Technical Information

Construction • Manufacturing process

Construction

An aluminium electrolytic capacitor consists of two electrically conductive aluminium layers, separated by a dielectric layer. One of the electrodes (the aluminium foil called anode) undergoes a process called 'forming', by which a dielectric layer of aluminium oxide (Al_2O_3) is electrochemically coated on it. The other electrode is a conductive liquid, called the electrolyte. The second aluminium foil, the cathode, acts as a large surfaced contact area for passing current to the electrolyte.

The basic principle of the capacitor is to store electrical charge and is defined as:

Q = CV

Q = charge in Coulombs
C = capacitance in Farads (between the plates)
V = potential difference between the plates

Based on the formula given above, it can be said that the unit of capacitance, the Farad, is the capacitance between the plates, across which appears a potential difference of 1 Volt when it is charged by 1 Coulomb of electricity.

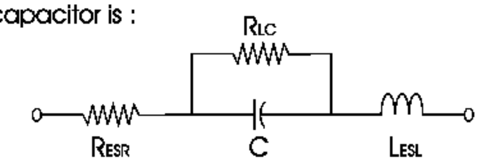
The value of capacitance in a capacitor is directly proportional to the area of the plates and is inversely proportional to the distance between them. Hence capacitance is expressed by the equation:

$$C = \epsilon_o . \epsilon_r . \frac{A}{d}$$

A = surface area of the plates in m^2
d = distance between the plates (or dielectric thickness)in metres
ϵ_o = permittivity of free space = 8.885×10^{-2} F/m
ϵ_r = relative permittivity of the dielectric (9.5 for Al_2O_3)

The surface area of the anode is enlarged (up to 200 times) by an electrochemical etching process. Similarly the cathode is also etched to increase the surface area. The thickness of the dielectric layer is very small (in microns) and increases in proportion to the forming voltage (approximately 1.2 nm/v), making the distance between the two plates very small. This construction of aluminium electrolytic capacitors allows for very high capacitance per unit area in comparison with capacitors which use other dielectric materials.

An equivalent circuit of an aluminium electrolytic capacitor is :



R_{ESR} = equivalent series resistance (ESR)
C = capacitance
R_{LC} = resistance due to leakage current
L_{ESL} = equivalent series inductance (ESL)

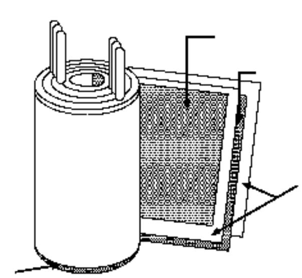
The capacitance of the anode foil will depend on the etching pattern and the forming voltage. The cathode foil is etched and has a thin oxide layer on it, which is caused due to atmospheric oxidation.

Manufacturing Process

The main stages of the manufacturing process are:

Etching → Forming
↓
Winding
↓
Impregnation
↓
Assembly
↓
Ageing
↓
Testing
↓
Sleeving
↓
Packing

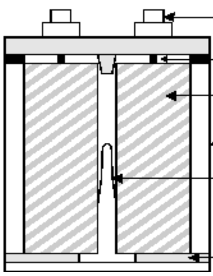
Super pure aluminium foil is etched to increase the surface area. The anode foil undergoes an electrochemical process called forming by which a dielectric layer is 'formed' on it. The anode and cathode are interleaved with support and/or absorbent papers and wound into a cylinder as shown in the fig. below. During winding, aluminium tabs are attached to the foils for electrical contacts by a cold welding process.



Technical Information

Manufacturing process • Electrical characteristics

The capacitor element is impregnated with an electrolyte, under vacuum. In the assembly process, terminals are riveted and/ or welded to the tabs and g housed in an aluminium can with or without anchorin material as shown:



Capacitors are then sealed and aged. The aging process repairs any damage to the oxide layer that may have been caused during the process of assembling the capacitor into the aluminium can. A thorough test is carried out for seepage by placing the capacitors in an oven. A visual check is carried out on each capacitor for any sign of electrolyte leakage.

Next, capacitors are tested for the following electrical parameters:

i) Capacitance ii) ESR
iii) Leakage current iv) Tan δ

The capacitors are then sleeved and packed. After completion of the production process, the company's Q.A. personnel carry out a sample test.

Electrical Characteristics

- **Rated voltage** : The rated voltage is the DC voltage for which the capacitor has been designed. The capacitors can be operated continuously at the full rated voltage within the operating temperature range.

- Surge voltage : The surge voltage is the maximum DC voltage that a capacitor can be subjected to, for a very short duration, not exceeding 30 seconds. This includes transients and peak ripple at the highest line voltage. Capacitors with surge voltage ratings higher than these specified are available as custom designed capacitors.

The capacitor will withstand a surge test (at 25°C to 30°C) of 1000 charge / discharge cycles. Each "charge"cycle will surge voltage for a maximum of 30 seconds, thereafter capacitor will then kept for discharge mode through a 1000 ohm resistor for 5 minutes and 30 second.

- **Ripple voltage** : The ripple voltage is the superimposed AC voltage that may be applied to the capacitor provided that:
  i) the sum of DC voltage and superimposed AC voltage does not exceed the rated voltage.
  ii) rated ripple current is not exceeded.

- **Reverse voltage** : Aluminium electrolytic capacitors are polar capacitors. Reverse voltage ≤1.5 V can be applied for a duration of less than 1 second, but not continuously or repeatedly. The reverse voltage of 1.5 V is the voltage at which the breakdown of the oxide layers on the cathode takes place. Where necessary a diode may be connected to prevent any reverse voltage from appearing on the capacitor.

