Dear Partner,

Let us introduce ourselves.

Itelcond has over 45 years of experience in the design and production of aluminium electrolytic capacitors.

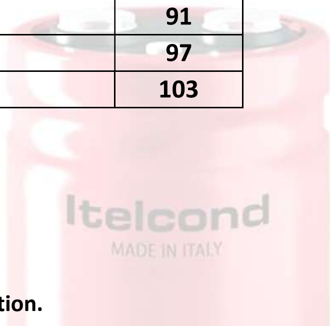
Our production range covers any application where a high-quality capacitor is required. Our products are found in industrial products, such as UPS, inverter, solar, wind, e-mobility, automation, railways, welders, drives and medical.

An electrolytic capacitor represents many trade-offs in performance, price and lifetime. It is only through experienced understanding that the full benefits can be harnessed to deliver a long service life. At Itelcond, we have that experienced understanding along with state-of-the-art manufacturing facility using European sourced materials in order to specify and deliver a long-life product.

Please find the latest updates on our website.

www.itelcond.it

Data Book



Specification, dimensions, and drawings are subjected to change without prior information.

Itelcond

Screw Terminal Series

Series	Capacitance Range [µF]	Voltage range [V]	Temperature range [°C]	Case DxH [mm]	Expected lifetime [hrs]	Applications
AR	100 47.0000	40 – 450	-40° + 85° Self-extinguishing construction and electrolyte	35x56/76x145	5.000hrs	Industrial applications
AY	1.000-100.0000	40 – 500	-40° + 85° Self-extinguishing construction and electrolyte	51x105/90x220	10.000hrs	High reliability Energy storage
AD	2.200 – 22.000	350 – 450	- 55°+ 85°	51x80/90x220	10.000hrs	High Ripple High reliability Heavy transient Energy storage
AP	1.000-15.000	350 – 500	-40° + 85° Self-extinguishing construction and electrolyte	64x105/90x220	12.000hrs	High Ripple Heavy transient Energy storage Solar and wind application
AS	150-330.000	25 - 500	-40° + 85° Self-extinguishing construction and electrolyte	35x56/90x220	15.000hrs	Long life High reliability Telecom, Railways applications
AF	1.000-15.000	350-500	-40° + 85°	64x105/90x220	20.000hrs	Extra Long life Energy storage Railways applications
AZ	1.000-15.000	160-450	-40°+ 105°	51x105/90x220	5.000hrs	Wide temperature range Long life High reliability
AT	100–10.000	350–450	-55°+ 105°	64x105/90x220	8.000hrs	Wide temperature range Very High reliability Very Long Life

Solder Pin Series

Series	Capacitance Range [µF]	Voltage range [V]	Temperature range [°C]	Case ΦxH [mm]	Expected lifetime [hrs]	Applications
ARC/S	100-3.300	200	-40° + 85° Self-extinguishing construction and electrolyte	30x40/45x100	2.000	Solder pin mounting Industrial application High reliability 2-4 pins configuration
AKS	100- 47.000	40-450	-40° + 85° Self-extinguishing construction and electrolyte	30x40/40x100	5.000	Solder pin mounting Industrial applications
ACC ACS	150- 33.000	25 - 500	-40° + 85° Self-extinguishing construction and electrolyte	30x40/50x100	5.000	Snap-in type, Industrial application High reliability 2-4 pins configuration
AZK	100 – 2.200	200 450	-40° +105°	30x40/40x100	5.000	Solder pin mounting Solar and wind application Energy Storage
AZC AZS	100 – 4.700	200 450	-40°+ 105°	30x40/50x100	5.000	Solder pin mounting Industrial applications
ATC ATS	100 – 1.500	200 450	-55°+ 105°	30x40/50x100	8.000	Very Long life Low ESR Solar and wind application
ATK	100 – 2.200	160 450	-55°+ 105°	30x40/40x100	8.000	Long life Low ESR Solar and wind application

Construction

A capacitor is made up of 2 metal plates, separated by a dielectric. The surface areas of the metal plates, the dielectric and the gap between the plates all go towards determining the characteristic of the capacitor. See figure 1.

