Just like the real thing!

SPICE library for current-compensated and linear chokes

An efficient circuit design requires advance simulations. But, each simulation is only as good as the data used at the start. SCHURTER provides sophisticated simulation models for many of its chokes.

Circuit simulation is an important part of the circuit design and can be simplified with the use of many computer-based tools. A proven tool for this is SPICE (Simulation Program with Integrated Circuit Emphasis). SPICE was first presented in 1973 at the University of California. This program has been further developed over the past 40 years and is now a perfected and widely used program, which is available in different versions and different suppliers. SPICE calculates algorithmic approximated solutions for analog, digital and mixed circuits. The individual simulation components are based on the physical model descriptions or also on abstract formulated functions. These component models are subsequently mapped out as a network list and calculated using a multitude of different equations.

As realistic as possible
The aim of the simulation is to provide as accurate a picture as possible of the actual real functional behavior. In order to achieve this, the components must take into account, for example, parasitic parts or thermally induced reductions, which correspondingly requires more complex simulation models of the individual components and therefore leads to more accurate simulation results.

The individual components are summarized in libraries [1], which can be easily imported into standard SPICE simulation tools. The entire product family is then
subsequently available for the circuit simulation and can be selected according to different parameters (e.g., rated current). The different current compensated chokes can be compared with the simulation models, and their frequency behavior and their saturation behavior can be analyzed. This preliminary analysis significantly reduces the time and money spent in the prototyping phase.

Simulation models
The following simulation models for linear chokes featured below were verified several times with real components and checked with the freeware simulation tool LTSPICE [2] from Linear Technologies.

Because of their structure, the libraries provided can also be used with other SPICE programs that are available. The structure of the simulation model for the linear choke is explained below. Starting with a simple coil, the model has been extended to become a sophisticated model which takes into account all parasitic components as well as the magnetic saturation. The verification measurements are then also subsequently compared with the simulation results in order to illustrate the accuracy of the models presented.

Basis of the choke
The figures below show the European equivalent circuit diagrams for the components selected in the simulation instruments. On the basis of a linear choke, so only the inductance (Fig. 1). The inductance is labeled with the international abbreviation L. The value of the inductance is specified using the unit Henry.

Extended model with parasitic parts
In reality, all electrical transmissions are carried out with losses. For example, the coil winding has an ohmic resistance R in addition to the inductance L. Also, coupling capacitances C may arise due to the multiple windings. These parasitic properties can also be influenced from the outside with the circuit configuration. That is why the circuit model is correspondingly extended with these elements (Fig. 2).

Simulation saturation of the linear choke
The simulation of the saturation behavior is particularly evident with a voltage jump. The simulation model is accordingly combined from the two detail models presented, taking into account not only the parasitic but also the saturation dependent behavior (Fig. 5).

Model verification with measured coils
Below is an illustration of the approximation precision of the simulation models with the real coil on the basis of a measured reference coil using several measurement curves. The following curve shows the frequency dependency of the choke DS1-20-0003 without saturation (Fig. 7).
Now the same choke is simulated taking into account the saturation current of 5 A. To achieve this, a direct current source is used in the simulation. In 10 steps the DC current is increased from 0 A to 5 A and the impedance is simulated. Because of the saturation, the inductance decreases and the resonant frequency moves visibly into the higher frequency range (Fig. 8, red curve shifts to the right).

Measurement of the chokes

The circuit configuration for measuring the coils was constructed according to the following circuit diagram (Fig. 9). The resistance $R_2$ plays an important role in this process. This value is measured in advance at the choke (Fig. 10) and then introduced into the model (Fig. 9).

Conclusion

With these detailed SPICE models, it is now possible to simulate current-compensated and linear chokes, so that the saturation problems that are influenced by the core material can be identified in advance. The circuit design already supports this in the simulation so that the right coils can be selected for the respective area of application.

Thanks to these detailed SPICE simulation models, SCHURTER is able to provide reliable support for the secure and cost-effective development of electronic circuits, in which current-compensated or linear chokes are used. The respective damping curves, SPICE models and mechanical CAD models are available for various SCHURTER products from the choke range.

**Fig. 8: Simulation of the frequency response taking into account the coil saturation**

**Fig. 10: Measuring the series resistance $R_2$**

1. Simulation
2. Measurement
3. Theoretical current flow without saturation

It is apparent from the measurement (Fig. 11) that the linear choke has a high correlation with the simulation model.

**Fig. 11: Measurement result of the measured reference coil in saturation**

**Links**


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