capacitor impedance is high; current, if actual capacitor impedance is low
$f > 1$ kHz	current

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(see also Tests and requirements) — $0{,}30 \times U_R$

DEVELOPMENT SAMPLE DATA

Ripple current

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

Maximum permissible r.m.s. ripple current at other frequencies and temperatures — see Tables 4 and 5, and Fig. 5

Maximum permissible r.m.s. ripple current at 100 Hz and T_{amb} = 85 °C for capacitors with lower ESR value than the maximum ESR — $\sqrt{ESR_{max}/ESR_{actual}}$ x value stated in Table 2

Table 4 Temperature multiplier of ripple current ($\sqrt{k}$), at 100 Hz

T_{amb} °C	$\sqrt{k}$
25	2,2
30	2,15
35	2,1
40	2,05
45	2,0
50	1,9
55	1,8
60	1,7
65	1,6
70	1,45
75	1,35
80	1,2
85	1,0

Table 5 Frequency multiplier of ripple current ($\sqrt{r}$) at 25 °C

frequency kHz	$\sqrt{r}$
0,05	0,8
0,1	1,0
0,2	1,2
0,5	1,4
1	1,55
2	1,70
5	1,80
10	1,95
20	2,05
50	2,15
100	2,20
200	2,25
500	2,30
1000	2,35

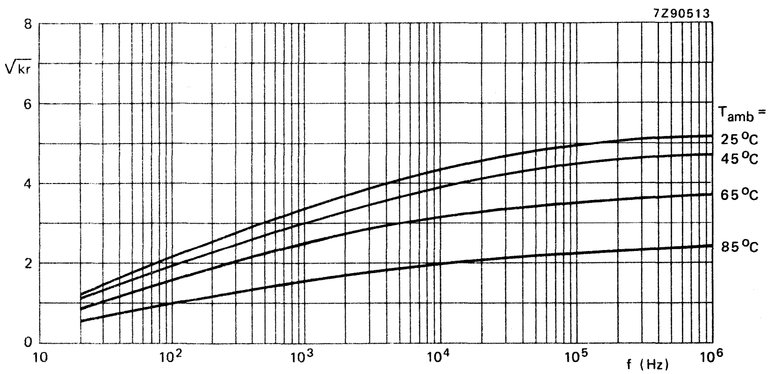


Fig. 5 Combined temperature/frequency multiplier of ripple current ($\sqrt{kr}$) as a function of frequency. $I_{r\,max} = I_{r0}\sqrt{kr}$.

Note: Neither the maximum permissible ripple current nor the maximum permissible ripple voltage values are to be exceeded. Refer to Table 3 (paragraph "Voltage") to find whichever factor will be decisive.

Calculation of ripple currents

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 and 85 °C (see Table 2);

$\sqrt{k}$ = temperature multiplier (neglecting the frequency dependence) = $\sqrt{P_{max}/P_{85}}$;

$\sqrt{r}$ = frequency multiplier (neglecting the temperature dependence) = $\sqrt{ESR_{100}/ESR_{max}}$;

(for $\sqrt{k}$ and $\sqrt{r}$, see Tables 4 and 5, for $\sqrt{kr}$, see Fig. 5);

while P_{max} = max. permissible power dissipation, temperature dependent;

P_{85} = max. permissible power dissipation at 85 °C = $I^2_{r0}\,ESR_{100}$;

ESR_{max} = max. equivalent series resistance, frequency dependent;

ESR_{100} = max. equivalent series resistance at 100 Hz.

The formula is derived for any temperature and frequency as follows:

$$I^2_{r\,max} = P_{max}/ESR_{max}$$
$$= kr\,P_{85}/ESR_{100}$$
$$= kr\,I^2_{r0}\,ESR_{100}/ESR_{100}$$

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

The values of the temperature multiplier $\sqrt{k}$ and of P_{85} have been calculated allowing a capacitor temperature of 98 °C and assuming the values of ESR_{max} at 98 °C to be 0,8 times the ESR_{max} at 25 °C at all frequencies.

The values of the frequency multiplier $\sqrt{r}$ have been measured at 25 °C assuming it to be the same at all temperatures.

The power dissipation (P_{max}) has been calculated assuming it to be governed by the simplified relation:

$P_{max} = \beta \times S \times \Delta T$,

where β = heat transfer coefficient, taken as 18 W/m²K (capacitor mounted on a thermally well-conducting printed-circuit board, in free flowing air, the board being in vertical position);

S = capacitor outer surface;

ΔT = temperature difference between capacitor surface and the ambient atmosphere, taken as 13 °C at T_{amb} = 85 °C.

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.

DEVELOPMENT SAMPLE DATA

Leakage current

Maximum leakage current 15 s after application of U_R, at T_{amb} = 25 °C	see Table 2 (0,025 CU or 1 μA whichever is greater)
Maximum leakage current 1 min after application of U_R, at T_{amb} = 25 °C	see Table 2 (0,01 CU or 0,4 μA whichever is greater)
Leakage current during continuous operation at U_R	
at T_{amb} = 25 °C	approx. 0,05 x 15 s-value stated in Table 2
at T_{amb} = 85 °C	approx. 0,25 x 15 s-value stated in Table 2

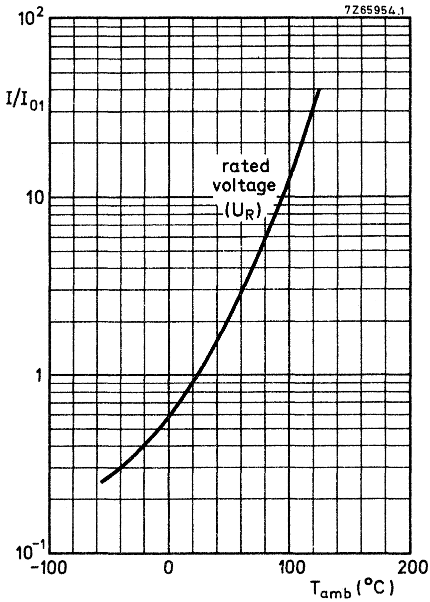


Fig. 6 Multiplier I/I_{01} as a function of ambient temperature; I_{01} = leakage current during continuous operation at U_R, T_{amb} = 25 °C.