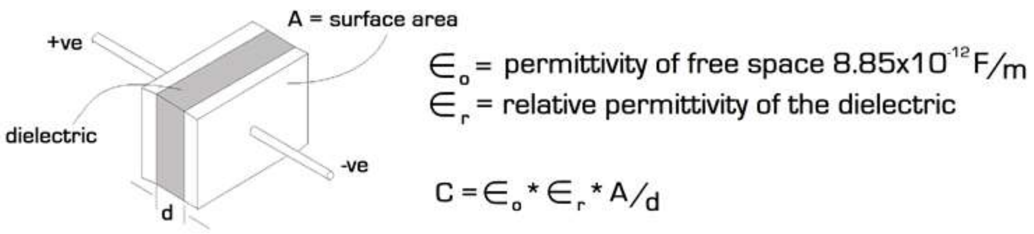


Figure 1

This is the theory. In practice, the metal plates are aluminium foil and the dielectric is an oxide layer on the anode. The cathode is a chemical soaked in paper with the cathode foil acting as a terminal plate. As can be seen in figure 2, the foils and papers are rolled into a cylinder to minimise volume. Interconnecting tabs connect the winding to the terminals mounted on the deck of the capacitor. The winding is fitted into an aluminium can. The interconnecting tabs are welded to the terminal pads on the underside of the terminal deck. The terminal deck is secured down and sealed to the can with a gasket.

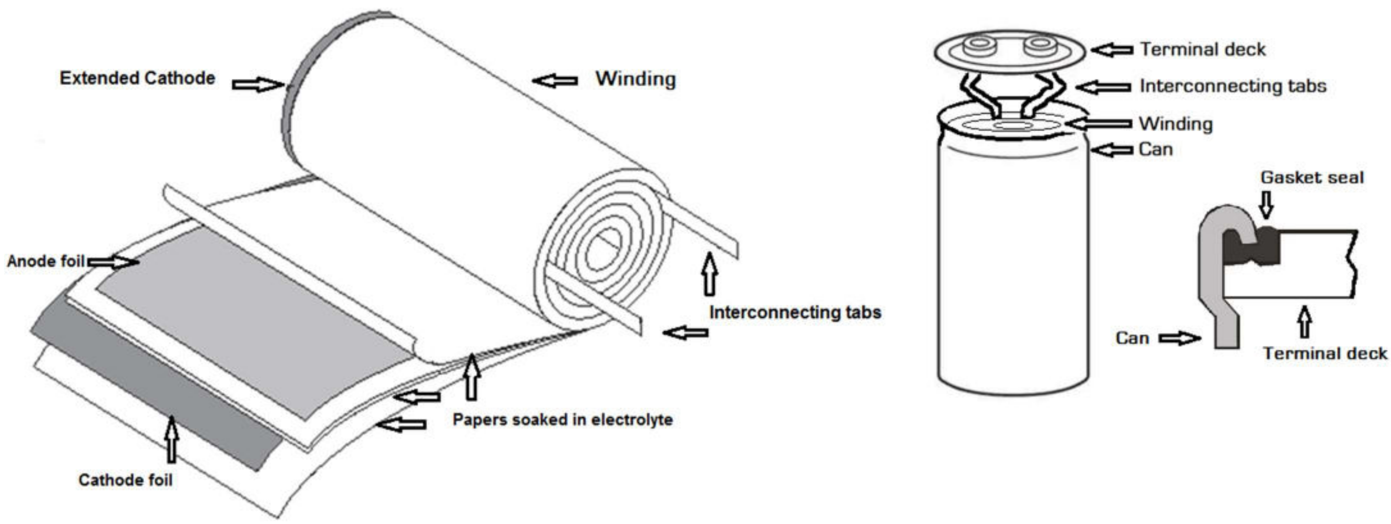
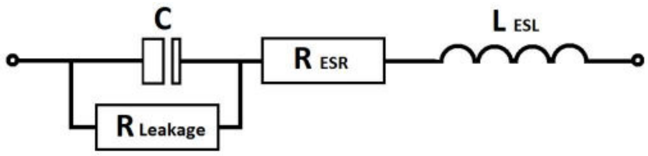


Figure 2

Electrical Characteristics

Capacitance

The DC equivalent circuit of an aluminium electrolytic capacitor is shown in Figure 3.



