Electrical Characteristics

Capacitance

The DC equivalent circuit of an aluminium electrolytic capacitor is shown in Figure 1

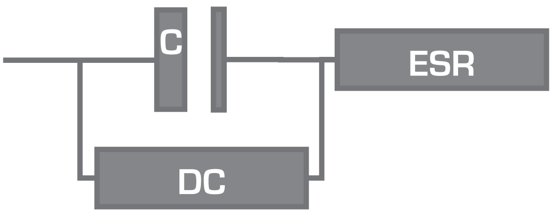

Figure 1

Where:

- DC leakage is the leakage current I_f
- C is the capacitance
- ESR is the series resistance

The capacitance of a capacitor is the number of Coulomb/Volt that a capacitor may store. This value is normally expressed in microFarad (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 concomitant 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 that a capacitor opposes to the passage of the alternating current and represents the "component producing heat when an alternating current is seen by a capacitor". Its percent variation vs. frequency and temperature is shown on Figure 2.

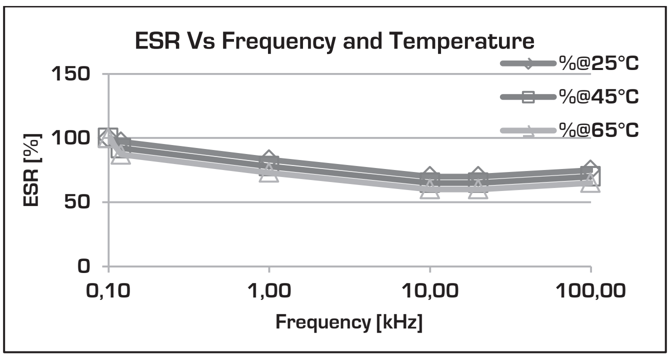

Figure 2

Dissipation Factor (DF)

It is the ratio of the equivalent series resistance to the capacitive reactance as per Equation 1.

$$DF = tg\delta = ESR / X_C$$

Equation 1

Where the dissipation factor depends on temperature and frequency. Considering Equation 2

$$X_C = 1 / (2 \bullet \pi \bullet f \bullet C)$$

Equation 2

the dissipation factor becomes:

$$DF = tg\delta = 2 \bullet \pi \bullet f \bullet C \bullet ESR$$

Equation 3

This relation shows the variation of the dissipation factor with the ESR and the capacitance.
Measurement shall be made at frequency of 100Hz and at a temperature of 25°C±2°C

Impedance (Z)

The impedance of an electrolytic capacitor depends on capacitance, ESR and ESL in accordance with the Equation 4.

$$Z = \sqrt[2]{\left\{(ESR)^2 + \left[\left(1 / (2 \bullet \pi \bullet f \bullet C)\right)^2 - (2 \bullet \pi \bullet f \bullet ESL)^2\right]\right\}}$$

Equation 4

Where:

- E.S.L.is the equivalent series inductance

Superimposed Alternating Current (IRipple)

The superimposed alternating current is the root mean square (rms) value of the alternating current which may be applied to the capacitor. The maximum value tabulated in each data sheets for the different ITELCOND types applies at frequency of 100Hz and ambient temperature of 85 °C, with sine waveforms.
The conversion coefficients given for each type must be applied if temperature and used frequency differ from the conventional one. If, moreover, even the waveform is not sinusoidal the new waveform and the rms values are to be considered.
The maximum value of the alternating current that may be applied to the capacitor shall be determined by
Equation5:

$$P = I_{rms}^2 \bullet ESR + V \bullet I_f$$

Equation5

The value $V \bullet I_f$ is negligible compared with $I_{rms}^2 \bullet ESR$ so the above equation can be simplified to Equation 6

$$P = I_{rms}^2 \bullet ESR = \Delta T \bullet S \bullet \mu$$

Equation 6

giving, finally Equation 7

$$I_{rms} = \sqrt[2]{\Delta T \bullet S \bullet \mu / ESR} = \sqrt[2]{\Delta T \bullet S \bullet 2 \bullet \pi \bullet f \bullet C / tg\delta}$$

Equation 7

Where:

- ΔT is the difference between ambient temperature and the temperature of capacitor surface [°C]
- S is the capacitor surface [cm^2]
- $tg\delta$ is the value of dissipation factor
- μ is the dissipation coefficient [$W/cm^2 * °C$]
- f is the frequency [Hz]
- I^2_{rms} is the superimposed alternating current [A]
- ESR is the equivalent series resistance [mΩ]
- P is the dissipated power [W]

Temperature variation influences the dissipation coefficient while the dissipation factor (or $tg\delta$) is influenced by the variation both of temperature and frequency (see par.1.2).