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

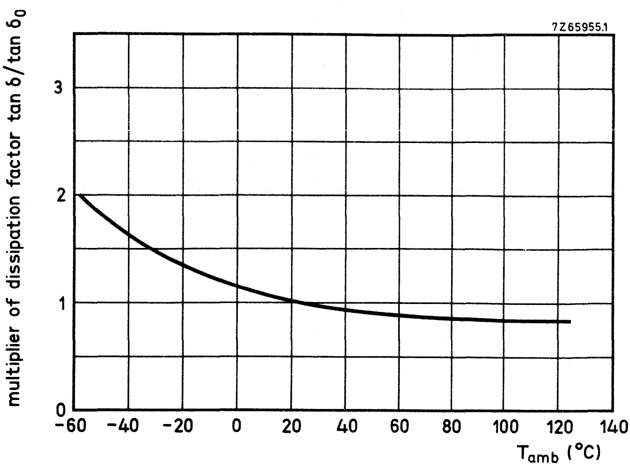


Fig. 7 Typical multiplier of dissipation factor as a function of temperature; tan δ_0 = dissipation factor at T_{amb} = 25 °C, 100 Hz.

DEVELOPMENT SAMPLE DATA

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

Maximum ESR at 100 Hz and T_{amb} = 25 °C (calculated from maximum tan δ and 0,8 x nominal capacitance) — see Table 2

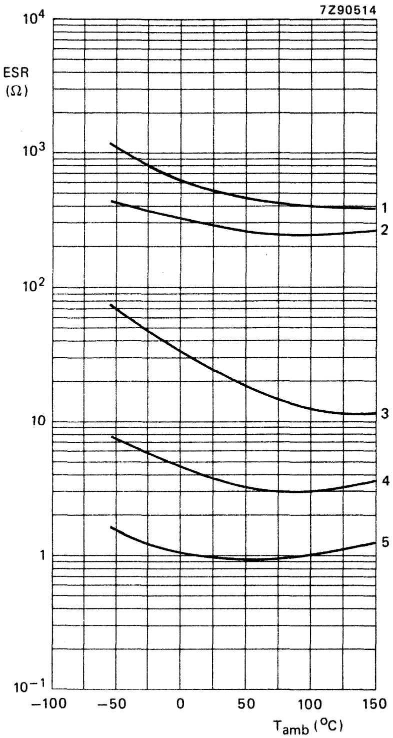


Fig. 8 Typical ESR as a function of ambient temperature at 100 Hz.

Curve 1 = 0,1 μF, 40 V;
curve 2 = 1,5 μF, 40 V;
curve 3 = 3,3 μF, 25 V;
curve 4 = 22 μF, 10 V;
curve 5 = 68 μF, 6,3 V.

DEVELOPMENT SAMPLE DATA

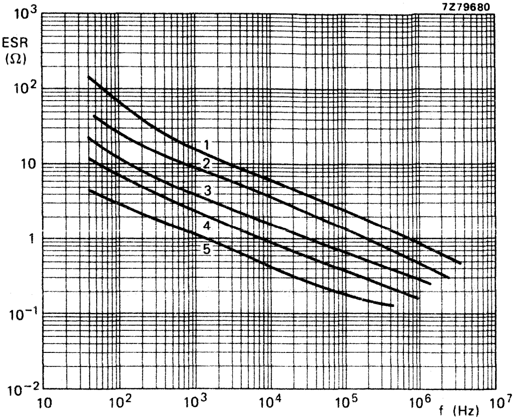


Fig. 9 Typical ESR as a function of frequency at T_{amb} = 25 °C; **case size 1.**

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.

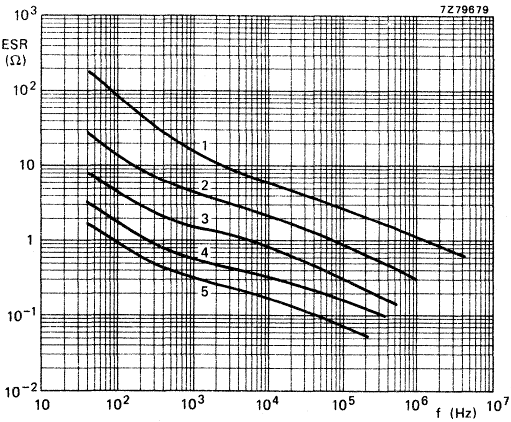


Fig. 10 Typical ESR as a function of frequency at T_{amb} = 25 °C; **case size 2.**

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.

Impedance

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

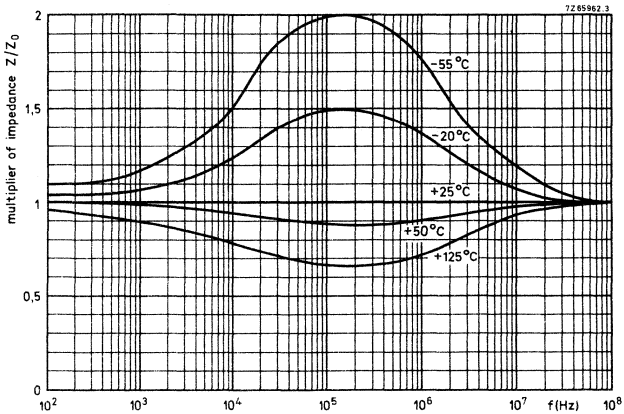


Fig. 11 Typical multiplier of impedance Z/Z_0 as a function of frequency at different temperatures; Z_0 = impedance initial value at T_{amb} = 25 °C.