Where:

- **R Leakage is DC leakage current IL**
- **C is the capacitance**
- **R ESR is the equivalent series resistance**
- **L ESL is the equivalent series inductance**

Figure 3

The capacitance of a capacitor is the number of Coulomb/Volt that a capacitor can store. This value is normally expressed in microfarads (1µF = 10^{-6} F) and the rated value is marked on the capacitor. The capacitance value depends on the ambient temperature in which the capacitor shall operate: the possible variations for every ITELCOND type are indicated in the graphs of individual data sheets: the largest deviations are at low temperature while at high temperature they are negligible.
It should be mentioned that the capacitance varies not only according to the temperature and frequency but even to the operational life of the capacitor: during the service life of the capacitor capacitance shows a regular decay determined by a series of simultaneous causes; such drift is less marked if the operational voltage decreases.
The percent values of capacitance drift for ITELCOND capacitors, after life tests of 2000/5000/10000hrs according to the type, are largely within the tolerance limits indicated in our catalogue and they are definitely lower than stated by DIN or CECC specifications.
Measurement shall be made at frequency of 100Hz and at a temperature of 25°C±2°C.

Equivalent Series Resistance (ESR)

The equivalent series resistance of a capacitor is the resistance seen by the alternating current and it is this I^2 R that causes a capacitor to warm up. Figure 4 shows a set of ESR curves for a typical electrolytic capacitor.

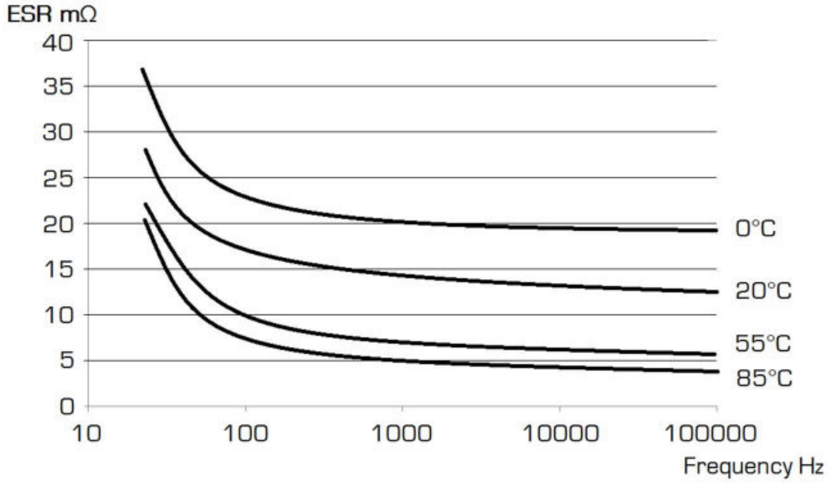


Figure 4

Dissipation Factor (DF)

Dissipation factor (tanδ) or DF is the ratio of the equivalent series resistance (ESR) to the capacitive reactance (Xc);
DF = tanδ = ESR/Xc
The capacitive reactance (Xc) can be expressed in terms of frequency (f) and capacitance (C):
$Xc = 1/(2*\pi*f*C)$
Combining the two equations expresses dissipation factor (tanδ) or DF in terms of frequency (f), capacitance (C) and equivalent series resistance (ESR): DF = tanδ = $2*\pi*f*C*ESR$
Measurements are made at frequency of 100Hz and at a temperature of 25°C±2°C

Equivalent Series Inductance (ESL)

Equivalent series inductance (ESL) is the inductance seen by the alternating current. Generally, the larger the physical size of a capacitor, the larger the ESL. ESL is made up of the physical aspects of the capacitor such as leads and terminals, are deemed parasitic inductances, and are not ideal, but they have to be taken into account as inductive reactance (Xc). The inductive reactance can be expressed in terms of frequency (f) and equivalent series inductance (ESL): $Xc = 2*\pi*f*ESL$

