SIMULATING THE EFFECT OF MOUNTING ON SRF AND S-PARAMETERS FOR HIGH FREQUENCY MULTI-LAYER CERAMIC CAPACITORS

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The S-parameters reported by Johanson Technology's MLCSoft® software are analytically measured and then mathematically de-embedded to represent the capacitor alone. The de-embedding is done because the lab test fixture used during measurements may not accurately reflect actual in-circuit mounting situations. This de-embedded data can be used as a starting point and then modified using the techniques described in this note to yield S-parameters which represent a specific in-circuit mounting situation more accurately.

The actual measurement is made in a series mounting configuration with a 50 ohm microstrip environment where the width of the microstrip line is identical or close to the width of the capacitor. This 50 ohm microstrip environment is on an alumina substrate (used during TRL* calibration, and also for launching to/from the DUT), except for directly under the DUT where the substrate is air. After de-embedding, the physical length of the capacitor under test and the very small capacitances from the capacitor body to ground are included in the measured S-parameters. Reported data including these two effects is desirable because these effects will be present when the capacitor is mounted in an actual circuit. During measurement in our fixture, the capacitor is de-embedded to its terminations, causing the capacitor's physical length to be included in the S21 phase (as opposed to the mathematically de-embedded S-parameters presented in MLCSoft®.)

The method of mounting the capacitor in the final circuit application can alter the discontinuity impedance and cause the reported S-parameters to differ significantly from those created in a particular application. Some of the variables effecting S-parameters include mounting configuration (series or shunt), transmission line width, substrate (PCB) dielectric constant and solder fillet geometry/quality. At high frequencies, the capacitor, it's mounting, the PCB material, etc. make up a "network" that defines the SRF. Therefore the SRF of the capacitor itself has no meaningful definition.

As an example, the Series Resonant Frequency (SRF) increases approximately 20% (as indicated by the S11 magnitude dip) when the PCB material is changed from FR-4 to Alumina (capacitor mounted in series configuration.) Mounting in a shunt configuration (SRF = S21 dip) could decrease the SRF by about 40% from that measured when in a series configuration.

We have found in the lab that these effects can be closely simulated in a microwave CAD program (such as ADS, Eagleware, Compact) by using the S-parameters given in MLCSoft®, and then adding values for C1, C2, Lext, and Dly1 as shown in **Figure A** below.

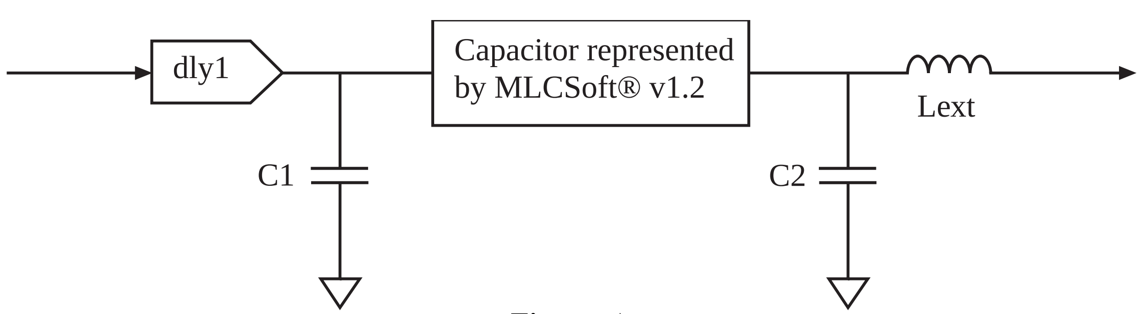

Figure A

C1 and C2 represent the capacitance as it varies with the dielectric constant of the PCB material used. Lext represents the reduced SRF that occurs when shunt mounting. Dly1 represents the delay caused by the mechanical length of the capacitor (MLCSoft data is presented de-embedded to the center of the capacitor.)

Four common mounting scenarios were examined:

Mounting #1.) Series Mounted over air as in MLCSoft® v. 1.2 (for comparison)

Mounting #2.) Series Mounting on 0.025" Thick FR-4 with an opposing ground plane

Mounting #3.) Series Mounting on 0.025" Thick Alumina with an opposing ground plane

Mounting #4.) Shunt Mounting on 0.025" Thick Alumina with an opposing ground plane

We determined the values of C1, C2, Lext and Dly1 by the following method. First, actual S-parameter measurements were made in the lab on capacitors mounted in the configurations outlined above. Next, we downloaded the S-parameters from MLCSoft® into our microwave simulation software. Then we varied C1, C2, Lext and Dly1 in the simulator until the S-parameters displayed were as close as possible to the measured values obtained in the first step.

The values we obtained are as follows:

Mounting #1.): For C1 & C2 & Lext: N/A (all 0.00); {Add the delay as shown below}

Mounting #2.): C1≃0.03pF, C2≃0.03pF, Lext=0.0nH (Modeled in **series** mode in CAD)

Mounting #3.): C1≃0.07pF, C2≃0.07pF, Lext=0.0nH (Modeled in **series** mode in CAD)

Mounting #4.): C1≃0.07pF, C2≃0.07pF, Lext=0.5nH (Modeled in **shunt** mode in CAD)

0402 Size: Dly1≃ 15 pS (applies to all mounting situations shown above)

0403 Size: Dly1≃ 15 pS (applies to all mounting situations shown above)

0504 Size: Dly1≃ 20 pS (applies to all mounting situations shown above)

0603 Size: Dly1≃ 25 pS (applies to all mounting situations shown above)

0805 Size: Dly1≃ 32 pS (applies to all mounting situations shown above)

1210 Size: Dly1≃ 45 pS (applies to all mounting situations shown above)

The values of C1 and C2 will affect the SRF (S11) but the PRF (S21) will be unaffected when in the series mounted configuration. The values of C1 and C2 will affect the PRF (S11) but the SRF (S21) will be unaffected when in the shunt mounted configuration.

A future update to MLCSoft® that will include S-parameters for common mountings using the simulation techniques described above is under development.

NOTE: Johanson Technology makes no warranty of any kind with regard to the MLCSoft® software package, or to the design methods discussed in this note. In-circuit device performance is subject to many variables that may not be evident in our simulations. JTI shall not be liable for errors contained in the software or this application note, or for incidental or consequential damages in connection with the furnishing, performance, or use of the software or methods contained in this application note.