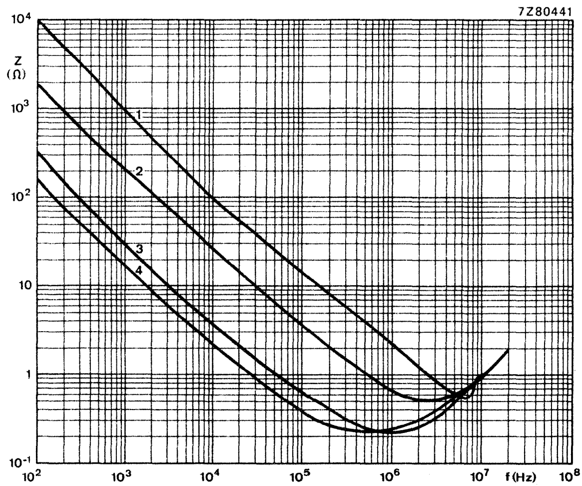


Fig. 12 Typical impedance as a function of frequency at T_{amb} = 25 °C, **case size 1.**

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.

DEVELOPMENT SAMPLE DATA

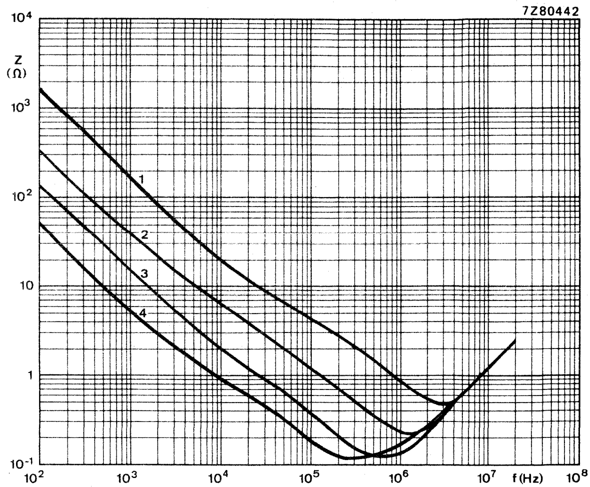


Fig. 13 Typical impedance as a function of frequency at T_{amb} = 25 °C; **case size 2.**

Curve 1 = 1 μF, 40 V;
curve 2 = 4,7 μF, 25 V;
curve 3 = 10 μF, 16 V;
curve 4 = 47 μF, 6,3 V.

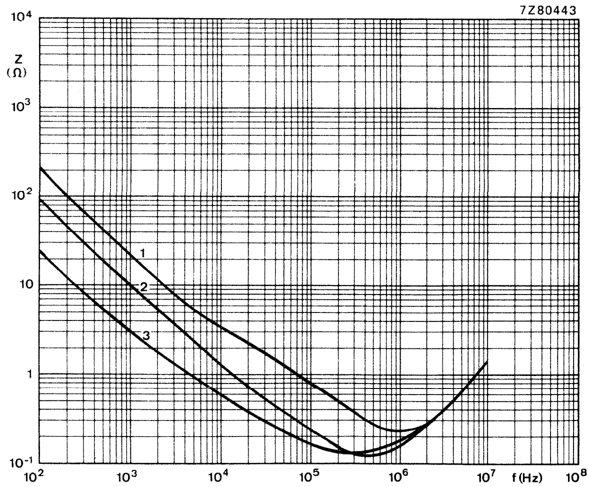


Fig. 14 Typical impedance as a function of frequency at T_{amb} = 25 °C; **case size 2.**

Curve 1 = 6,8 μF, 25 V;
curve 2 = 15 μF, 16 V;
curve 3 = 68 μF, 6,3 V.

Equivalent series inductance (ESL)

Equivalent series inductance, measured by means of a four-terminal circuit (Thomson circuit), at 10 MHz	max. 20 nH; typ. 9 to 16 nH

OPERATIONAL DATA

Category temperature range	−55 to + 85 °C
Typical life time at T_{amb} = 85 °C	> 20 000 h

PACKING

Capacitors of styles 1 and 2 are supplied in boxes, those of style 3 on tape on reel.
The number of capacitors per box or per reel is:

styles 1 and 2, case size 1: 500 capacitors per box; 100 per plastic bag, 5 bags per box;
styles 1 and 2, case size 2: 400 capacitors per box; 100 per plastic bag, 4 bags per box;
style 3, all case sizes : 1000 capacitors per reel.

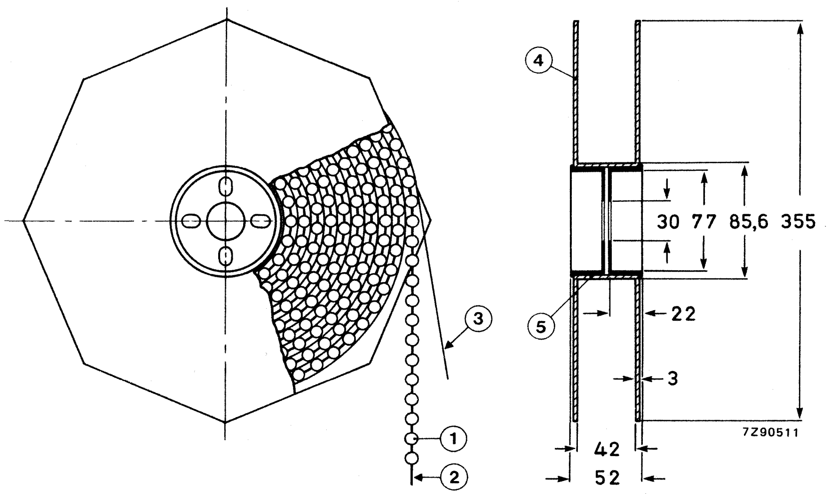


Fig. 15 Style 3 capacitors on tape on reel.
1 = capacitor
2 = tape
3 = paper
4 = flange
5 = cylinder

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 °C);
- calgonite solution (20 g/l, 70 ± 5 °C);
- mixture of 4,5% 2-butoxyethanol, 4,5% 2-amino-ethanol, and 91% water (70 ± 5 °C);
- 1.1.1. trichloro-ethane;
- mixtures of 1.1.2-trichloro-1.2.2-trifluoro-ethane (fluorocarbon 113) and the following solvents in the respective mass percentage ratios of these solvents to fluorocarbon:
  - 2-propanol (isopropanol), 25%: 75% (Arklone K*); up to the ratio 35%: 65%;
  - dichloromethane (methylene chloride), 49,5%: 50,5% (Freon TMC**);
  - ethanol, 4,5%: 95,5% (e.g. Arklone A*, Freon TE**);
  - methanol and nitromethane, (5,7%: 0,3%: 94% (Freon TMS**).