Impedance (Z)

Impedance (Z) is the total resistance to the alternating currents and includes both resistive and inductive components. The impedance of an electrolytic capacitor depends on the equivalent series resistance (ESR), the capacitive reactance (Xc) and inductive reactance (Xl): $Z = \sqrt{ESR^2 + (Xc - Xl)^2}$

Self-Resonant Frequency (Fr)

When the inductive reactance (Xl) and the capacitive reactance (Xc) are equal the self-resonant frequency (Fr) of the capacitor is reached and can be expressed in terms of equivalent series inductance (ESL) and capacitance (C): $Fr = 1/(2*\pi*\sqrt{(ESL*C)})$. Figure 5 shows the relationship between the equivalent series resistance (ESR), capacitive reactance (Xc), inductive reactance (Xl) and impedance (Z).

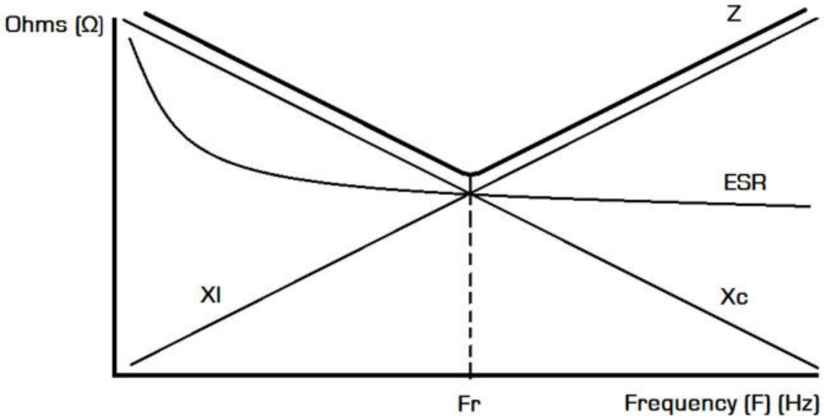


Figure 5

As can be seen from figure 5, the self-resonant frequency (Fρ) is when the inductive reactance (Xλ) and the capacitive reactance (Xχ) are equal. At this point, the impedance (Z) and equivalent series resistance (ESR) converge. Below the self-resonant point (Fρ) the capacitive reactance (Xχ) is the strongest aspect and the capacitor performs like a capacitor. Above the self-resonant point (Fρ) the inductive reactance (Xλ) is the strongest aspect, and the capacitor performs like an inductor.

Voltage

The various voltage terminologies are shown in figure 6.

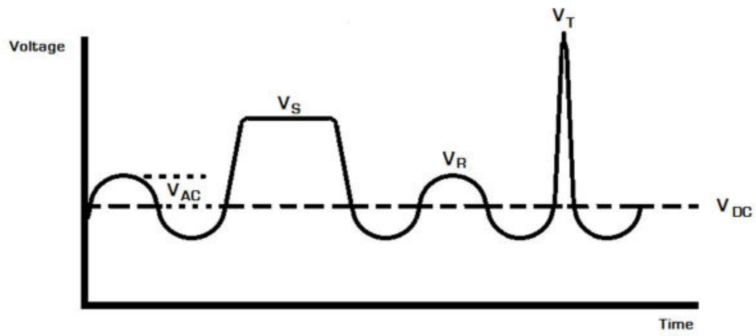


Figure 6

V_R is the rated voltage of the capacitor. The maximum peak voltage of any ripple voltage component must not exceed the rated voltage.
V_{DC} is the mean value of the applied DC voltage.
V_{AC} is the maximum superimposed ripple voltage.
V_S is the surge voltage. A surge voltage is caused by disturbances, such as switching and the values are stated for each capacitor range. The limitations are a maximum of 1000 random occurrences during the life of the capacitor with a load period of 30s and no load period of 330s. The RC time constant equals 0.1s.
V_T is the transient voltage. Transients are application specific are there are no stated values. However, a typical transient could have a rise time ranging from a few hundred µs to several ms. Contact Itelcond if your application involves transients.

