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.

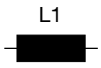

Fig. 1: Wiring diagram for inductance

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).

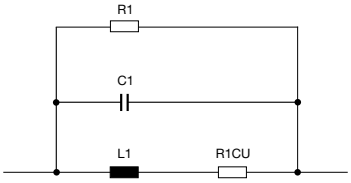

Fig. 2: Equivalent circuit diagram of a coil with parasitic components

It is apparent here that this equivalent circuit diagram is a resonant circuit which has a specific frequency response and a specific resonance frequency.

Taking the saturation into account

Metal cores are used to produce coils with higher magnetic permeability values. Different core materials are used here depending on the transmission power and the frequency range.
Due to the properties of the ferromagnetic core materials, they cannot increase the magnetization when the current increases. In such a case, we refer to the magnetic saturation of the choke.

As a result, the inductance drops at a certain current (Fig. 4). In this case, the material-specific saturation behavior in the simulation model (Fig. 3) is taken into account based on the magnetic flux depending on the rated current.

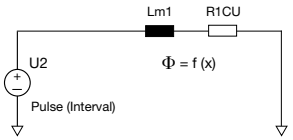

Fig. 3: Saturation model of the choke

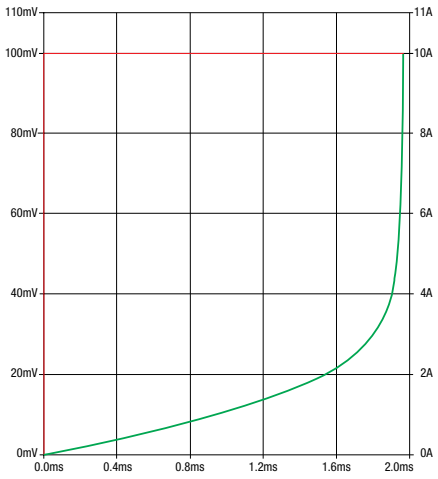

Fig. 4: Saturation behavior of the choke depending on the current

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).

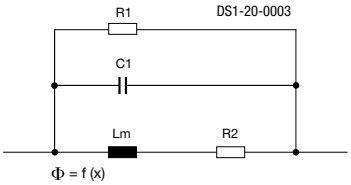

Fig. 5: Example of a specific combined equivalent circuit diagram

The behavior is now integrated into the linear model. To achieve this, the inductances are coupled and given an "infinite inductance". Parallel to the linear inductance, the magnetization inductance is connected with the target saturation behavior.

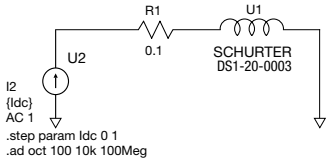

Fig. 6: SPICE model of a specific coil

In order to make the simulation as much like the real behavior as possible, all the saturation currents were measured beforehand and treated as parameters in the Term Isat in the model. This current value is the point at which the inductor saturates. This must be measured for each choke. All other parameters can be taken from the standard choke model and do not need to be measured again.

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).

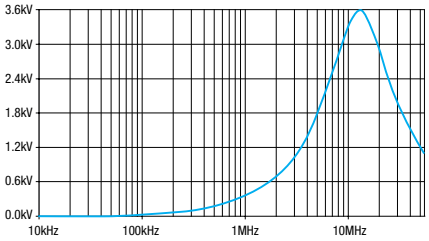

Fig. 7: Simulated frequency response of the choke DS1-20-0003 without saturation

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).

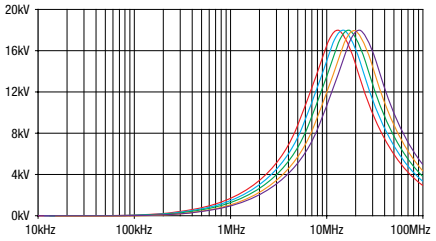

Fig. 8: Simulation of the frequency response taking into account the coil saturation

Measurement of the chokes

The circuit configuration for measuring the coils was constructed according to the following circuit diagram (Fig. 9). The resistance R2 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).

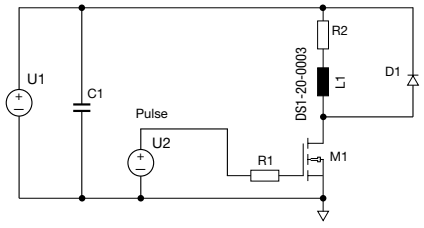

Fig. 9: Measurement setup for measuring the reference coil

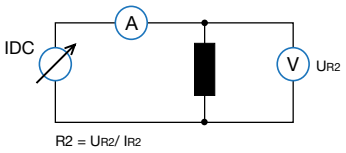

Fig. 10: Measuring the series resistance R2

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.

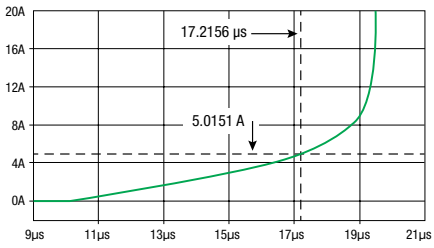

Fig. 11: Measurement result of the measured reference coil in saturation

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 used. The respective damping curves, SPICE models and mechanical CAD models are available for various SCHURTER products from the choke range.

Links

[1] SPICE libraries of SCHURTER: https://live.schurter.com/content/download/676780/13553298/file/SCHURTER_SPICE_Library_160114.zip
[2] LTSPICE: http://www.linear.com/desi-gntools/software

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SCHURTER continues to be a progressive innovator and manufacturer of electronic and electrical components worldwide. Our products ensure safe and clean supply of power, while making equipment easy to use. We offer a broad range of standard products including circuit protection, connectors, EMC products, switches and input systems, as well as electronic manufacturing services. Moreover, SCHURTER is ready to work with our customers to meet their application specific requirements, not covered in our standard range. You can rely on SCHURTER's global network of companies and partners to guarantee a high level of local service and product delivery.

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