Requirement: visual appearance not affected.

Note: Tests are carried out using non-contaminated solvents.

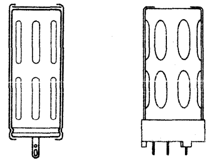
DEVELOPMENT SAMPLE DATA

* Trade mark of I.C.I.

** Trade mark of Dupont de Nemours.

MAINTENANCE TYPES

ALUMINIUM ELECTROLYTIC CAPACITORS



- **Large type**
- **Long life**
- **Industrial applications**

QUICK REFERENCE DATA

Nominal capacitance range (E6 series)	680 to 22 000 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
2200				5	6	8
3300			5	6	7/8a	9
4700		5	6	7/8a	8	10
6800		6	7/8a	8/9a	9	
10 000	6	7	8	9	10	
15 000			9	10		
22 000	9a		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	
9a		φ 35 x 55,8
9	φ 35 x 80	φ 35 x 84,7
10	φ 40 x 80	

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.

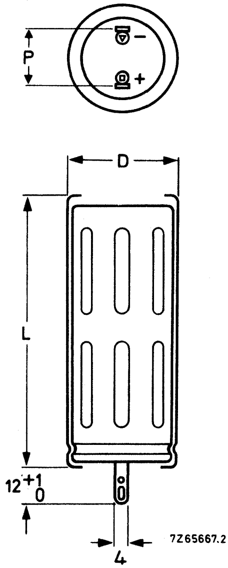
DESCRIPTION

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



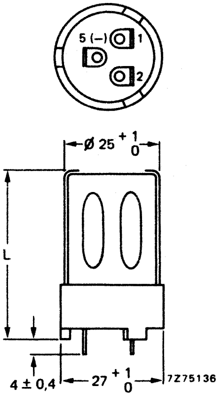
See Table 1 for dimensions D, L and P.

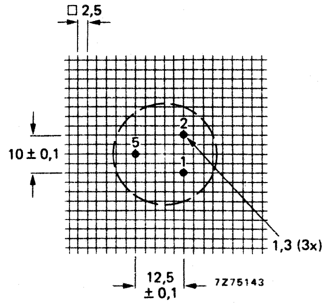
Table 1

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
9	35		80		19		100
10	40		80		19		130

* P at emergence of terminals.

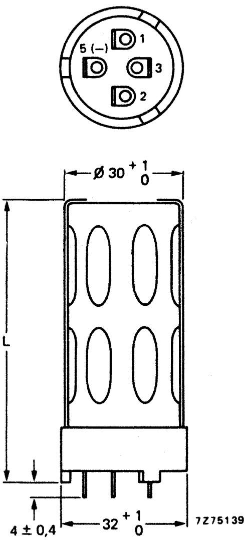
Capacitors with printed-wiring pins

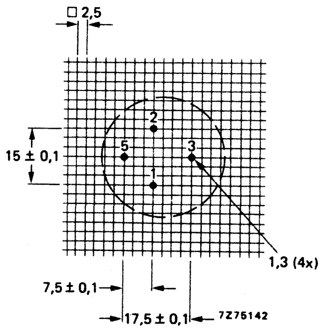




Piercing diagram viewed from component side.

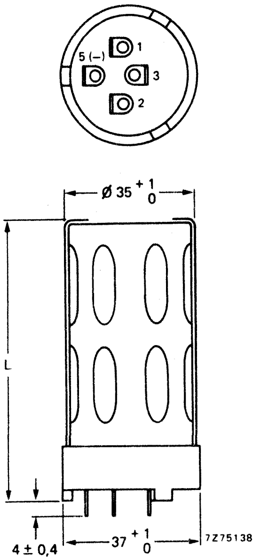
case size	L	mass approx. g
6	55,5 ± 0,8	30

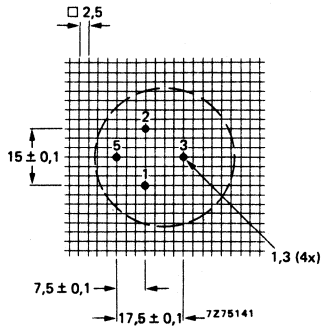




Piercing diagram viewed from component side.

case size	L	mass approx. g
8a	55,8 ± 0,8	40





Piercing diagram viewed from component side.

case size	L	mass approx. g
9a 9	55,8 ± 0,8 84,7 ± 0,8	60 100

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

WARNING

Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled. Caution is necessary should the outer case be fractured.

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 86 to 106 kPa and a relative humidity of 45 to 75%.

