WHAT IS Q & ESR?

One of the most important qualities in evaluating a microwave chip capacitor is the Q factor, or the related equivalent series resistance (ESR). At Johanson Technology (JTI), we work hard to provide you with accurate and complete data.

In theory, for a "perfect" capacitor, the ESR would be 0 ohms, and the part would be purely reactive with no 0 degree (resistive) component. The current going through the capacitor would lag the voltage across the capacitor by exactly 90 degrees at all frequencies.

In real world usage, no capacitor is perfect, and they will always exhibit some ESR. ESR varies with frequency for a given capacitor, and is "equivalent" because although it is modeled as a series parasitic element, its source is from imperfections in both the conducting structures and in the insulating dielectric structure. In past decades, all capacitor parameters where measured at a standard of 1 MHz, but in today's high frequency world, this is far from sufficient. Typical values for a high quality microwave capacitor of a given value could run in the order of about 0.05 ohms at 200 MHz, 0.11 ohms at 900 MHz, and 0.14 ohms at 2000 MHz.

The quality factor Q, is a dimensionless number that is equal to the capacitor's reactance divided by the capacitor's parasitic resistance (ESR). The value of Q changes greatly with frequency as both reactance and resistance change with frequency. One can see that the reactance of a capacitor can change tremendously with frequency or with capacitance value, and therefore the Q value could vary by a great amount.

ESR and Q are measured here at JTI on the Boonton 34A resonant line. The capacitor under test is resonated with an inductive line of an accurately characterized impedance and Q, and from the resultant data (the center frequency and bandwidth of the resulting peak), the Q, ESR, and capacitance value of the device is output. This method has been for decades (and still is) an industry standard for the measurement of Q and ESR at RF frequencies. Since this method depends on the frequency accuracy of a signal generator (which can be measured with extreme precision), the data taken by this method can be reasonably accurate. As the ESR of modern capacitors goes ever lower, the accuracy, even of this method, can only be in the order of +/- 10% (reference Boonton 34A Instruction Manual, page 2.2). This is still better than any other method (for measuring Q and ESR at RF frequencies) presently available.

Using S-parameter data to derive the ESR can be dangerous since the accuracy of the reported data is limited by the calibration of the S-parameter measurement setup in a 50 ohm system. A typical amplitude calibration of +/-0.05 dB is obviously not accurate enough in the passband of the capacitor where ESR is normally the parameter of paramount concern.

For the highest Q and lowest ESR values, be sure to ask for the inexpensive Johanson Technology "C" series of multilayer microwave capacitors.