

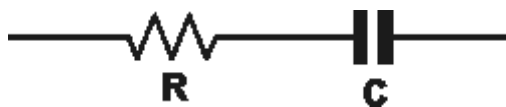
ESR - Equivalent Series Resistance, DF - Dissipation Factor, and Q or Quality factor are three important factors in the specification of any capacitor. They have a marked impact on the performance of the capacitor and can govern the types of application for which the capacitor may be used. As the three parameters are interlinked, ESR, DF and Q will all be addressed on this page.

ESR, DF and Q are all aspects of the performance of a capacitor that will affect its performance in areas such as RF operation. However ESR, and DF are also particularly important for capacitors operating in power supplies where a high ESR and dissipation factor, DF will result in large amount of power being dissipated in the capacitor.

## Capacitor ESR, Equivalent Series Resistance

The equivalent series resistance or ESR of a capacitor is particularly important in many applications. One particular area where it is of paramount importance is within power supply design for both switching and linear power supplies. In view of the high levels of current that need to be passed in these applications, the equivalent series resistance, ESR plays a major part in the performance of the circuit as a whole.

The ESR of the capacitor is responsible for the energy dissipated as heat and it is directly proportional to the DF. When analysing a circuit fully, a capacitor should be depicted as its equivalent circuit including the ideal capacitor, but also with its series ESR.



**The Equivalent Series Resistance, ESR associated with a capacitor**

Capacitors with high values of ESR will naturally need to dissipate power as heat. For some circuits with only low values of current, this may not be a problem, however in many circuits such as power supply smoothing circuits where current levels are high, the power levels dissipated by the ESR may result in a significant temperature rise. This needs to be within the operational bounds for the capacitor otherwise damage may result, and this needs to be incorporated within the design of the circuit.

It is found that when the temperature of a capacitor rises, then generally the ESR increases, although in a non-linear fashion. Increasing frequency also has a similar effect.

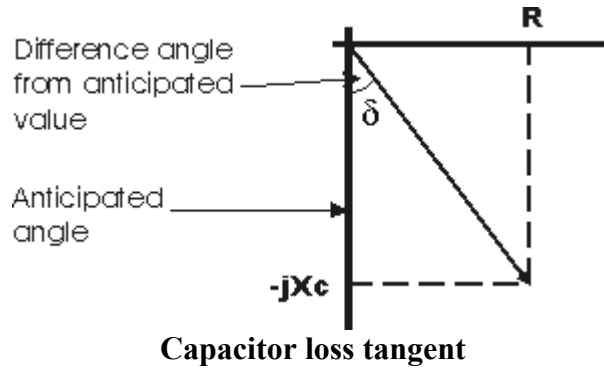
## Dissipation factor and loss tangent

Although the ESR figure of a capacitor is mentioned more often, dissipation factor and loss tangent are also widely used and closely associated with the capacitor ESR.

Although dissipation factor and loss tangent are effectively the same, they take slightly different views which are useful when designing different types of circuit. Normally the dissipation factor is used at lower frequencies, whereas the loss tangent is more applicable for high frequency applications.

The dissipation factor can be defined as: the value of the tendency of dielectric materials to absorb some of the energy when an AC signal is applied.

The loss tangent is defined as: the tangent of the difference of the phase angle between capacitor voltage and capacitor current with respect to the theoretical 90 degree value anticipated, this difference being caused by the dielectric losses within the capacitor. The value  $\delta$  (Greek letter delta) is also known as the loss angle.



Thus:

$$\tan \delta = DF = \frac{1}{Q} = \frac{ESR}{X_c}$$

Where:

- $\delta$  = loss angle (Greek letter delta)
- DF = dissipation factor
- Q = quality factor
- ESR = equivalent series resistance
- $X_c$  = reactance of the capacitor in ohms.

## Capacitor Q

It is convenient to define the Q or Quality Factor of a capacitor. It is a fundamental expression of the energy losses in a resonant system. Essentially for a capacitor it is the ratio of the energy stored to that dissipated per cycle.

It can further be deduced that the Q can be expressed as the ratio of the capacitive reactance to the ESR at the frequency of interest:

$$Q = \frac{X_c}{ESR}$$

As  $Q$  can be measured quite easily, and it provides repeatable measurements, it is an ideal method for quantifying the loss in low loss components.