Table 2a Capacitors with solder tags

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
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
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
	10000	3,5	960	0,25	50	8	071 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
	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
	4700	3,1	1130	0,15	80	8	071 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
	2200	2,6	835	0,10	80	8	071 18222
	3300	3,5	1250	0,10	40	9	071 18332
	4700	4,5	1780	0,10	40	10	071 18472

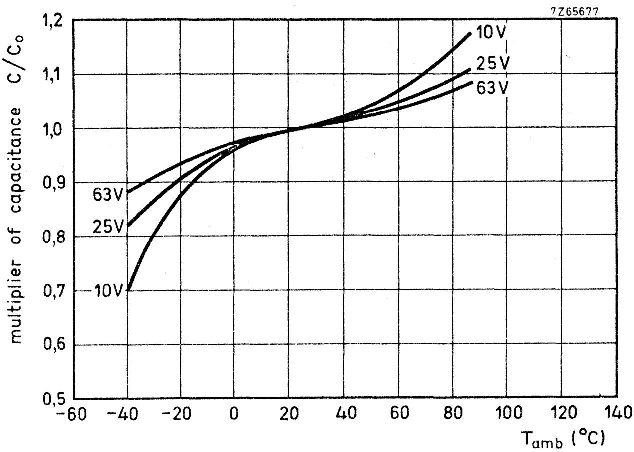
Table 2b Capacitors with printed-wiring pins

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	22000	3,3	840	0,50	30	9a	073 53223
10	6800	1,8	410	0,35	60	6	071 54682
16	4700	1,7	450	0,25	60	6	071 55472
	6800	2,4	655	0,25	50	8a	073 55682
25	6800	2,9	1020	0,20	30	9a	073 56682
	10000	4,3	1500	0,20	25	9	071 56103
40	3300	1,7	795	0,15	80	8a	073 57332

* 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.

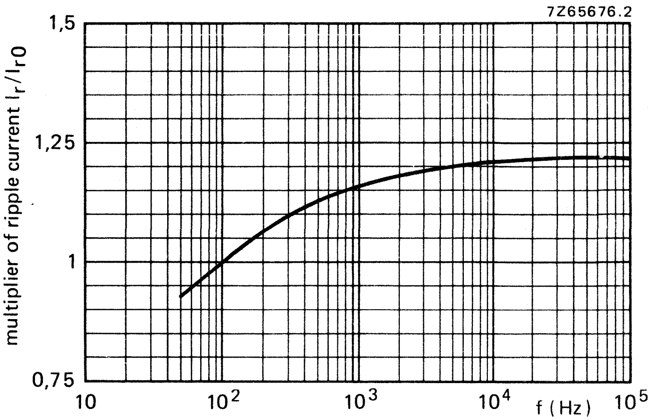
Voltage

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 $T_{amb} \leqslant$ 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	⩽ 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

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

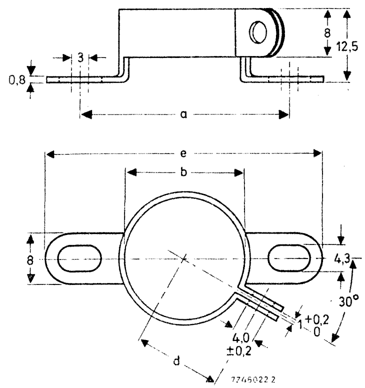
See Introduction, section 9, under aluminium electrolytic capacitors.

Note: Capacitors 2222 071 and 2222 073 are large types, long-life grade.

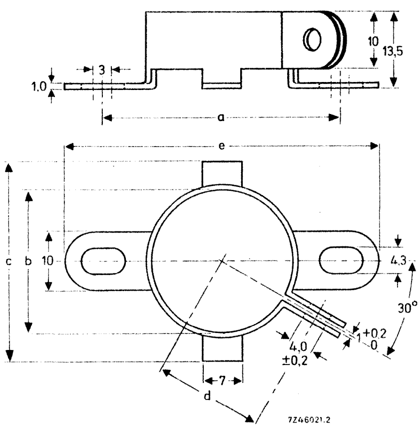
MOUNTING ACCESSORIES

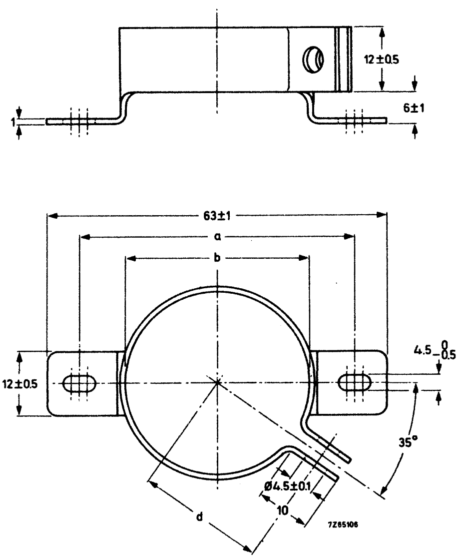
Clamps

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.





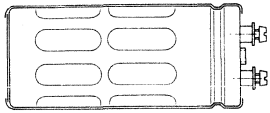
For case sizes 6, 7, 8, 8a and 10.

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:

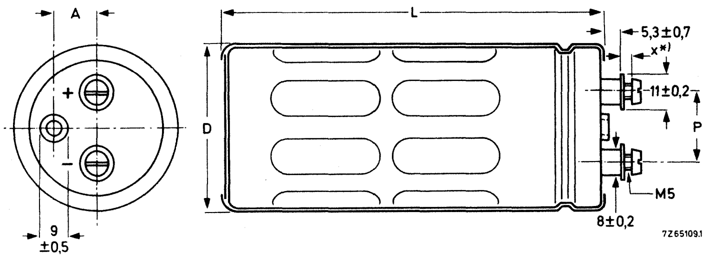
- switched-mode power supplies;
- power supplies in digital equipment;
- energy storage in pulse systems;
- filters in measuring and control apparatus.

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	approx. mass (g)
11	35	80	15	8,4	105
12	35	112	15	8,4	140
14	50	80	22	14,3	200
15	50	112	22	14,3	280
16	65	112	31	19,0	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 vertically or horizontally, with or without mounting clamp. For proper functioning the vent should be on the upper side, whether the capacitor is mounted horizontally or vertically. When a number of capacitors are connected in a bank, they must not be closer 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

WARNING

Non-solid electrolytic capacitors may contain chemicals which can be regarded as hazardous if incorrectly handled. Caution is necessary should the outer case be fractured.

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%.