Reverse voltage not exceeding 1.5 Volts may be applied to the capacitors without significant change in normal performance characteristics.

Leakage Current and Shelf Life

Figure 3 described the $R_{Leakage}$ component as the DC Leakage current I_L. Leakage current is the residual current that flows once a capacitor has been fully charged. During the manufacture of an electrolytic capacitor the leakage current is managed down to the level specified in the range data. Figure 7 shows this process. Leakage current is specified at 20°C temperature.

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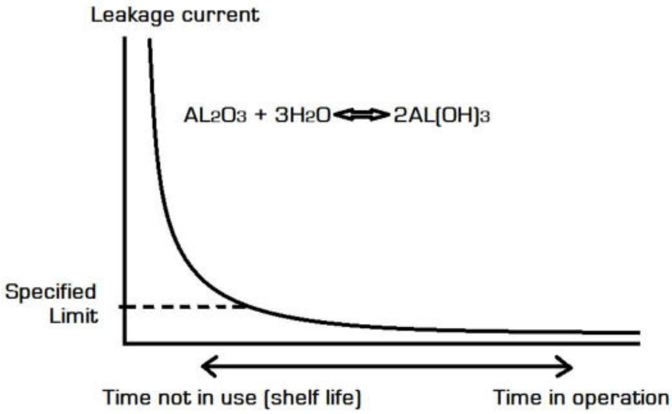


Figure 7

In operation, the leakage current will continue to gradually reduce and settle to a level somewhat less that the specified level. The time to settle will vary depending on the size of the capacitor but can typically take several hundred hours for a screw terminal capacitor.

Leakage Current Multipliers

The leakage current value of an aluminium electrolytic capacitor is influenced by ambient temperature and by ratio of working voltage to rated voltage. Figure 8 give some indication of the multipliers that can be generally applied to each series.

Tamb [°C]	AR-AY-AKS-ACC-ACS	AS	AP	AZ	AT
25	1	1	1	1	1
35	1.2	1.2	1.2	1.2	1.2
45	1.4	1.4	1.2	1.4	1.4
55	1.8	1.8	1.6	1.8	1.8
65	2.5	2.4	2.2	2.4	2.4
75	3.5	3.0	2,8	3.0	3.0
85	5.0	4.0	3,9	4.5	4.5
95	N.A.	N.A.	N.A.	6.8	6.2
105	N.A.	N.A.	N.A.	9.0	8.3

Figure 8

Leakage current decrease Vs. Voltage derating

If the voltage applied to the capacitor is lower than the rated voltage, the leakage current decreases accordingly and the approximate reduction factor is shown in Figure 9

Vapplied/Vrated	1	0,9	0,8	0,7	0,6	0,5	0,4
Multiplier	1	0,75	0,70	0,55	0,45	0,30	0,20

Figure 9

Shelf life

Shelf life is where the electrolytic capacitor is stored dormant, either within equipment, or individually. Time, humidity and temperature will have an effect on a dormant capacitor where the leakage current will slowly increase over time without voltage present. A reversal of the aging process will occur as a chemical change will occur. As such, re-aging will be required before use. For how long you can leave a capacitor on the shelf at what temperature is shown in figure 10.

