Powerfully flexible software models are now available for surface-mount (SMT) resistor, inductor and capacitor (RLC) components that are accurate over wide ranges of frequency, part value and mounting configurations. These unique, substrate-scalable Global Models™ are developed from careful measurements taken in typical application circuit mounts on multiple boards. Global Models account for the complex interactions between the board, ground planes, solder pads and the component. The models, formatted for use in electronic design automation (EDA) software such as Agilent ADS™ Ansoft Designer™ Applied Wave Research Microwave Office™ and Eagleware Genesys™ are generally valid through the first two higher order resonances of the parts, and are scalable over wide ranges of substrate properties and part values (for example, 1 to 100 nH inductance, 0.5 pF to 10 µF capacitance, or 10 to 120 kΩ resistance).¹ The Modelithics CLR Library™ contains over 40 well-documented Global Models, representing literally thousands of components, and delivers unparalleled ease of use and design speed.

Commonly overlooked, the presence of substrate-dependent parasitic effects in the frequency response of SMT components typically becomes evident above a few to several hundred megahertz. These effects are attributable to the physical size of the component and are described by parameters such as the effective series inductance (ESL) and effective series resistance (ESR). In addition to the intrinsic component characteristics, there can be significant extrinsic effects that are related to the circuit environment in which the part is mounted. An accurate model of an SMT RLC component must account for both intrinsic and extrinsic parasitics through suitable equivalent circuit parameters. The models should be capable of scaling all circuit parameters with changes in the substrate height and dielectric constant to increase the versatility of the model. The models should remain valid through multiple harmonics of the design frequency, particularly when used to represent

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bias or matching elements in nonlinear circuit simulations.

In addition, models that scale all equivalent circuit parameters with the nominal component value can play an important role in improving the efficiency of the design process. Such models allow a designer to incorporate true component performance from the outset, and eliminate the need to successively substitute individual models (or S-parameter data sets) as a design matures.

Modelithics Global Models are a significant improvement over the more widely available RLC models built into EDA software or downloadable from vendor Web sites that can be clearly seen.

The Smith chart in Figure 3 illustrates the measured S-parameters of a 10 nH 0805-style inductor mounted in a series configuration on different FR4 substrates. The frequency of the parallel resonance on the 14 mil FR4 is about 2 GHz higher than for the 59 mil case. Substrate effects are evident even in the low frequency range (2 to 3 GHz), as indicated by the S11 data in the inset.

The Smith chart in Figure 3 demonstrates the versatility of global, substrate-dependent models. The input impedance of series-mounted resistors (0 to 10 kΩ), inductors (10 to 4700 nH) and capacitors (1 to 1800 pF) is shown at 2.5 GHz. The display contrasts ideal element values (circles) with the predicted responses of three Global Models (one each for the resistors, inductors and capacitors) mounted on four FR4 substrate thicknesses (5, 14, 31 and 59 mils). The performance on each board is dramatically different than ideal component behavior, and differs from board-to-board. Here the value of a single R, L or C model that can track the wide variation in frequency response is self-evident. The increasing effects as board thickness decreases can be clearly seen.
An example simulation in Eagleware Genesys is shown in Figure 4. Shown is a substrate sweep for a 4.7 pF chip capacitor. The self-resonance frequency changes nearly 7 GHz over the 5 to 62 mil substrate variation.

The accuracy of a substrate-dependent parasitic model is key to the simulation process, the results presented in the previous section highlight the non-ideality of typical SMT components above several hundred megahertz. One effect of the non-ideality is that, more often than not, the optimum part value in a given application is best determined via iteration after the first-pass design is completed. Even in a schematic with a small number of components, manual substitution of individual models is very tedious, and increases geometrically with parts-count. Figure 5 illustrates how the part-value scalability of Modelithics Global Models enables the use of automated circuit optimization techniques to greatly improve the overall efficiency of the design process.

The final example, shown in Figure 6, demonstrates the accuracy attainable for substrate effect prediction for circuits containing multiple SMT components, such as the bandpass filter shown, as well as the ability to simulate variations in circuit performance due to either part-value tolerances, substrate tolerances, or both.