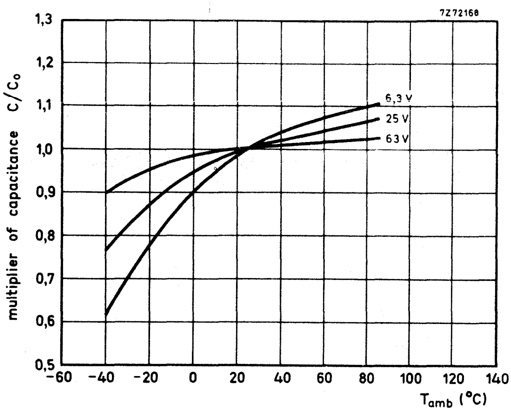
U_R (V)	nom. cap. (μF)	max. r.m.s. ripple current at T_{amb} = 85 °C (A) 1)	max. leakage current at U_R after 5 min (mA) 1)	typ. ESR (mΩ) 1)	max. tan δ 1)	impedance at 20 kHz (mΩ) 1) typ.	impedance at 20 kHz (mΩ) 1) max.	case size	catalogue number
6,3	22000	5,5	0,9	13,0	0,32	8,5	13,0	11	2222 106 33223
	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.

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 x 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 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 (see also "Tests and requirements") — 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 voltages are not applicable if the maximum permissible ripple current is exceeded. In that case the ripple current is decisive.

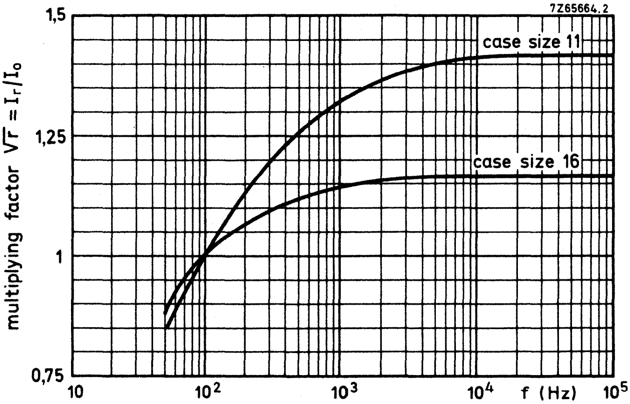
Ripple current

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

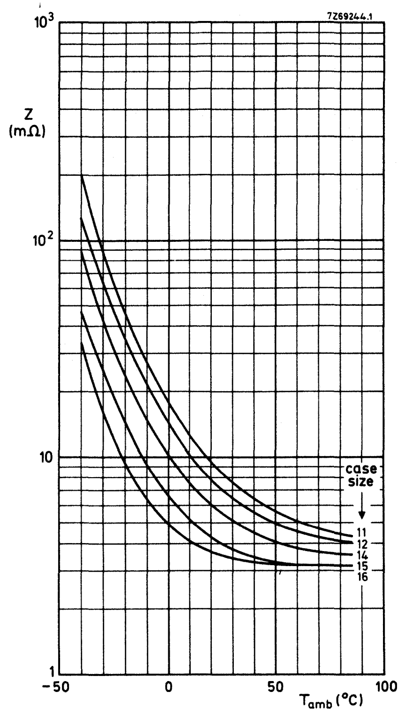
If owing to prolonged storage and/or storage at an excessive temperature the leakage current is too high, application of the rated voltage for some hours will cause the leakage current to fall to a value lower than specified in Table 2.

Tan δ (dissipation factor)

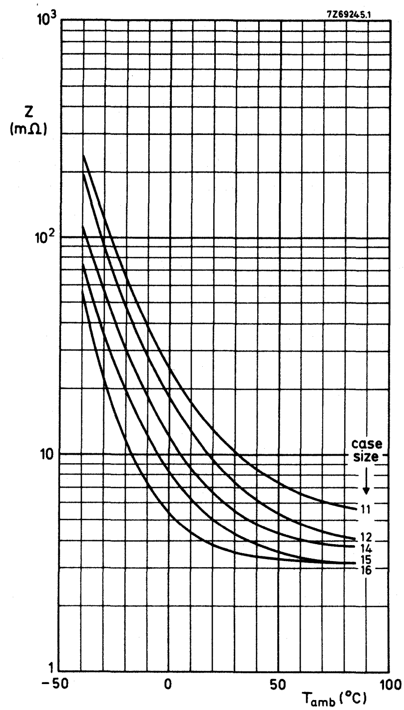
Tan δ at 100 Hz and T_{amb} = 25 °C, measured by means of a four-terminal circuit (Thomson circuit)	see Table 2

Impedance

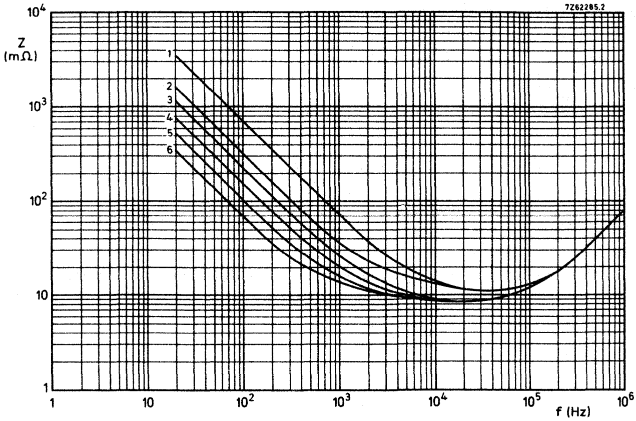
Impedance at 20 kHz and T_{amb} = 25 °C, measured by means of a four-terminal circuit (Thomson circuit)	see Table 2



Typical impedance as a function of temperature at 20 kHz for 6,3 V to 25 V types.



