Sage Model Notes

InductorFerriteCore.stl

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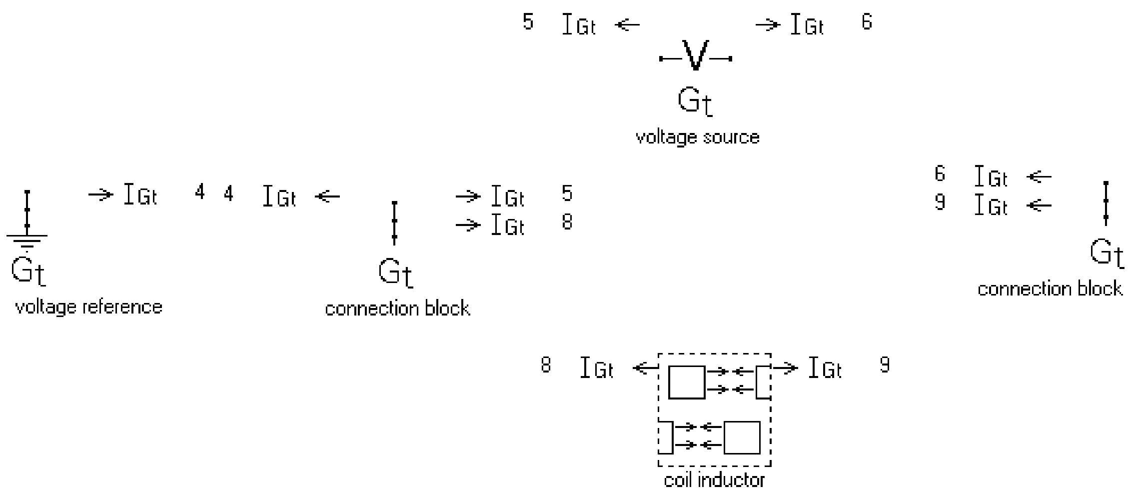
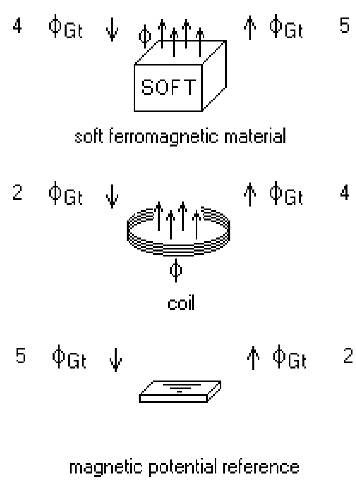
A model of a ferrite-core solenoid from first principles. Similar to the model InductorAirCore.stl except the inductance is increased by replacing the air core with ferrite. You might want to review the document InductorAirCore.pdf before reading further.

The Sage model looks like this:



A voltage source (top row) drives electrical current through a coil inductor submodel where the resistance and inductance come from coil and soft ferromagnetic material components shown here



The Material selection in the soft ferromagnetic material component is 'Ferrite NiZn'.

Referring to the theoretical inductance formula shown in the InductorAirCore.pdf documentation, the inductance is proportional to the magnetic permeability of the core material. According to the data in Sage the relative permeability for ferrite at the 300 K operating temperature is 350. So the theoretical inductance for this model is 350 time the air-core inductance, or 4.400E-02 H compared to 1.257E-04 H for air.

Saturation

The purposes of the present model are to confirm that the ferrite core produces the correct increase in induction compared to an air core and also demonstrate the phenomenon of magnetic saturation for high electrical currents.

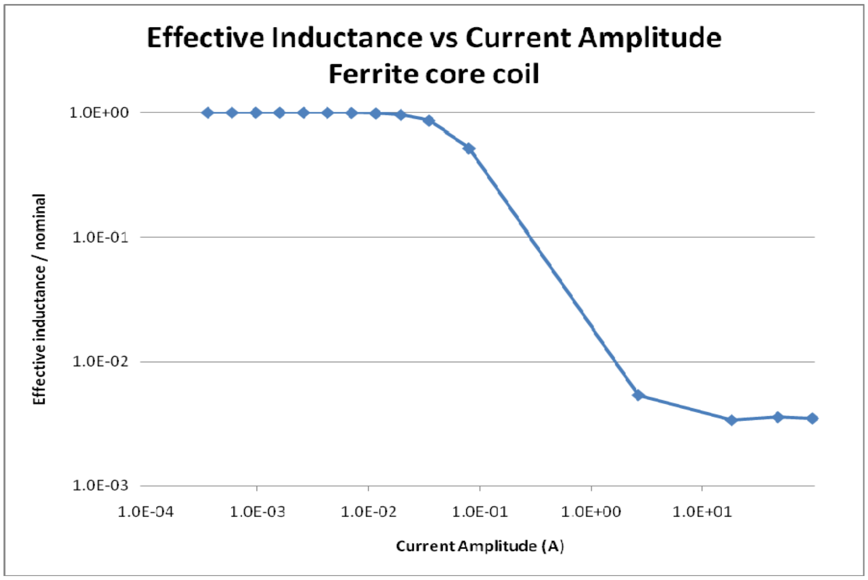
So the model is set up to map driving voltage over a range and record the results with a number of user-defined outputs:

Outputs

Lair   air core inductance   1.257E-04
  1.257E-6 * Nw*Nw * Acore / Lcore
LferriteTheor   nominal ferrite core inductance   4.400E-02
  Mur * Lair
Lfraction   fraction nominal inductance   3.948E-01
  LferriteActual / LferriteTheor
Jfraction   fraction max saturation   7.917E-01
  Jamp / Jsat

These are defined in terms of other user-defined variables in the model. Relative permeability Mur and Jsat come directly from the ferrite material. LferriteActual is just the effective inductance output Lcoil of the coil component. Jamp is the first harmonic amplitude of magnetic polarization FJ in the soft ferromagnetic material component.

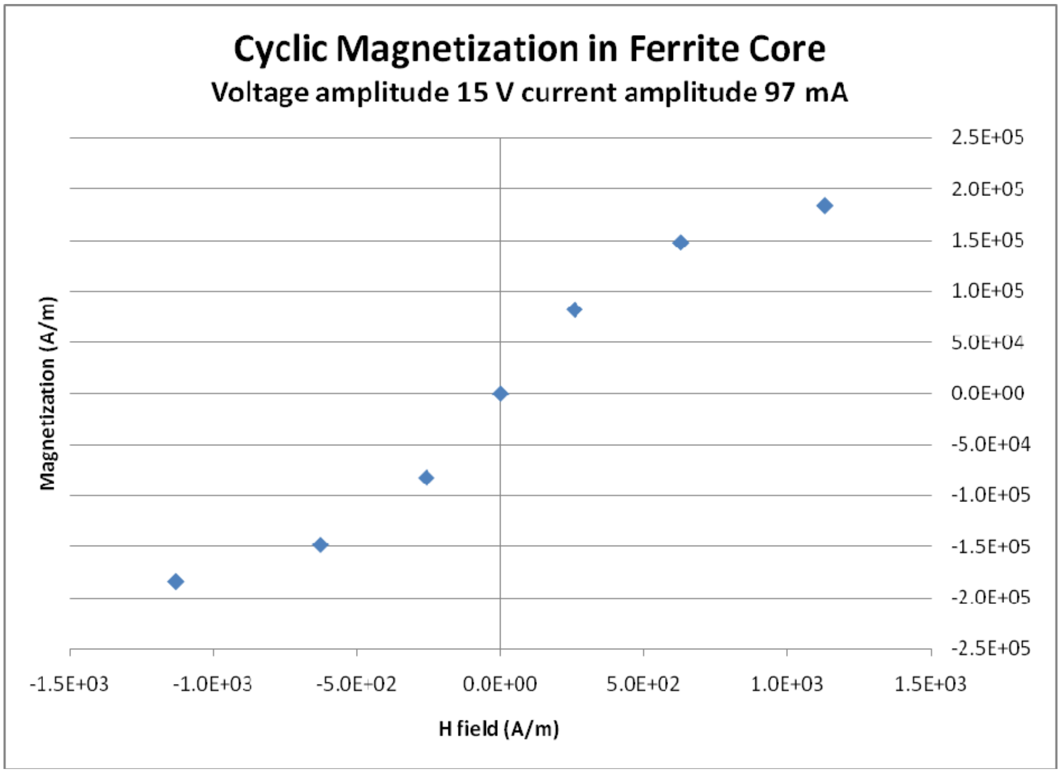
The mapping outputs show how the effective inductance of the model compares to the theoretical value as a function of coil electrical current amplitude. The plot below comes from spreadsheet InductorFerriteCore.xlsx



The model inductance compares well with the expected theoretical value until current amplitude reaches about 10 mA after which it declines rapidly to the air-core value, which is 1/350 = 2.86E-3 in relative terms.

The reason for the inductance drop off is that at high currents the ferrite core saturates and no longer boosts the magnetic flux B in response to the applied magnetic field H produced by the coil windings. For high enough current amplitudes (H field) the magnetization is saturated for most of the time and there is almost no advantage of ferrite compared to air.

The following plot shows the magnetization beginning to saturate for a current amplitude of about 100 mA.



The magnetization traces the familiar curve except there is no discernable hysteresis because the coercive force (H intercept of magnetization) is only about 0.5 A/m for ferrite. Sage soft ferromagnetic material output Whyst reports only 0.27 mW loss for this case.