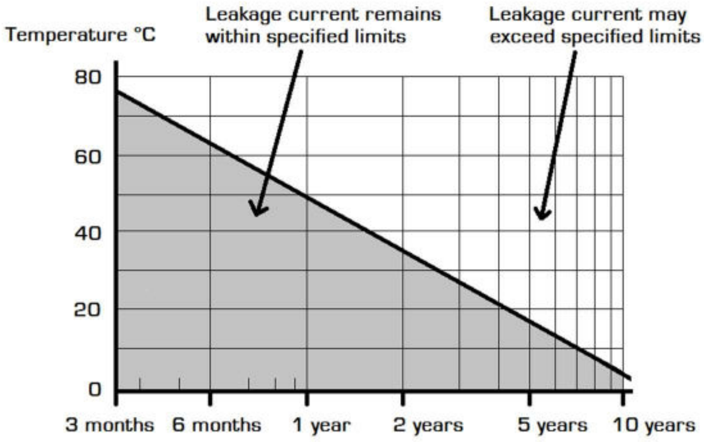


Figure 10

In a typical warehouse, the shelf life should be a minimum of 2 years. Beyond this, the leakage current may exceed the limits. If re-aging is required then this needs to be completed at room temperature. Connect a voltage supply equal to the rated voltage, but current limited to a value equal to the specified leakage limit of the capacitor. Anything from 1 to 4 hours may be required to re-age depending on the initial condition. Care should be taken when re-aging with high voltages.

Voltage Deration

Voltage deration is the operation of an electrolytic capacitor below its rated voltage. This may occur through personal choice based on 'best practise' or through mandated requirements of the end market. How voltage deration works is shown in Figure 11.

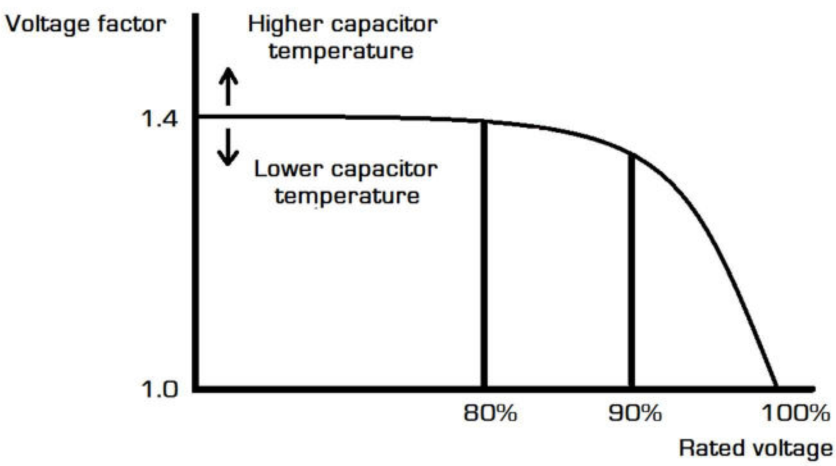


Figure 11

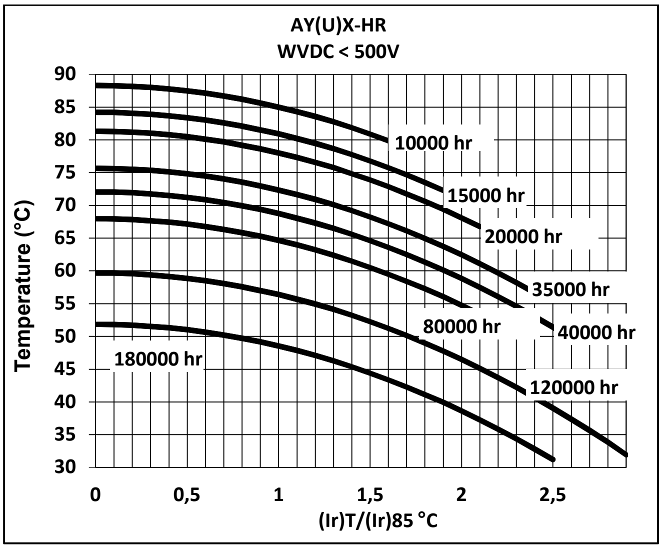
From the figure 11, you can see that you do not gain any further benefit from derating the capacitor below 80% of the rated voltage. Voltage factor has more effect at higher capacitor temperatures and is a parameter that is included in an expected life calculation. The 1.4 value represents a 40% increase in expected life.