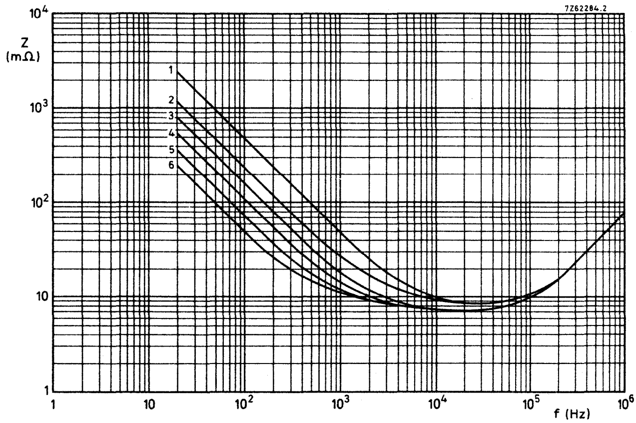
Typical impedance as a function of temperature at 20 kHz for 40 V and 63 V types.



Typical impedance as a function of frequency at T_{amb} = 25 °C.

case size 11

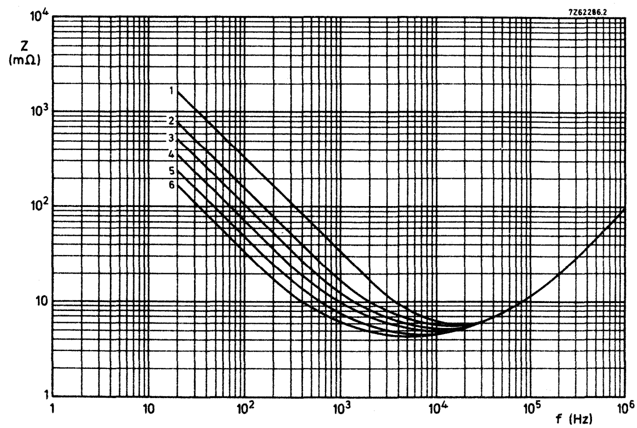
curve 1 = 2200 µF, 63 V
2 = 4700 µF, 40 V
3 = 6800 µF, 25 V
4 = 10 000 µF, 16 V
5 = 15 000 µF, 10 V
6 = 22 000 µF, 6,3 V



Typical impedance as a function of frequency at T_{amb} = 25 °C.

case size 12

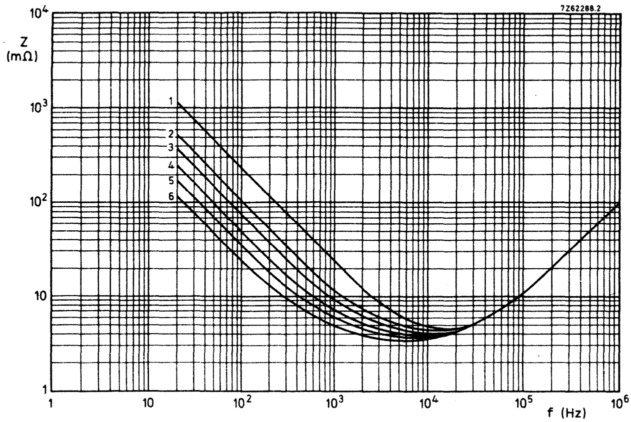
curve 1 = 3300 µF, 63 V
2 = 6800 µF, 40 V
3 = 10 000 µF, 25 V
4 = 15 000 µF, 16 V
5 = 22 000 µF, 10 V
6 = 33 000 µF, 6,3 V



Typical impedance as a function of frequency at T_{amb} = 25 °C.

case size 14

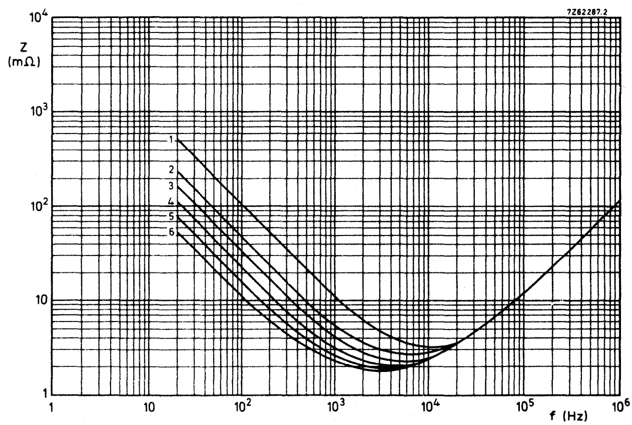
curve 1 = 4700 µF, 63 V
2 = 10 000 µF, 40 V
3 = 15 000 µF, 25 V
4 = 22 000 µF, 16 V
5 = 33 000 µF, 10 V
6 = 47 000 µF, 6,3 V



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



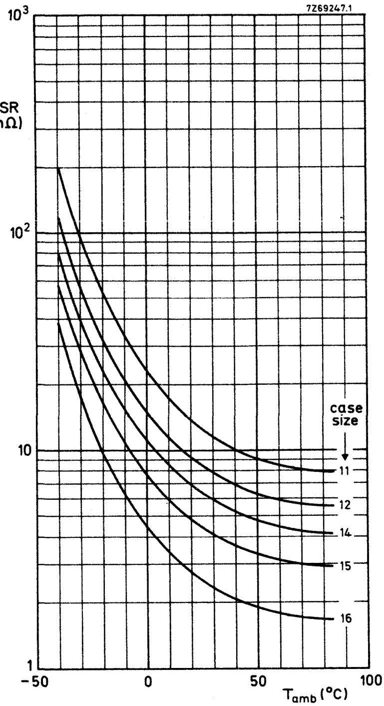
Typical impedance as a function of frequency at T_{amb} = 25 °C.