- **Selection of current limiting resistor** :
  A current limiting resistor, which is to be connected in series with the capacitor, may be chosen as follows :
  a) for capacitors of rating up to 2500 µF, the limiting resistor will be of 1000 ohms.
  b) for capacitors of rating higher than 2500 µF, the value of current limiting resistor will be determined by the formula:

$$R = \frac{2.5 \times 10^6}{C}$$

C = capacitance in µF
R = resistor value in Ohms

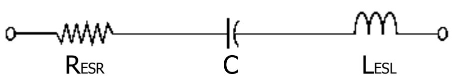
- **Capacitance** : Capacitance can be measured by :
  i) measuring its AC impedance after taking into account amplitude and phase
  ii) measuring the charge it will hold when DC voltage is applied
  DC capacitance is approximately equal to 1.1 to 1.5 times AC capacitance

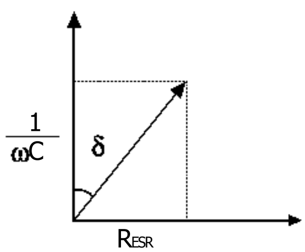
Note: Measurement of capacitance is made at frequency of 100 Hz and ambient temperature of 25°C. The value is in microfarads (µF or MFD) and is indicated on the capacitor. Capacitance increases with temperature and decreases with increase in frequency.

Technical Information

Electrical characteristics

- **Dissapation factor (power factor-Tan δ) :** This is the ratio of ESR to capacitive reactance in the equivalent series circuit. Alternatively, it could be defined as the ratio of effective power (dissipated power) to the reactive power for a sinusoidal voltage:





$$\tan\delta = R_{ESR} \div \frac{1}{\omega C} = \omega C R_{ESR}$$

- **Equivalent series resistance (ESR)** : The equivalent series resistance is the resistive component of equivalent series circuit. It is related to dissipation factor by the formula:

$$R_{ESR} = \frac{\tan\delta}{\omega C_s}$$

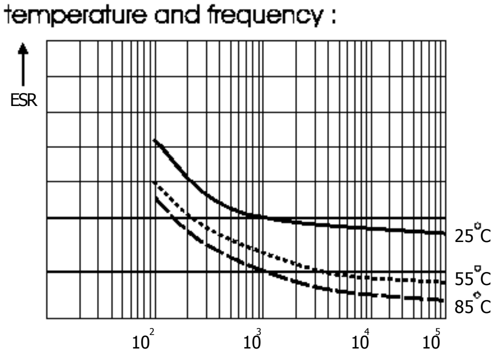
R_{ESR} = equivalent series resistance in Ω

Tan δ = dissipation factor

Cs = series capacitance in Farads

ω = 2Πf (f=frequency)

ESR values are measured by the bridge method (to eliminate the resistance of lead wires) at a frequency of 100 Hz and ambient temperature of 25°C. ESR values decrease with increase in temperature and frequency :



- **Impedance :** Impedance is given by the formula :

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

Z = impedance in Ohms

ESR = equivalent series resistance (Ω)

X_L = 2Π f L

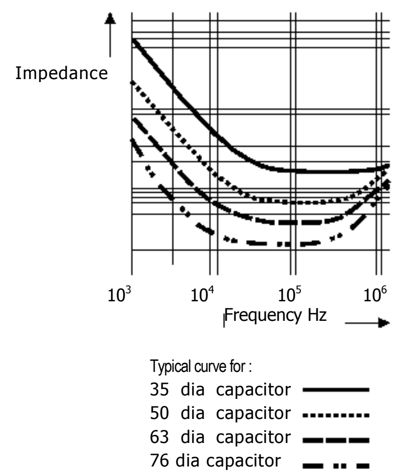
$$X_C = \frac{1}{2\Pi f C}$$

Impedance is dominated by capacitive reactance (X_C) at lower frequencies and by inductive reactance (X_L) at higher frequencies.

Resonance occurs when :

$X_L = X_C$ at which Z = ESR

Impedance below resonance decreases with increase in temperature and frequency. However, impedance above resonance, decreases with temperature but increases as frequency increases.



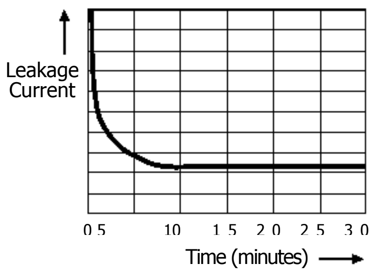
- **Leakage current :** Leakage current is the residual current which continues to flow through the capacitor even after the capacitor has been charged to the set voltage or rated voltage. After the capacitor has been fully charged to the set voltage, the leakage current will continue to fall with time until a steady state has been reached. Leakage current is a measure of the quality of the dielectric layer and is dependent on capacitance voltage and capacitance temperature.

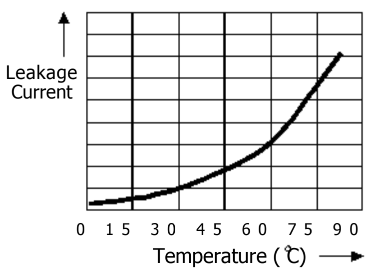
Measurement of leakage current is made at the rated DC voltage of the capacitor, which is applied from a steady source like a regulated power supply. A current limiting resistor must be connected in series with the capacitor under test.

Technical Information

Electrical characteristics • Application notes

Measurement is carried out at an ambient temperature of 25°C ± 3°C. The rated voltage is applied for 5 minutes before the leakage current measurements are taken:





- **Ripple current** : The ripple current rating of a capacitor is the rms value of AC current that flows through a capacitor due to the presence of ripple voltage.

