QuadTech

Application Note

Power Factor of a Capacitor

Is there a difference between the power factor and dissipation factor of a capacitor? Yes and no. Both quantities indicate energy or charge potential of a capacitive component yet which factor to use to define the electrical properties of the component is based on its physical makeup. What material is it made of? What are the plates comprised of? The dielectric sandwiched between the conductors, how does it affect power? The dielectric selected is based on the capacitor's application and desired value. For an example a 01.pF value capacitor may likely have a ceramic core and a 1F capacitor may have an aluminum electrolytic core. Another consideration: a series or parallel equivalent circuit influences the capacitive measurement.

Power Factor: [ELEC] The ratio of the average (or active) power to the apparent power (root-mean-square voltage times rms current) of an AC circuit. Abbreviated Pf*. In other words, it is the real V_{rms}/I_{rms} divided by the complex impedance R + jX.

The Power Factor of a capacitor is defined as:

$$P f = \frac{R s}{Z c}$$

The 1900 Series Precision LCR Meters do not display the power factor parameter (Pf) but the instruments do measure 20 parameters including of interest to this discussion, series resistance (Rs), dissipation (D or D_f), impedance $|Z|$ and series reactance Xs. The voltage across and current through the DUT can also be measured (the active component of the power factor definition). This is the real value of the voltage and current at the DUT, not simply the programmed test voltage.

Dissipation Factor of a capacitor is defined as:

$$D = \frac{R s}{X c}$$

For most capacitors the angle δ is very small and Z ≅ Xc, i.e. the impedance of a capacitor is equal to its capacitive reactance. The phase angle (θ) is equal to the tangent (90° - δ).

Since capacitance is a measure of the quantity of electrical charge that can be stored (held) between the two electrodes, capacitors are often termed 'low loss' or 'high loss'. A low value capacitor (≤0.01uF) represents a higher impedance (Z) and conversely, a high value capacitor (≥10uF) represents a relatively low impedance (Z). Recall the last equation: Z ≅ Xc for a small change in phase.

* Defined in McGraw Hill Dictionary of Scientific and Technical Terms, © 1974.

Phase Relationship

Figure 1 illustrates the phase relationship of a capacitor in a series equivalent circuit. Reviewing the previous equation and Figure 1, it can be projected that for a low loss capacitor, the dissipation factor is approximately equal to the power factor:

$$D \cong Pf$$

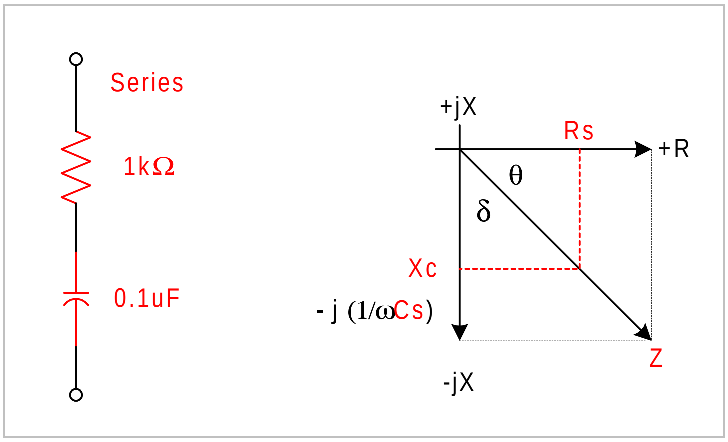

Figure 1: Phase Relationship of Resistance and Reactance

For safety sake of the user and measuring equipment to which capacitors are connected, make sure capacitors are fully discharged before proceeding with measurements. It is important to remember that once a capacitor is charged it gives up its total charge reluctantly because of the phenomenon termed "dielectric absorption". High value capacitors are the most likely for charge buildup. If stored un-shorted for a long time they should be discharged before handling or connection to the measuring instrument.