case size 16

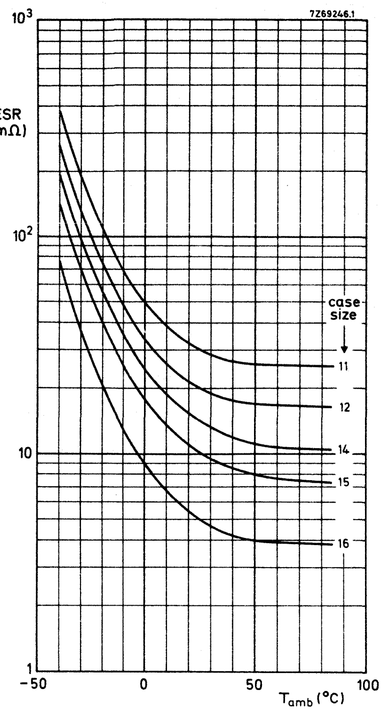
curve 1 = 15 000 μF, 63 V
2 = 33 000 μF, 40 V
3 = 47 000 μF, 25 V
4 = 68 000 μF, 16 V
5 = 100 000 μF, 10 V
6 = 150 000 μF, 6,3 V

Equivalent series resistance (ESR = tan δ/ωC)

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

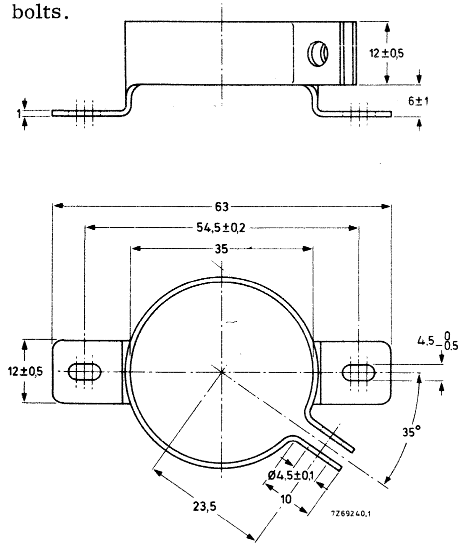
See Introduction, section 9, under aluminium electrolytic capacitors.

Note: Capacitors 2222 106 and 2222 107 belong to the large types with screw terminals, long-life grade.

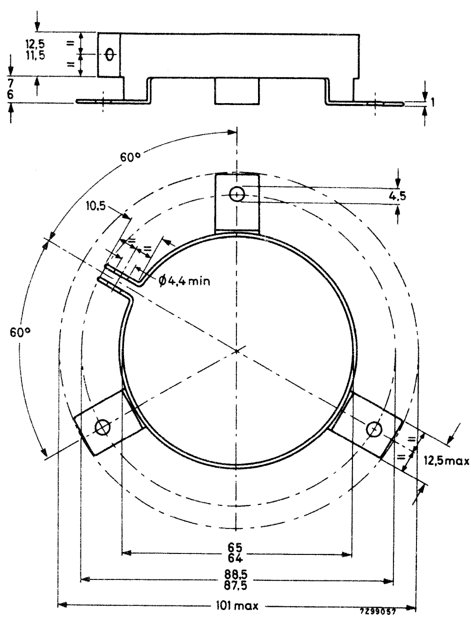
MOUNTING ACCESSORIES

Clamps

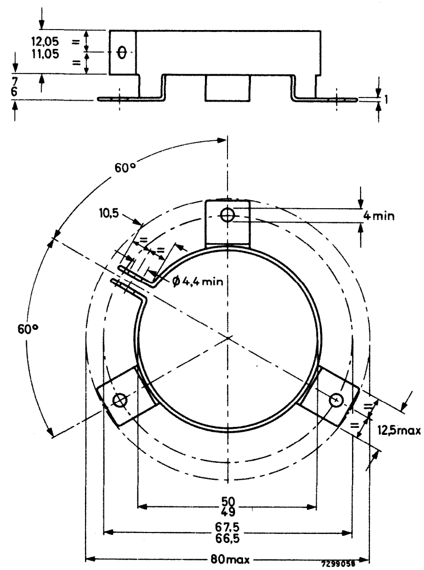
To facilitate vertical mounting, a series of rigid clamps made of cadmium-plated steel are available. They can easily be slid over the capacitor and then fixed to it with a nut and bolt. They are provided with two or three mounting lugs. Three types are available, one for each case diameter of the capacitor 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.

ELECTROLYTIC AND SOLID CAPACITORS

STANDARD SERIES OF VALUES IN A DECADE

for resistances and capacitances

according to IEC publication 63

E192	E96	E48	E192	E96	E48	E192	E96	E48	E192	E96	E48	E192	E96	E48
100	100	100	169	169	169	287	287	287	487	487	487	825	825	825
101			172			291			493			835		
102	102		174	174		294	294		499	499		845	845	
104			176			298			505			856		
105	105	105	178	178	178	301	301	301	511	511	511	866	866	866
106			180			305			517			876		
107	107		182	182		309	309		523	523		887	887	
109			184			312			530			898		
110	110	110	187	187	187	316	316	316	536	536	536	909	909	909
111			189			320			542			920		
113	113		191	191		324	324		549	549		931	931	
114			193			328			556			942		
115	115	115	196	196	196	332	332	332	562	562	562	953	953	953
117			198			336			569			965		
118	118		200	200		340	340		576	576		976	976	
120			203			344			583			988		
121	121	121	205	205	205	348	348	348	590	590	590			
123			208			352			597					
124	124		210	210		357	357		604	604				
126			213			361			612					
127	127	127	215	215	215	365	365	365	619	619	619			
129			218			370			626					
130	130		221	221		374	374		634	634				
132			223			379			642					
133	133	133	226	226	226	383	383	383	649	649	649			
135			229			388			657					
137	137		232	232		392	392		665	665				
138			234			397			673					
140	140	140	237	237	237	402	402	402	681	681	681			
142			240			407			690					
143	143		243	243		412	412		698	698				
145			246			417			706					
147	147	147	249	249	249	422	422	422	715	715	715			
149			252			427			723					
150	150		255	255		432	432		732	732				
152			258			437			741					
154	154	154	261	261	261	442	442	442	750	750	750			
156			264			448			759					
158	158		267	267		453	453		768	768				
160			271			459			777					
162	162	162	274	274	274	464	464	464	787	787	787			
164			277			470			796					
165	165		280	280		475	475		806	806				
167			284			481			816					

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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