  Ripple current generates heat inside the capacitor which is :

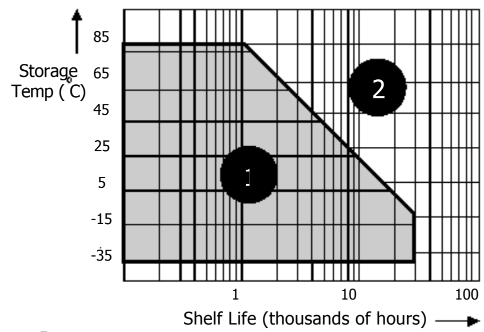
  P = I_r^2 x ESR
  P = power loss in Watts
  Ir = rms value of ripple current in Amperes
  ESR = equivalent series resistance in Ohms

  The maximum ripple current that a capacitor can handle depends on :
  i) the winding design
  ii) aluminium can design
  iii) surface area of the can
  iv) ESR

  Since ripple current increases the temperature of the capacitor, it has a significant effect on the operational life of the capacitor. Ripple current handling capacity is dependent on frequency and temperature. Heat sinking and forced air cooling will aid heat transfer and allow higher ripple currents to be applied.

- **Shelf life** : Shelf life is defined as the time for which a capacitor can be stored without voltage being applied.

Normally the capacitance, ESR and impedance of a capacitor do not change significantly after extended storage period. However, the leakage current can slowly increase. The shelf life versus storage temperature graph is shown below:



Region 1 Leakage current remains unchanged

Region 2 Leakage current increases

In both cases capacitance, ESR and impedance do not change significantly.

If the capacitors are in region 2, capacitors should be preconditioned prior to use. The procedure follows under, "precoditioning" :

- **Preconditioning** : Preconditioning is carried out by applying the rated working voltage across the capacitor. The power source should be a regulated power supply. A suitable current limiting resistor should be connected in series with the capacitor. The voltage should be maintained for one hour after its value has become equal to the rated working voltage applied ±3%. After this the capacitor should be discharged through a resistor of suitable value. The capacitor can now be stored idle for 12 to 24 hours. After this period, the capacitor can be tested for any of the specified parameters.

Application Notes

- **Mounting positions** : During operation, the leakage current of the capacitor will cause electrolysis of the electrolyte. The oxygen produced during electrolysis, helps in 'self healing' of the dielectric layer. The minute quantity of hydrogen released at this time, may increase the internal pressure in the capacitor over an extended period of time.

  All capacitors are provided with a safety vent, which punctures when the pressure inside the capacitor increases beyond the safe limit of 70 psi.

Technical Information

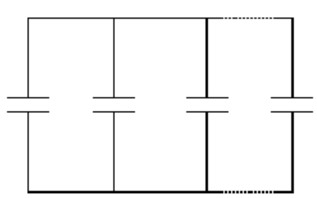
Application notes

Therefore, it is recommended that the capacitors be mounted upright or horizontal, with the vent on top, as shown:

If capacitors are mounted with the safety vent at the lowest position (shown below), a small pool of electrolyte may form near the safety vent. When the vent punctures, the electrolyte may spray out, on to other components, causing damage. Alternatively, the electrolyte may dry and crystallize inside the safety vent, over a period of time, making it non-functional.

- **Capacitor bank design** : Capacitors may require parallel or series connections or both. This depends on the application.

Parallel connection



In a bank of 'n' capacitors connected in parallel, each with capacitance rating of C_1, C_2, ... C_n and voltage ratings V_1, V_2, ...V_n, respectively, the effective capacitance and voltage of the bank will be:

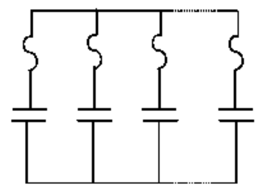
$C_{bank} = C_1 + C_2 + \ldots\ldots + C_n$

V_{bank} = minimum voltage rating of any capacitor in the bank.

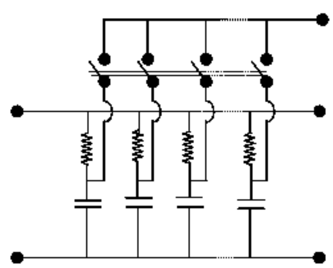
It is advisable to use capacitors of the same nominal capacitance value and voltage rating to avoid excessive stress on any one capacitor in the bank.

In this circuit, if any capacitor in the bank fails due to an internal short circuit, then all the other capacitors in the bank will discharge through this particular capacitor, leading to an extremely abrupt and severe discharge phenomenon.

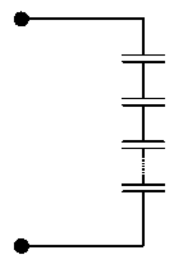
Hence it is advisable to connect these capacitors through a fuse:



For impulse discharge circuit, where it may not be feasible to use the fuses, the capacitors can be protected during charging by means of a suitable current limiting resistor and then connected in parallel at the time of discharge:



Series Connection



In a bank of 'n' capacitors connected in series, each with capacitance rating of C_1, C_2, ... C_n and voltage ratings V_1, V_2, ….V_n, respectively, the effective capacitance and voltage of the bank will be:

$$\frac{1}{C_{bank}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots\ldots + \frac{1}{C_n}$$

$$V_{bank} = V_1 + V_2 + \ldots\ldots + \ldots\ldots V_n$$

It is advisable to use capacitors of the same capacitance value and voltage rating to avoid excessive stress on any one capacitor in the bank.

