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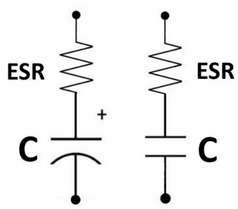
Capacitor Parameters:

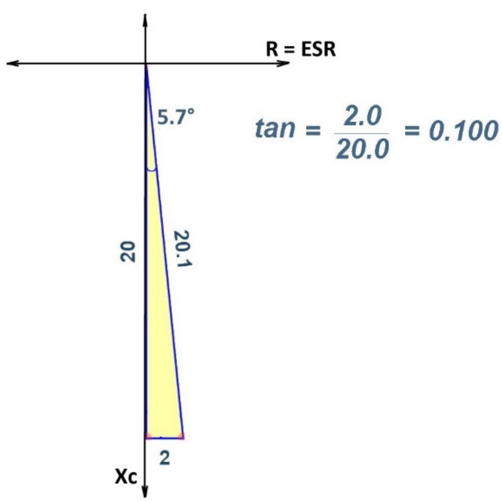
Dissipation Factor (DF), Loss Tangent (tanδ), Equivalent Series Resistance (ESR) and **Quality Factor (Q)**

Capacitor product specifications include multiple parameters which are useful when selecting or comparing capacitors for a given circuit application. Typical lumped element model for capacitors contains a lossless (ideal) capacitor in series with a resistive element (sum of dielectric and metal losses) represented by the equivalent series resistance (ESR) value.



When operating at lower frequencies (less than 1MHz) the dissipation factor (DF) is the predominant characteristic to compare the capacitor loss. This accounts for capacitor product specifications including references to maximum dissipation factor (DF) value at 120 Hz (electrolytic capacitors), 1 KHz (class II ceramic capacitors and film capacitors) or 1 MHz (class I ceramic capacitors). The dissipation factor is of concern to designers of AC circuits, particularly power transfer and resonance, matching networks and power supply circuits.

The dissipation factor is also referenced as the loss tangent (tanδ) of the capacitor as it represents the deviation from 90° (phase angle between capacitor current and capacitor voltage) due to losses in the capacitor. In an ideal capacitor (no losses), the capacitor current (Ic) leads the capacitor voltage (Vc) by 90°



Xc = Capacitive reactance
The magnitude of the reactance of a capacitor (**Xc**) decreases in proportion to increasing frequency

DF = **ESR** / **Xc**
tanδ = **DF**

Example (*see phaser diagram, left*) shows the **dissipation factor** (tangent of the loss angle) is **0.100** (10%) for a capacitor with an **Xc** of 20 Ω and **ESR** of 2 Ω

Q = 1/**DF** ... **Q** = **Xc** / **ESR**

'Q' - Quality factor is the reciprocal of the dissipation factor (DF)
The quality factor "**Q**" of this example is **Q = 10**

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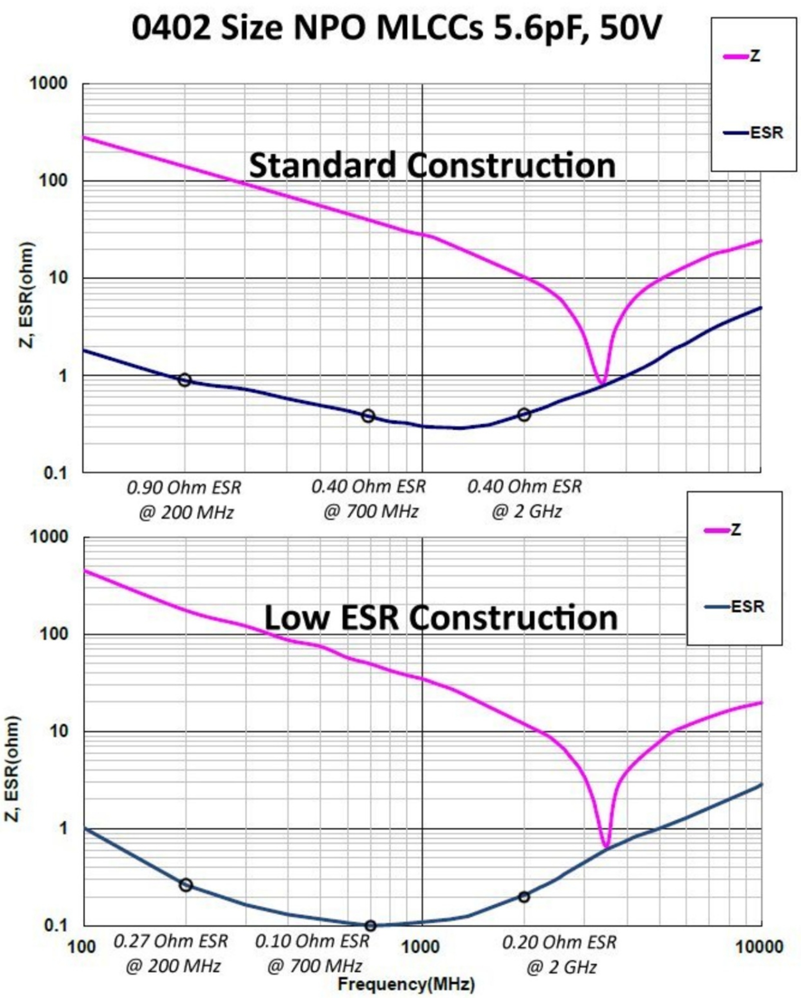
In higher frequency operating circuits (above 1 MHz) the quality factor '**Q**' or equivalent series resistance (**ESR**) of the capacitor is used to characterize the capacitor performance in RF circuits.

The example below, shows a comparison of ESR over frequency (100 MHz to 10 GHz) for two MLCC constructions; standard construction and low ESR construction.



The table below shows the calculated '**Q**' values based on the above **ESR** over frequency performance data. **Q** = **Xc** / **ESR**

Frequency	Xc (5.6pF)	*Standard Construction*	*Low ESR Construction*
200 MHz	142 Ω	ESR = 0.90 Ω **Q = 158**	ESR = 0.27 Ω **Q = 526**
700 MHz	40.6 Ω	ESR = 0.40 Ω **Q = 102**	ESR = 0.10 Ω **Q = 406**
2 GHz	14.2 Ω	ESR = 0.40 Ω **Q = 36**	ESR = 0.20 Ω **Q = 71**

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Substitution Guide:

Parameter	*Substitution Rule*	*Guide*
Dissipation Factor *(DF)* ***Loss Tangent*** *(tanδ)*	↓	Component with **lower** DF or tanδ can be substituted for component with higher DF or tanδ rating
Equivalent Series Resistance *(ESR)*	↓	Component with **lower** ESR can be substituted for component with higher ESR rating
Quality Factor *(Q)*	↑	Component with **higher** Q can be substituted for component with lower Q rating

Understanding capacitor parameters and selection of lower loss (aka; lower DF, tanδ, or ESR) and higher Q components can provide multiple benefits to circuit performance and end-use applications, including:

- improved efficiency of the design
- longer operational time in battery powered applications
- extended operating range
    - increased output power and sensitivity
- extended end-use lifetime and improved component reliability
    - due to a reduced operating temperature of the component

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