University of Utah
Electrical & Computer Engineering Department
ECE 3600 Lab 2

Equivalent Circuit of an Iron Core Inductor

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Objectives

1. From measurements and calculations, derive an equivalent circuit for an iron-core inductor, in this case, the primary of a transformer.
2. Observe that the current is nonlinear, implying that the permeability is not linear.
3. Observe the dynamic B-H curve, called the hysteresis loop.

Equipment and materials to be checked out from stockroom:

- Power wire kit
- Wattmeter panel
- Power strip
- “Suicide” cord
- 3-prong to 2-prong adapter
- Vari-AC (Auto-transformer)
- MTC (Mountain Transformer Company) Transformer

Parts to be supplied by the student:

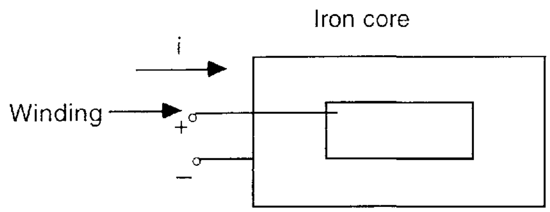
- 5 Ω, and 1 MΩ resistors, ¼ watt
- 0.1 µF Capacitor
- bread-board and wires

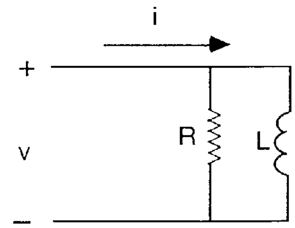
Experiment Setup

Switch off the power strip and plug it in. Switch off the vari-AC, turn it to 0V and plug it into the power strip. Make sure the suicide cord’s leads are free and clear and plug it into the vari-AC using the adapter. Hook one lead of an AC voltmeter to a ground. There is a ground terminal on the bench power supply or use one of the oscilloscope grounds.) Switch on the power strip and check that both the suicide cord’s leads are at near-ground potential. Switch on the vari-AC and check again. If you measure AC line voltage on either lead in either case something is wired incorrectly and is dangerous-- inform your TA. If there are no problems, turn up the vari-AC to about 30 V and see which lead is hot. If it’s not the red lead, turn the plug over in the vari-AC. Switch off the vari-AC and turn it back down to 0 V. Whenever you perform some task like this as part of the lab, you should include some description in your lab notebook.

Experiment description

We can model (an equivalent circuit is a model) the performance of an iron-core inductor reasonably well with the parallel combination of a resistor and pure inductor. You will make measurements and calculations that will lead to the numerical values of R and L of the model shown. A series combination of a different R and different L could be also used as a model of the inductor; however, for this laboratory job, we will use the parallel combination. This has some advantages that are not necessarily obvious at this point.





All work described below should be performed on the primary winding of an MTC transformer (rated 115/115 volts, .25 kVA). The secondary winding should be left unconnected. This transformer is designed for use in power circuits at 60 Hz, with sinusoidal voltages. Ignoring the resistive drop in the winding, with no connections on the secondary winding, the applied voltage is

$$v = \frac{Nd\phi}{dt}$$

Therefore, if v is sinusoidal, so is the flux. During your laboratory investigation, you will discover that with an applied sinusoidal voltage, the current in the iron-core inductor will be nonsinusoidal, implying that the iron-core device is nonlinear. It is obvious that a model consisting of an R and an L, each value independent of current or voltage, cannot perform precisely like the iron-core inductor. In such a model, the currents will be sinusoidal when the applied voltage is sinusoidal. Nevertheless, our model can be highly useful even though inaccurate in this one respect.

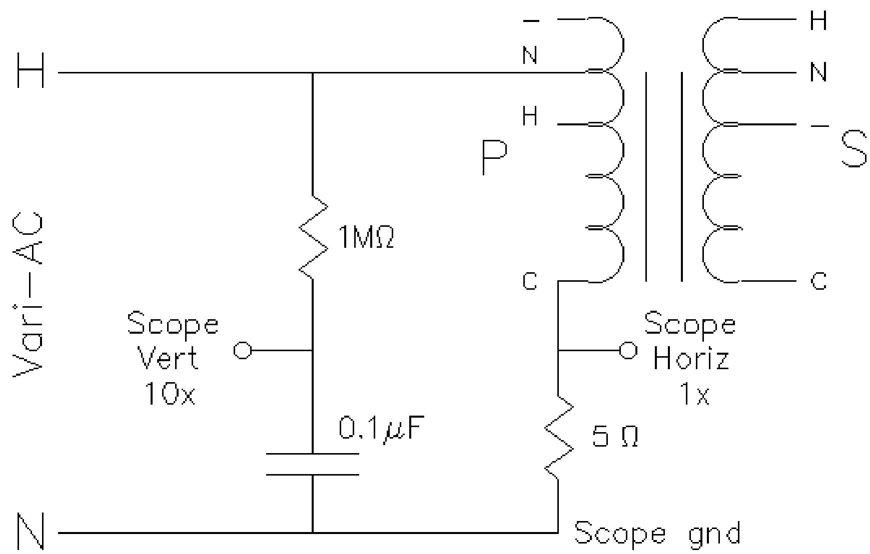
The effective cross-sectional area of the iron core is 13.3 cm^2 and the effective magnetic path length is 23.5 cm. There are 260 turns on the primary. Calculate the peak flux and peak flux density in the core when 115 V (RMS. Of course) is applied to the primary winding.

Make appropriate measurements to find an R and L in the model to best represent the iron-core circuit at 115 V. I suggest you use the power meter and measurements of the current and voltage with the vari-AC set at 115 V. Since we are looking for a linear model, we will ignore the harmonic content of i.

Devise a circuit that will enable you to measure simultaneously the applied voltage v and the resulting current i (use the 5Ω resistor) and display both simultaneously on an oscilloscope. Remember that the two oscilloscope channels and the power cord have a common ground. The primary side of the transformer is labeled “P”. You will use the “C” (common) and the “N” (normal voltage, as opposed to “H” high and “-” low) terminals on this side of the transformer. Make sure that all other leads are free and clear. Implement the circuit to measure v and i simultaneously. Switch on the vari-AC and turn it up to 115 V. Sketch both v and i your note book. Include units in your sketch, that will require that you calculate the current peak from the scope measurement. Is it true that i is nonsinusoidal?

The nonlinearity of the iron-core inductor is often described by a B-H curve, where B is the flux density in the iron($B = \phi/\text{area}$), and H is the magnetic-field intensity ($H = Ni/l_m$ where N = the number of turns, l_m = average length of the magnetic path). Calculate H_{max} from your measurements above.

Look at the circuit below. Show that the 1 MΩ resistor and the capacitor will do a reasonable job integrating the applied voltage to give you a measurement of ϕ and thus B. Implement the circuit to observe a dynamic B-H curve, called the hysteresis loop, for the transformer on an oscilloscope. Caution: Be sure the scope ground is also source ground and remember that both horizontal and vertical inputs have a common ground. Sketch the loops for several values of applied voltage above, below, at, and above the rated voltage. Calculate B_{max} from your measurements.



Check-off and conclude.