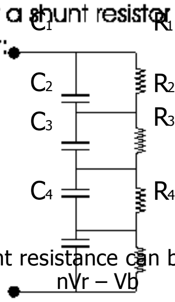
ALCON ELECTRONICS PRIVATE LIMITED

ALUMINIUM ELECTROLYTIC CAPACITORS

Technical Information

Application notes

When capacitors are connected in series, the voltage of any individual capacitor should not exceed the maximum permissible voltage. The total DC voltage applied is divided among individual capacitors in proportion to their insulation resistance value (leakage current). Hence to avoid any imbalance during charging of the bank, it is recommended that a shunt resistor be connected with each capacitor:



The value of the shunt resistance can be computed as follows:

$$A)\ R = \frac{nVr - Vb}{L.C.max\{(Vb / Vr) - ((n+9)/10)\}}$$

R : Shunt resistance value (minimum) in ohms

Vr : Rated voltage of each capacitor.

n : Number of capacitors in series (n 2)

Vb : Bank voltage.

L. C. max : Maximum leakage current of one capacitor (in amp.).

B) Suggested wattage of resistor. Vr^2 / R

(Vr in volts & R in Ohms)

Combined series-parallel connections

Capacitors may be connected as follows :

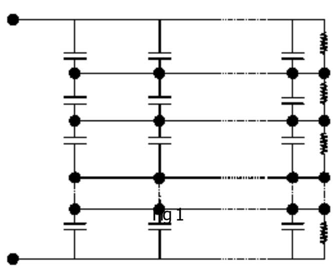


Fig 1

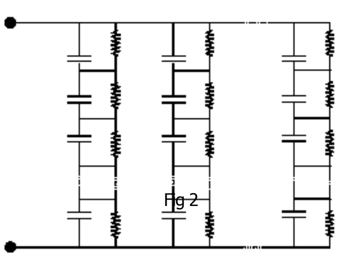


Fig 2

If one capacitor in the series bank (Fig. 1) fails due to a short circuit, the other capacitors will be subjected to the total voltage. This may lead to an excess voltage bank to fail. Hence it is recommended that capacitors are connected as shown in Fig 2, where only one "series bank" suffers the risk of failure, in the event of a short circuit of one capacitor.

- **Life expectancy :** During the working life of capacitors, certain physical and parametric changes occur. These changes eventually make the capacitor unusable, either due to "thermal runaway" leading to catastrophic failure or an excessive parametric drift. At a higher temperature, degradation of the material, used to manufacture the capacitor, accelerates these effects.

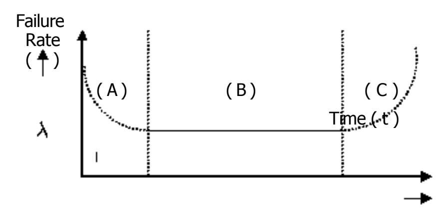
There are many reasons for these changes. Some performance aspects of the capacitors cannot be predicted. Hence evaluation of the capacitor's long term behavior must be determined by 'endurance' tests.

Useful life (service life or operational life) is the life achieved by the capacitor without exceeding a specified failure rate. Useful life can be prolonged by operating the capacitors at load factors below the rated values specified, like lower operating voltage, ripple current and ambient temperature. Capacitor life can also be prolonged by appropriate cooling methods.

Failure percentage is the ratio of number of failures to total number of inspected capacitors.

Failure rate (or long term failure) is the number of components failing per unit time.

The characteristic curve is as follows:



Region A is the early failure period (or infant mortality). This can be decreased by improvement in the manufacturing process

Region B is the useful life (operational life or service life) where failure rate is nearly constant

Region C is the 'wear-out' period. This occurs due to the end of life of the capacitors and occurs when capacitor properties deteriorate.

End of life can be due to:

i) catastrophic failure like short circuit, open circuit or operation of the safety vent

ii) Parametric failure like
- ESR increases to more than twice the initial specified limit
- leakage current greater than specified maximum limit

Technical Information

Application notes • Precautions

Reliability is the probability that the capacitors will perform satisfactorily under given set of conditions for a given length of time

For calculation of useful life the components are taken from a normally manufactured batch. The components are tested under controlled conditions and the data for long term reliability is based on a confidence level of 55%. The figure can be taken only as a guide for reliability since actual working conditions are likely to deviate significantly from those used in routine testing.

Meantime between failure (MTBF) is the inverse of failure rate

$$\mathbf{MTBF} = \frac{1}{\lambda}$$

e.g. *for given set of conditions*

No. of components used in the field	N = 12,000
No. of operating hours	to = 10,000 hrs
No. of failures	n = 12

$$\text{Failures \%} = \frac{n}{N} = \frac{12}{12{,}000} = 0.1\% = F(\%)$$

$$\text{Failures rate } \lambda = \frac{F(\%)}{to} = \frac{0.1\%}{10{,}000} = 0.01\%/1000\text{hours}$$