For a high loss capacitor it does not hold that the dissipation factor is equal to the power factor. One must evaluate each parameter separately. As illustrated in Figure 2.0, Rs plays a more significant role in the total value of capacitive reactance when C is high. To determine the power factor (Pf) measure both the series resistance Rs and the impedance Z of the capacitor.

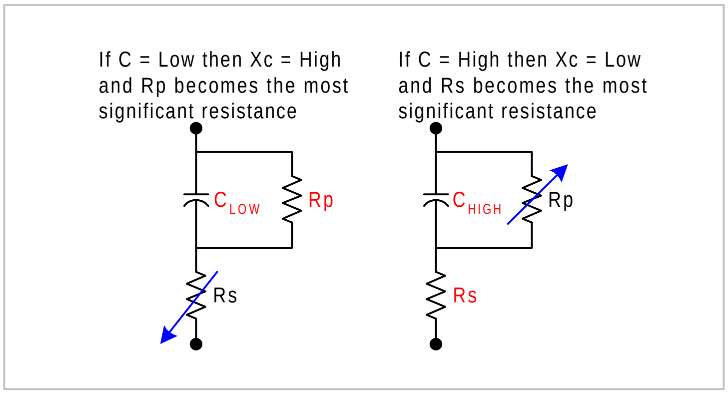

Figure 2.0: Capacitive Reactance: Rs versus Rp

Dissipation Factor

The Dissipation Factor, D, for a capacitor is comprised of three complex parts: D1, the actual series resistance, D2, the leakage resistance and D3 the dielectric loss. These are the three sources of loss in a real capacitor and cause effect dependent upon frequency. Figure 3 illustrates the log relationship of dissipation versus frequency.

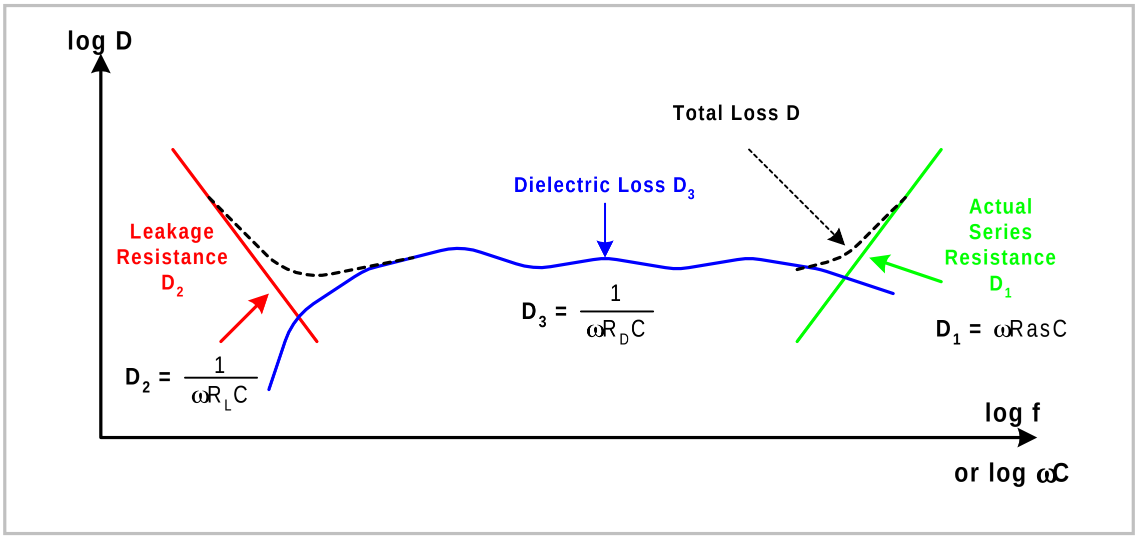

Figure 3: Dissipation Factor Components

Figure 4: 1900 Series Precision LCR Meter

For complete product specifications on the 1900 Series Precision LCR meters or any of QuadTech's products, visit us at http://www.quadtech.com/products. Call us at 1-800-253-1230 or email your questions to info@quadtech.com.

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