Determining Accurate ESR values of Ceramic Decoupling Capacitors
USNC-URSI National Radio Science Meeting

Sai Ram Anand Vempati*(1), Sunil Sumanth Kollipara(2), Aleksandr Gafarov(2), Melinda J.Piket-May(1), Eric Bogatin(1)

(1) Electrical, Computer and Energy Engineering, University of Colorado at Boulder

(2) Mentor Graphics Corporation, Longmont, CO http://www.mentor.com/

Ceramic Capacitors are widely used in electronic designs, including RF impedance matching, DC blocking, and as decoupling capacitors in a Power Distribution Network (PDN). A typical ceramic capacitor has an intrinsic Equivalent Series Resistance (ESR) having a value in the range of 0.001 to 0.1 Ω. It is a representation of the total losses that result from the dielectric and metal elements of the capacitor. Knowing the correct ESR value of the capacitor is important in predicting the peak impedances in multi-capacitor systems which are a part of the PDN. This paper describes the procedure for fitting an equivalent RLC model to characterize the capacitor behavior over a given frequency range followed by introduction of a new technique for accurate measurement of ESR values.

A set of two port S-parameter files available from popular ceramic capacitor vendors are collected initially on the basis of the capacitor value, dielectric material, package size, and its rated voltage. The ESR can be calculated using the one port Z-parameter data extracted from the two port S-parameter files. A major problem associated with this method of ESR estimation is the measurement technique that is used by the vendor while creating the two port S-parameter data. The current methods that are used in the industry for measuring S-parameter data are the one-port and two-port series measurement techniques. Both these techniques inherently add the probe contact resistance in series with the capacitor. Due to this, the estimated ESR will consist of the intrinsic ESR of capacitor as well as the contact resistance of the probe.

The first step towards resolution of this inaccurate ESR value is to design an equivalent RLC model to fit the behavior of the capacitor over the given frequency range. The fitting process will be performed on the QUCS SPICE tool. By fitting the three parameter values of the R, L and C to the measured data, approximate values of the capacitance, equivalent series inductance (ESL) and ESR can be determined.

The next step uses the two port shunt measurement technique that involves placing the capacitor as a shunt connection between the two probes of the network analyzer. This arrangement reduces the effect of the probe contact resistances on ESR. Thus, we get an accurate measure of ESR that helps in predicting peak impedances which are likely to cause problems in complex PDN systems.