The DIN (41332, 41270, 42348, 41250) and CECC (30300-016 and 30300-017) specifications give the maximum values of superimposed alternating current that may be applied to the capacitor: the values correspond or are inferior to those indicated for the ITELCOND capacitors.

When the ripple current is a sum of rms values at different frequencies, the equivalent current seen by the capacitor is calculated as per Equation 8.

$$I_{rms100Hz} = \sqrt[2]{\sum_{f=1Hz}^{nHz} \left(I_f / K_f \right)^2}$$

Equation 8

Where

$$K_f = ESR_f / ESR_{100Hz}$$

Equation 9

K_f is listed for each product family.

Voltage

Rated Voltage (V_n)

Is the maximum operating voltage for continuos duty at the rated temperature.

Surge Voltage (V_S)

The overvoltages due to transients or peaks due to superimposed alternating component must be always inferior to surge voltage. The surge voltage maximum value for each rated voltage is given in the table of electrical data

Reverse Voltage

Reverse voltage not exceeding 1,5 Volts may be applied to the capacitors without significant change in normal performance characteristics.

NOTE: for special applications (e.g. magnetising equipment) where a certain percentage of reverse voltage shall be applied, capacitors in accordance with customer requirements may be designed.

Expected Life

From the life test and the life test procedure (see introduction) the life expectancy graphs have been drawn. These graphs correlate ambient temperature, applied ripple current and expected life: the ripple current is expressed as a ratio between the ripple current at the ambient temperature and the ripple current at the category temperature.

Marking

ITELCOND capacitors shall be marked as per Table 1.

ITELCOND
Series
Rated capacitance [µF][1]
Rated DC working voltage [V]
P.N.[2]
Date code of manufacture

Table 1

Capacitance Tolerance

Capacitance tolerances can differ in accordance with customer requirement.

Standard tolerances are :

Screw terminal		Solder pins		Customer request
M=±20%	standard	M=±20%	standard	
X=10%,+30%	on request	X=-10%,+30%	on request	A = Special Tolerance

Table 2

Leakage Current

This is the current flowing through the insulation resistance when a direct voltage is applied to the capacitor.

Note: the insulation resistance is the resistance to the flow of a direct current offered by two conductors separated by a layer of insulating material.

Due to the special features of the aluminium oxide layer acting as dielectric, a small current always flows, in electrolytic capacitors, even after applying a direct current for a very long period.

It should be mentioned that a gradual increase of direct voltage applied to the capacitors, till a well fixed value (which must be in no case higher than the working voltage of the capacitor) causes at the two poles of the capacitor a high current flow at first, then the leakage current decreases rapidly as the voltage reaches its maximum rated value.

Just after the first sharp decrease the current goes on diminishing in intensity following a nearly exponential curve till it reaches an asymptotic value largely inferior to the initial one.

---

[1] Capacitance tolerance when different from -10%+30%

[2] When required

The curve gradient of the leakage current decrease versus time can be considered as a measure of the quality of the capacitor: the steeper is the curve gradient the better is the capacitor; curves showing a slow decrease of leakage current in a due time indicates that the capacitor doesn't meet high quality standards.

The **ITELCOND** capacitors of all types, specially the **"GENERAL PURPOSE"** or the **"LONG LIFE"** series, have leakage current values largely inferior to the maximum values requested by international and national specifications

Anyway during the first period (minutes) of the equipment turning-on the leakage current rating can be sensibly higher than normal and this is to be taken into account for a correct design of the circuit.

Outgoing Leakage Current

This is the leakage current measured at the acceptance test: in accordance with **IEC 60384** the leakage current is to be measured at **20°C** after the rated voltage of units has been applied for **5** minutes.

When the ambient (or capacitor's body) temperature differs from **20°C** the conversion Table 3 applies.

Operating Leakage Current

Is the leakage current that is reached by the capacitor after a continuous operation.

The maximum limit for operating limit current is to be found on each section.

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. Table 3 give some indication of the multipliers that can be generally applied to each series.

