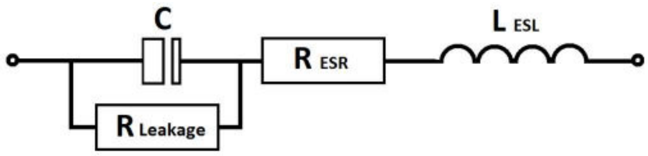
# Electrical Characteristics

## 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.**

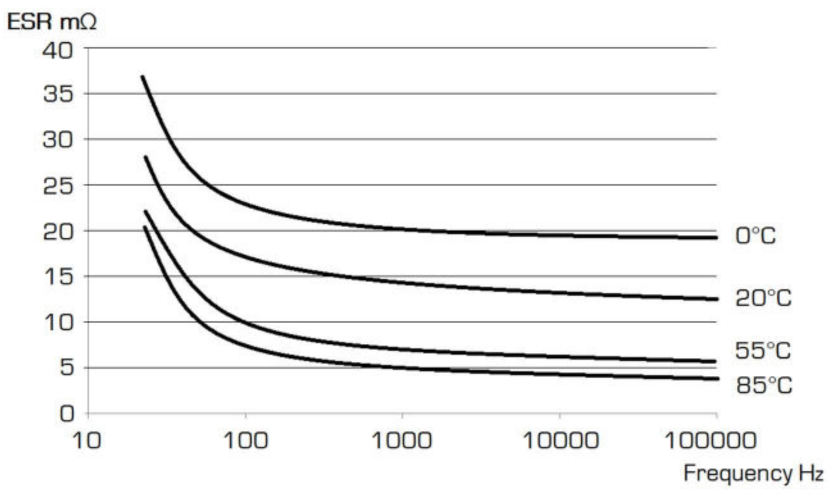



*Figure 4*

## Dissipation Factor (DF)

**Dissipation factor ($\tan\delta$) or DF is the ratio of the equivalent series resistance (ESR) to the capacitive reactance (Xc);**
**$DF = \tan\delta = ESR/Xc$**
**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 ($\tan\delta$) or DF in terms of frequency (f), capacitance (C) and equivalent series resistance (ESR): $DF = \tan\delta = 2*\pi*f*C*ESR$**
**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).**

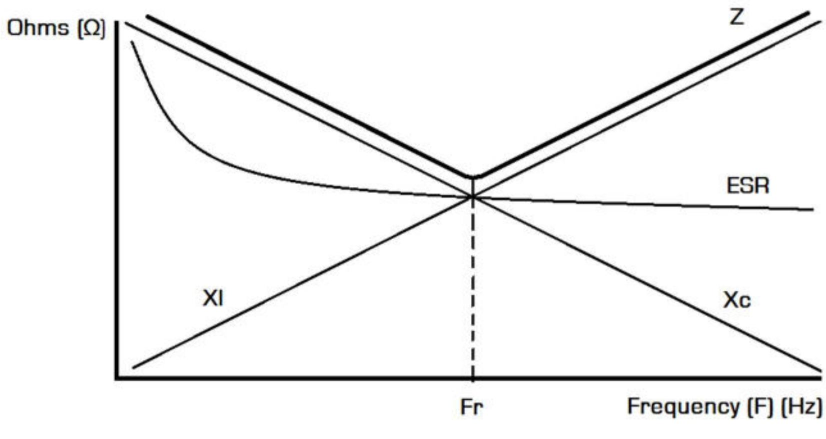



*Figure 5*

**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.**