Precautions

- **Polarity** : Aluminium electrolytic capacitors are polar. Therefore, the capacitors should be connected accordingly. If the polarity of a capacitor is reversed, the capacitor will heat up and normally the safety vent will operate. In extreme cases there is possibility of an explosion and fire.
- **Mechanical stress** : During installation capacitors should not be mechanically damaged.
  i) Capacitors have been designed with the can being negative. Hence damage to the insulation sleeve may cause a short circuit.
  ii) The terminals of screw terminal type capacitors (AEST) are made of highly pure aluminium, whereas the screws are made of brass, which is comparatively, a hard material. Hence mismatch of the threads during fitment can cause damage to the threads of the aluminium terminals. Also while connecting the screw terminals, the tightening torque should not exceed 2 Nm.
- **Cleaning agents** : Halogenated hydrocarbons, if in contact with capacitors, may cause serious damage. These solvents may decompose the insulation sleeve and reduce insulating properties below permissible levels. Moreover, these may penetrate the capacitor through the capacitor seal leading to premature failure. Commonly used halogeneted hydrocarbons and other solvents which should not be used are freon, trichloroethylene, methylchloride, carbon tetrachloride, acetone, meth l eth l ketone.
  Cleaning agents which normally do not have any detrimental effects are methanol, ethanol, propanol and isopropanol.
- **Operating conditions** : During operation, capacitors may fail due to the following:
  i) Operating in very high ambient conditions.
  ii) Surge voltage is exceeded or surge voltage is applied for longer periods than specified.
  iii) Voltage on the capacitor exceeds rated voltage.
  iv) Ripple current exceeds the specified values.
  v) Reverse polarity.
  These can lead to catastrophic failure, with the possibility of an explosion and fire. Hence care should be taken during use. Also capacitors should be used in a well ventilated enclosure.
- **Exposure to electrolyte :** When an electrolyte comes in contact with skin, wash thoroughly with water. If electrolyte comes in contact with eyes, wash thoroughly with water and immediately seek medical advice.
- **Storage :** The following conditions for storage are recommended:
  i) When not in use capacitors should be kept in their original packing.
  ii) Capacitors should be stored indoors, away from direct sunlight, at a temperature of 5 to 35°C and a humidity level of less than 70% RH.
  iii) Capacitors should be stored in an environment free from water, oil, salt water and gases like hydrogen sulphide. Keep away from other chemicals like sulfuric acid, hydrochloric acid, chlorine, ammonia or any corrosive environment.
  iv) When stored capacitors should not be subjected to severe mechanical shock or vibration, beyond specified limits.
-

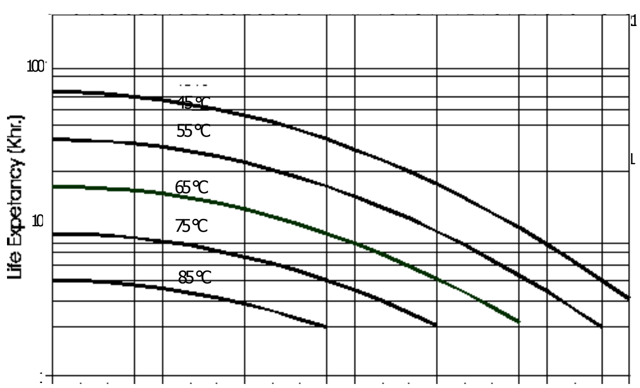
Technical Information
Calculation of expected life

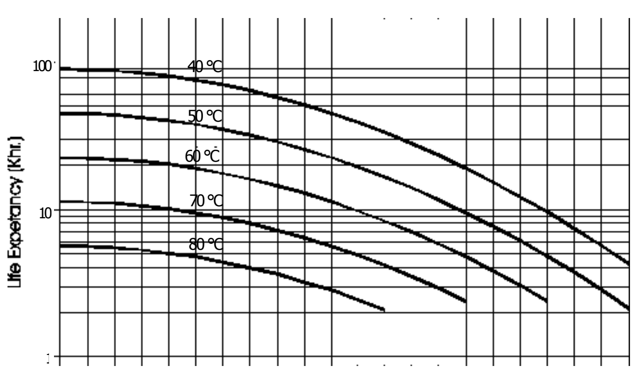
The useful life for known ripple current loads and ambient temperatures is determined on the basis of the useful life graphs as follows :

- Measure ambient temperature.
- Co-relate measured temperature with the nearest temperature curve given in the graph.
- Calculate the ratio of ripple to be applied (I_R) to ripple specified at 85 ^{0}C (I_{85C}) : I_R / I_{85C}
- Draw the line from X-axis though the quotient value to the desired temperature curve , the value at Y- axis will give the useful operation life a t given temperature and ripple current.

The frequency dependence of the ripple current has not been taken into account in the procedure described above.

Life Expetancy





Life Time Test Procedure	Life time criteria
Useful Life: Ambient Temperature = 85 ^{o}C ; at rated voltage and rated ripple current applied 2000 hours	A) Parametric failure I) Capacitance change of morethan ±15%. II) ESR increases to more than twice the initial specified limit III) Leakage current greater than specified maximum limit. B) Catastrophic failure I) Short circuit or open circuit II) Operation of safety vent.

Example:
Capacitor PG6-DI 10000 mfd 200 vdc
If working conditions are :
I_R = 28A Ambient temperature = 50 ^{0}C
Frequency = 100 Hz

1. I_R / I_{85C} = 28 / 18.63 = 1.5
2. Drawing line from point 1 .5 on X-axis to 50 ^{0}C life curve, corresponding Y-axis value is 9khr. Means the expected life is 9000 hr.

Thermal resistance values (Rha)

Can Size (DXL) mm	Air Flow Rate			
	0.5 m/s	1.0 m/s	2.5 m/s	5.0 m/s
	Clip mounted	Clip mounted	Clip mounted	Clip mounted
35X62	13.21	9.94	7.05	5.59
35X80	11.63	8.83	8.35	5.11
35X105	9.48	7.32	5.39	4.42
50X80	7.38	5.54	3.91	3.09
50X105	6.09	4.65	3.37	2.73
63X105	4.66	3.54	2.54	2.04
63x120	4.04	3.11	2.29	1.88
63X145	3.80	2.95	2.19	1.81
76X105	3.73	2.82	2.02	1.61
76X120	3.70	2.80	2.00	1.60
76X145	3.07	2.37	1.76	1.44
76X220	2.35	1.87	1.45	1.23
90X105	3.09	2.33	1.65	1.31
90X120	2.88	2.19	1.57	1.26
90X145	2.56	1.97	1.45	1.19
90X220	1.98	1.58	1.22	1.04

Note : Ripple current capacity of capacitors with AEST-D terminal will increase by 30% to 40% when mounted on a metal plate. Write- in for details.