Useful Life Calculation

The useful life of a capacitor is calculated in accordance with the tables of expected life per each series.
The rated ripple current at upper category is listed in the data sheets, while the ripple current at different temperature can be calculated using the tables shown on each series.
To know the useful life proceed as follows:

- **calculate the ratio (I_R) / ($I_{85°C}$) or (I_R) / ($I_{105°C}$)**
- **find on to the table the crossing between the working temperature and the calculated ratio**
- **on top of the table it appears the useful life in hours**

The example does not consider the frequency dependence of ripple current: the corresponding factor listed on each type must be used as an additional factor.



Example 1:

- **Capacitor AY(U)X-HR472M350DF1**
- **Working conditions: I_{Ripple} =25A@100Hz**
- **Ambient temperature =70°C**

VN=350V

Capacitance	Case	Tanδ	ESRmax/typ		Zmax	Iripple55°C/85°C		Ordering Code
[µF]@100Hz		[%]@100Hz	[mΩ]@100Hz		[mΩ]@10KHz	[A]@100Hz	[A]@100Hz	(U) for mounting stud
4700	DF	0,08	27	22	20	22,8	16,3	AF(U)X-HR472M350DF1

1. $I_{Ripple} / I_{Ripple@85°C} = \frac{25}{16,3} = 1,53$
    a. **Crossing 1,53 and T=70°C expected life is about 30.000 hours**

Example 2:

- **Capacitor AY(U)X-HR472M350DF1**
- **Working conditions: IRipple =25A@500Hz**
- **Ambient temperature =70°C**

VN=350V

Capacitance	Case	Tanδ	ESRmax/typ		Zmax	Iripple55°C/85°C		Ordering Code
[μF]@100Hz		[%]@100Hz	[mΩ]@100Hz		[mΩ]@10KHz	[A]@100Hz	[A]@100Hz	(U) for mounting stud
4700	DF	0,08	27	22	20	24,5	16,3	AF(U)X-HR472M350DF1

1. $I_{Ripple} = \frac{25}{1,32} = 18,9$
2. $I_{Ripple} / I_{Ripple@85°C} = \frac{18,9}{16,3} = 1,16$
   a. **Crossing 1,16 and T = 70 °C expected life is about 36000 hours**

Example 3:

- **Capacitor AY(U)X-HR472M350DF1**
- **Working conditions: IRipple =25A@500Hz**
- **Ambient temperature =60°C**

VN=350V

Capacitance	Case	Tanδ	ESRmax/typ		Zmax	Iripple55°C/85°C		Ordering Code
[μF]@100Hz		[%]@100Hz	[mΩ]@100Hz		[mΩ]@10KHz	[A]@100Hz	[A]@100Hz	(U) for mounting stud
4700	DF	0,08	27	20	17	23,9	17,1	AY(U)X-HR472M350DF1

3. $I_{Ripple} = \frac{25}{1,32} = 18,9$
4. $I_{Ripple} / I_{Ripple@85°C} = \frac{18,9}{16,3} = 1,16$
   a. **Crossing 1,10 and T =60 °C expected life is about 120000 hours**

Waveforms

All of the above examples assume a sine wave ripple current profile. Variations to a sine wave are shown in figure 12 along with the formula to calculate the equivalent sine wave ripple current.

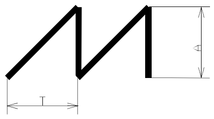
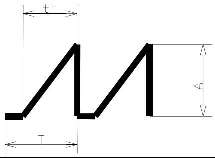
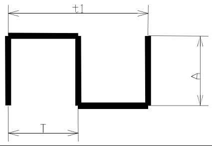
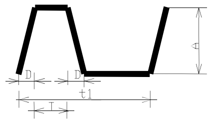
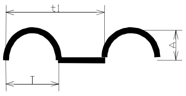
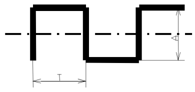
Waveform	r.m.s. value	Waveform	r.m.s. value
	$A \cdot \sqrt{T/3}$		$A \cdot \sqrt{t1/(3 \cdot T)}$
	$A \cdot \sqrt{T/t1}$		$A \cdot \sqrt{(2 \cdot D + 3 \cdot T)/(t1)}$
	$A \cdot \sqrt{T/(2 \cdot t1)}$		A

Figure 12