

## Impedance, Dissipation Factor and ESR

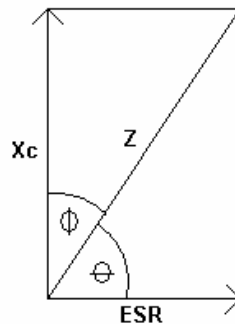
**Dissipation factor** ( $\tan \delta$ ) or DF is defined as the ratio of the ESR and capacitive reactance. It is the Dissipation factor is also known as the tangent of the loss angle and is commonly expressed in percent. Recognized standards express the dissipation factor at specific frequencies typically 120Hz for Aluminum electrolytic and Tantalum capacitors while for film capacitors is 1 kHz and 1 MHz for ceramic capacitors.

$$DF = ESR/X_c \text{ or } \tan \Phi$$

**Equivalent Series Resistance** or ESR for short is the sum of the ohmic losses of the dielectric, materials and connections used in the construction of the capacitor.

$$ESR = DF * X_c = DF / (2 * \pi * f * C)$$

ESR is normally expressed as a maximum value at specified frequencies, 120 Hz and 100kHz for aluminum electrolytic and tantalum capacitors and 100kHz for film capacitors.



**Impedance** is the total resistance the capacitor represents to alternating waveforms. This includes the inductive and resistive components.

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

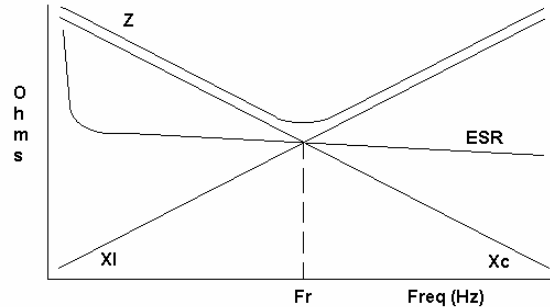
The equivalent circuit is shown below.

Below is a graphical illustration of how the above parameters change with frequency.



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An important observation is the Fr parameter. Fr is the self-resonant frequency. Defined as the frequency where Xl and Xc are equal.

$$Fr = 1 / [2 * \pi * \sqrt{L * C}]$$

At this frequency the impedance is equal to the ESR.

Below self-resonance the Xc component is dominant and the capacitor behaves like a capacitor. Above the self-resonant frequency the inductive component is dominant and the capacitor behaves more like an inductor.

Aluminum electrolytic and film capacitors have the impedance specified as a maximum at a specific frequency normally at 100 kHz and 20°C for aluminum electrolytic and 70°C for film capacitors.



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