ALCON ELECTRONICS PRIVATE LIMITED

ALUMINIUM ELECTROLYTIC CAPACITORS

Professional Grade

PG – 6D I with Screw Terminals

PG - 6D I range is designed for high reliability, high frequency and high ripple current applications like high frequency PWM inverters, high KVA on-line UPS systems, telecom SMPS.

- Small can size
- Low ESR
- Low leakage current
- High ripple current.

Specifications

- **Voltage range** : 50 VDC to 500 VDC
- **Can sizes** : 35 x 62mm to 90 x 220 mm
- **Operating temperature range** : – 40°C to +85°C
- **Capacitance** : 330 MFD to 250000 MFD
  The value of capacitance is given in microfarads, and with a tolerance of ± 20%.
- **Leakage current** : The maximum leakage current **(Ir)** is given by the formula :
  Ir = 0.003 CV (microamps)
  C = capacitance in microfarads
  V = DC rated voltage
  Pre-conditioning of the capacitors, prior to testing for leakage current, is essential (refer to page 5)
- **Ripple current** : All capacitors withstand **rms** ripple current at 100 Hz at 85°C. When capacitors operate at temperatures other than 85°C, the permissible **rms** ripple current at 85°C should be multiplied by the factors given below

+40°C	+45°C	+50°C	+65°C
2.10	2.00	1.90	1.60

Where capacitors are required to operate at frequencies other than 100 Hz the multiplying factors given below, may be used to determine the ripple current capacity, at that frequency.

Frequency Hz	100	250	500	1K to 10 K	>10K
Multiplying Factor	1.0	1.05	1.20	1.32	1.35

- Can is negative. However, it is isolated with a PVC insulating sleeve and polypropylene end-disc.

Custom - designed capacitors are available

Terminal styles

Capacitors are available in screw terminals in two can styles

AEST - Screw terminals with plain insulated base
AEST-D - Screw terminals with stud mounting

Note : For details of dimensions see page 25

Marking on capacitors

Each capacitor will have the following information printed on it, sequentially :

1. The Company's symbol followed by the words ALCON ELECTROLYTIC
2. The capacitor grade viz. PG-6DI
3. The capacitance value MFD
4. The rated voltage
5. The surge voltage
6. Capacity tolerance
7. Temperature range
8. Part number on non-standard capacitors

Professional Grade

PG – 6D I with Screw Terminals

Standard Capacitor Values

50	60	4700	0.082	0.343	4.29	35x62
		5000	0.078	0.322	4.4	35x62
		6800	0.069	0.238	4.68	35x62
		10000	0.047	0.162	6.05	35x80
		10000	0.051	0.162	7.26	50x80
		15000	0.022	0.107	9.7	35x105
		22000	0.020	0.073	11.66	50x80
		27000	0.016	0.060	13.11	50x80
		33000	0.012	0.049	16.24	50x105
		47000	0.011	0.035	19.67	63x105
		68000	0.012	0.025	21.45	76x105
		82000	0.011	0.021	22.55	76x1 20
		100000	0.009	0.017	23.96	76x120
		150000	0.009	0.012	27.12	76x146
		200000	0.009	0.010	30.77	76x220
63	75	4700	0.065	0.341	4.84	35x62
		5000	0.052	0.320	5.39	35x62
		6800	0.039	0.235	6.6	35x80
		10000	0.029	0.160	7.7	35x80
		10000	0.031	0.160	9.35	50x80
		15000	0.024	0.107	10.6	50x80
		22000	0.019	0.073	13.26	50x105
		27000	0.016	0.060	14.3	50x105
		33000	0.017	0.049	16.06	63x105
		47000	0.014	0.035	19.81	76x105
		68000	0.011	0.024	22.31	76x120
		82000	0.010	0.020	23.1	76x120
		100000	0.010	0.017	26.05	76x146
75	90	4700	0.043	0.340	6.34	35x80
		5000	0.040	0.319	5.53	35x80
		6800	0.026	0.235	9.09	35x105
		10000	0.023	0.160	10.79	50x80
		10000	0.025	0.160	11.44	50x105
		15000	0.019	0.107	13.26	50x105
		22000	0.016	0.073	16.46	63x105
		27000	0.015	0.060	17.05	63x105
		33000	0.014	0.049	19.8	76x105
		47000	0.012	0.035	20.96	76x120
		68000	0.011	0.024	24.24	76x146
		100000	0.011	0.017	28.3	76x220