Tamb [°C]	AR-AY	AS	AP	AZ	AKS	ACC	AZC/AZK	ATC/ATK
20	1	1	1	1	1	1	1	1
30	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
40	1.4	1.4	1.2	1.4	1.4	1.4	1.4	1.4
50	1.8	1.8	1.6	1.8	1.8	1.8	1.8	1.8
60	2.5	2.4	2.2	2.4	2.5	2.5	2.4	2.4
70	3.5	3.0	2,8	3.0	3.5	3.5	3.2	3.0
85	5.0	4.0	3,9	4.5	5.0	5.0	4.7	4.5
95	N.A.	N.A.	N.A.	6.8	N.A.	N.A.	7.0	6.2
105	N.A.	N.A.	N.A.	9.0	N.A.	N.A.	9.5	8.3

Table 3

Leakage current decrease Vs. Voltage derating

If the voltage applied to the capacitor is lower than the rated one, the leakage current decreases accordingly and the approximate reduction factor is shown in Table 4.

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

Table 4

Leakage Current At Voltage-Free Storage

The capacitors can be stored voltage-free for 2 years at least without any reduction in reliability. If these storage periods have not been exceeded, the capacitors can be operated at rated voltage directly without a re-anodization process.
During the first minutes of the turning-on period, however, the current ratings can be extremely superior to normal ones. This has to be taken into account when designing the circuit.
Due to long period of storage (in particular at high storage and/or high humidity temperature) the leakage current may increase and this phenomenon becomes more noticeable in high voltage capacitors. It's possible, re-applying voltage with a series resistor for a short period (one/two hours could be enough), to re-obtain the initial value.

Storage Temperature

Aluminium Electrolytic Capacitors can be stored up to the maximum category temperature with no voltage applied. It must be considered that storage at high temperature can affect electrical characteristics (namely leakage current) and consequently reliability of the unit. To avoid these undesirable inconvenient, the suggested stock temperature should be higher than +25°C and not exceeding +40°C. Temperature as low as minimum category temperature (-60°C) does not damage the units.

Shelf Life

The shelf life of aluminium electrolytic capacitors is limited and depends from stock conditions.
In a normal warehouse situation (i.e max 35°C,60% R.H.) the limits as per Table 5 apply.

Years	Limits
1	Units will meet initial electrical parameters level
2	Electrical parameters check is required to understand if re-ageing is required
3-5	Re-ageing is required before use
> 5	End of shelf life

Table 5

Re-Ageing Procedure

The re-ageing procedure must be done @ room temperature and following steps 1. through 5.:

1. connect units to a DC power supply through a resistor of :
   a. 10kΩ for units having working voltage lower than 100V
   b. 100kΩ for units having working voltage lower higher than 100V
2. increase the voltage checking that the charging current is not exceding the maximum initial DC leakage limit of the unit
3. when the rated voltage is reached keep it for at least 4(four) hours
4. discharge the unit through a 10kW keeping voltage decrease under control until discharge is complete
5. test units for DC leakage according to the specification

Important

When performing re-ageing operation of units keep in mind the operator is exposed to live voltage if unit is not properly insulated from surrounding. When operator is handling units he must wear insulating glooves and glasses to prevent any body damage due to possible and sudden unit explosion

Reliability

Technical data given for capacitors of different ITELCOND types agree with CECC norms (where applicable and/or available) following Table 6.

Series	CECC
Screw terminal type	30301-802/807/810
Solder pin type	30301-805/808/809/811

Table 6

The relative failure rate given in DIN specifications and fully met by ITELCOND capacitors of different series are reported here below in Table 7.

General Specification Requirements		
Working Voltage	Failure Rate	Series
<25Vdc	0.5%	Long life
30<Vdc<450	0.2%	Long life
6.3<Vdc<450	2.0%	General use

Table 7

In the following paragraphs there are the main terms occurring when considering problems concerned with reliability.
It should be considered that the values each parameter assumes in reliability are statistical figures and so they are valid only if great numbers or lots are considered.

Operational Life

The Operational Life is the period of time in which a capacitor reaches the maximum accepted values of modification of its electrical parameters.
To forecast the predictable operational life, MIL-STD-690 specifications with a "confidence level" of 60% (see next paragraph) are considered.
The following Figure 3 and Figure 4 based on before said specifications, indicate both the "failure rate" versus the testing time and the way to forecast the likely "failure rate" versus the number of "unit-hour", the "confidence level" and number of faulty ones.