Other capacitor values and sizes available on request

Professional Grade

PG – 6D I with Screw Terminals

Standard Capacitor Values

100	115	2200	0.102	0.727	3.85	35x62
		2500	0.098	0.640	4.18	35x80
		3300	0.093	0.486	4.29	35x80
		4700	0.036	0.340	6.93	35x80
		5000	0.035	0.319	8.8	50x80
		6800	0.041	0.236	8.14	50x80
		10000	0.019	0.160	13.26	50x105
		15000	0.017	0.107	15.95	63x105
		20000	0.016	0.080	17.85	63x120
		22000	0.014	0.073	19.25	76x105
		27000	0.014	0.060	19.8	76x105
		33000	0.009	0.049	24.94	76x120
		47000	0.008	0.034	28.31	76x146
		68000	0.008	0.024	33.00	76x220
		100000	0.007	0.016	38.5	90x220
150	172	1000	0.207	1.598	3.19	35x105
		2000	0.074	0.798	6.05	50x80
		2200	0.071	0.725	6.19	50x80
		2500	0.063	0.638	7.22	50x105
		3300	0.053	0.484	8.99	63x105
		4700	0.039	0.340	10.92	63x105
		5000	0.038	0.319	10.63	63x105
		6800	0.029	0.235	12.1	63x105
		10000	0.019	0.160	16.5	63x145
		12000	0.016	0.133	20.34	76x146
		15000	0.014	0.107	21.54	76x146
		20000	0.013	0.080	22.77	76x146
		22000	0.013	0.073	25.51	76x220
		27000	0.009	0.059	30.8	76x220
		33000	0.006	0.048	37.4	76x220
		40000	0.006	0.040	39.6	90x220
200	230	1000	0.158	1.595	3.3	35x80
		1500	0.142	1.065	3.85	35x105
		2200	0.060	0.725	7.4	50x105
		3300	0.048	0.483	9.5	63x105
		4700	0.039	0.340	11.23	63x1 20
		5000	0.034	0.319	12.16	63x120
		5600	0.031	0.285	12.65	63x120
		6800	0.022	0.235	15.51	76x120
		8200	0.021	0.195	16.4	76x120
		10000	0.016	0.160	2049	76x146
		12000	0.013	0.133	22.13	76x146
		15000	0.013	0.106	25.51	76x220
		22000	0.009	0.073	30.8	76x220
		27000	0.008	0.059	33.00	76x220
		33000	0.006	0.048	39.6	90x220

Other capacitor values and sizes available on request

250	288	470	0.326	3.394	2.16	35x62
		680	0.186	2.345	3.37	35x105
		1000	0.133	1.595	4.51	50x80
		2000	0.066	0.797	7.04	50x105
		2200	0.059	0.725	7.45	50x105
		2500	0.048	0.638	9.42	63x105
		3300	0.047	0.483	9.58	63x105
		4700	0.041	0.340	11.00	63x1 20
		5000	0.034	0.319	12.1	63x120
		5600	0.031	0.285	12.65	63x120
		6800	0.018	0.234	19.16	76x146
		8200	0.017	0.194	19.8	76x146
		10000	0.014	0.159	21.54	76x146
		12000	0.013	0.133	22.00	76x146
		15000	0.012	0.106	26.4	76x220
		22000	0.008	0.073	36.3	90x220
		27000	0.007	0.059	38.5	90x220
315	362	2200	0.072	0.725	7.7	63x105
		3300	0.069	0.484	8.8	76x120
		4700	0.044	0.340	11.00	76x1 20
		5000	0.042	0.320	11.28	76x1 20
		5600	0.037	0.285	12.1	76x146
		6800	0.027	0.235	15.4	76x146
		8200	0.027	0.195	17.88	76x220
		10000	0.018	0.160	22.00	76x220
		12000	0.016	0.133	23.1	76x220
		15000	0.011	0.106	29.7	90x220
		20000	0.009	0.080	33.00	90x220
350	385	330	0.406	4.832	2.06	35x80
		1000	0.124	1.594	5.15	50x105
		1500	0.102	1.63	6.5	63x105
		2200	0.056	0.725	9.37	63x120
		3300	0.042	0.483	10.89	63x120
		3300	0.041	0.483	11.44	76x1 20
		4700	0.033	0.339	13.95	76x146
		5000	0.027	0.319	15.43	76x146
		5600	0.026	0.285	15.95	76x146
		6800	0.022	0.235	17.24	76x146
		8200	0.024	0.195	18.95	76x220
		10000	0.010	0.159	28.6	76x220
		15000	0.006	0.106	40.7	90x220

Other capacitor values and sizes available on request

400	440	680	0.184	2.345	3.84	50x80
		1000	0.093	1.593	5.95	50x105
		1000	0.095	1.593	6.71	63x105
		1500	0.087	1.063	7.02	63x105
		2200	0.073	0.725	8.25	63x120
		3300	0.040	0.483	11.54	76x1 20
		4700	0.033	0.339	14.16	76x146
		5000	0.031	0.319	14.52	76x145
		5600	0.030	0.285	14.85	76x146
		6800	0.027	0.235	17.6	76x220
		8200	0.023	0.195	19.25	76x220
		10000	0.019	0.160	23.1	90x220
		15000	0.016	0.107	25.3	90x220
450	495	470	0.463	3.400	2.42	50x80
		680	0.157	2.344	4.58	50x105
		1000	0.140	1.595	5.54	63x105
		1500	0.129	1.065	6.2	63x120
		2200	0.097	0.740	7.15	63x120
		3300	0.063	0.484	10.19	76x146
		4700	0.041	0.340	12.65	76x146
		5000	0.037	0.319	13.2	76x146
		5600	0.034	0.285	13.75	76x146
		6800	0.033	0.235	15.95	76x220
		8200	0.027	0.195	17.6	76x220
		10000	0.023	0.160	20.9	90x220
		15000	0.012	0.106	28.6	90x220
500	550	820	0.154	1.944	4.95	50x105
		1000	0.138	1.595	5.23	50x105
		1500	0.100	1.064	7.02	63x105
		2200	0.069	0.725	9.44	76x105
		3300	0.051	0.484	12.1	76x145
		4700	0.041	0.340	14.88	90x145
		5600	0.035	0.285	15.95	90x145
		6800	0.033	0.235	18.7	90x220
		8200	0.028	0.195	20.35	90x220
		10000	0.020	0.160	22.00	90x220

Other capacitor values and sizes available on request

Screw Terminals type AEST/AEST-D

Fig. 1

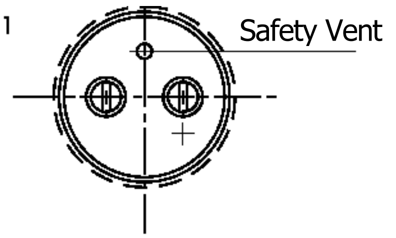
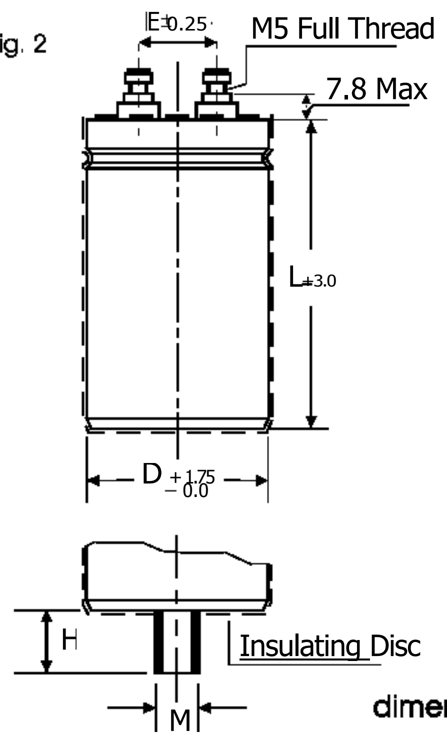


Fig. 2

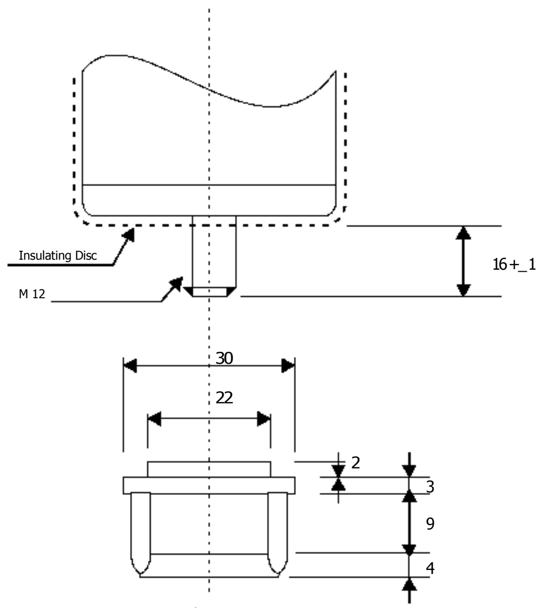


dimensions in mm

D	E	L	a (max)	b + 0.1	Tapping
35	12.6	62	7.8	9.5	M5
35	12.6	80	7.8	9.5	M5
35	12.6	105	7.8	9.5	M5
50	22.1	80	7.8	9.5	M5
50	22.1	105	7.8	9.5	M5
63	28.5	105	7.8	12.0	M5
63	28.5	120	7.8	12.0	M5
63	28.5	146	7.8	12.0	M5
76	31.6	105	7.8	12.0	M5
76	31.6	120	7.8	12.0	M5
76	31.6	146	7.8	12.0	M5
76	31.6	175	7.8	12.0	M5
76	31.6	220	7.8	12.0	M5
90	32.0	146	5.3	16.0	M6
90	32.0	220	5.3	16.0	M6

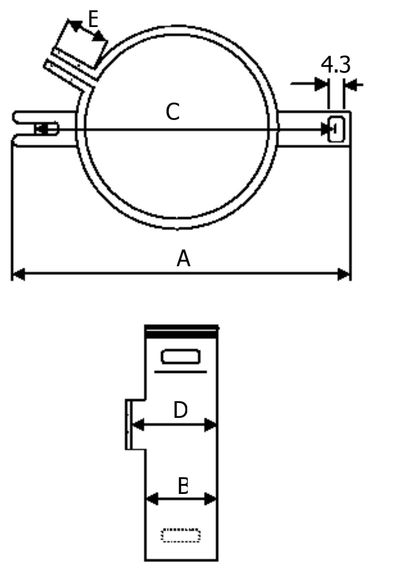
Mounting Accessories

- **Mounting Nut and Washers for Cans with Bottom Stud**



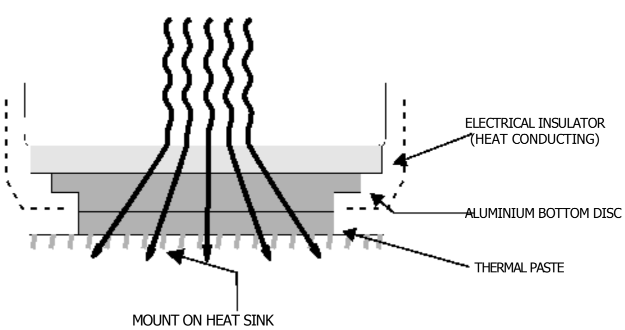
Nylon Nut
Internal Threads M1 2 x 1 5 mm Depth

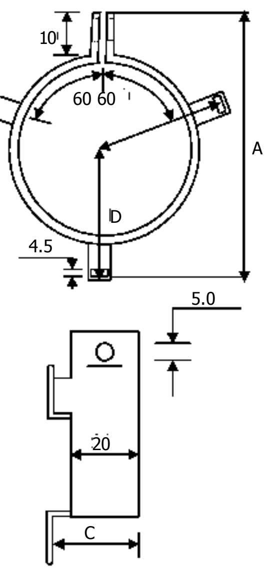
- **Vertical Mounting Clamps**



CAN DIA	A	B	C	D	E
35	63	35	54	20	10

- **Capacitor with Aluminium Bottom Disc**





CAN DIA	A	B	C	D
50	76	33	30	40
63	89	39.5	30	46.5
76	102	46	30	53

All dimensions in mm