Practical Core Loss Measurements Across Different Materials

Dominic Heye

DEXTER magnetic technologies

Presented at APEC 2023 on March 21st.

About Dominic Heye:

- Graduated from Northern Illinois University in May 2022 with a B.S. in Electrical Engineering
- Was previous President of the NIU section of IEEE-HKN, Eta Kappa Nu
- Been working with the field of electromagnetics for 3 years
- Currently working at Dexter Magnetics as an Electrical Engineer since 2021

Presentation Content

1. Introduction
2. Common Specifications
3. Approach to Measure Core Losses
4. How to Find Core Losses
5. Summary
6. Issues to Address
7. Questions
8. Conclusion

Introduction: Why is measuring core losses so important?

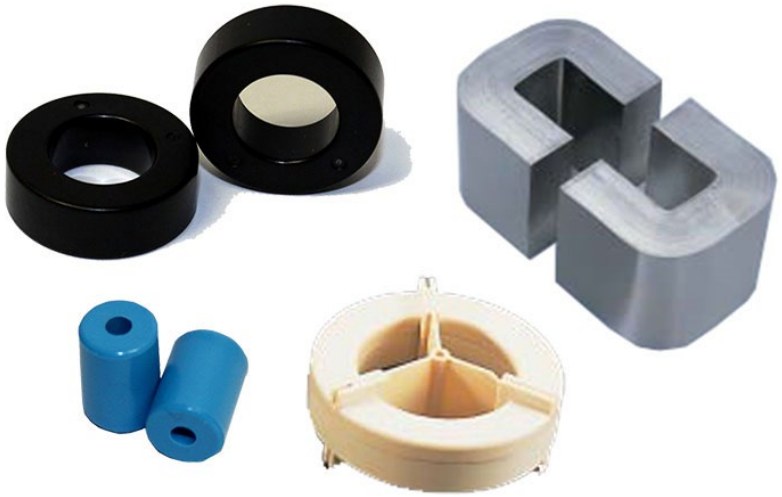
Using cores in any application, power or suppression, the material properties and core shape make a huge difference in how it affects the circuit.

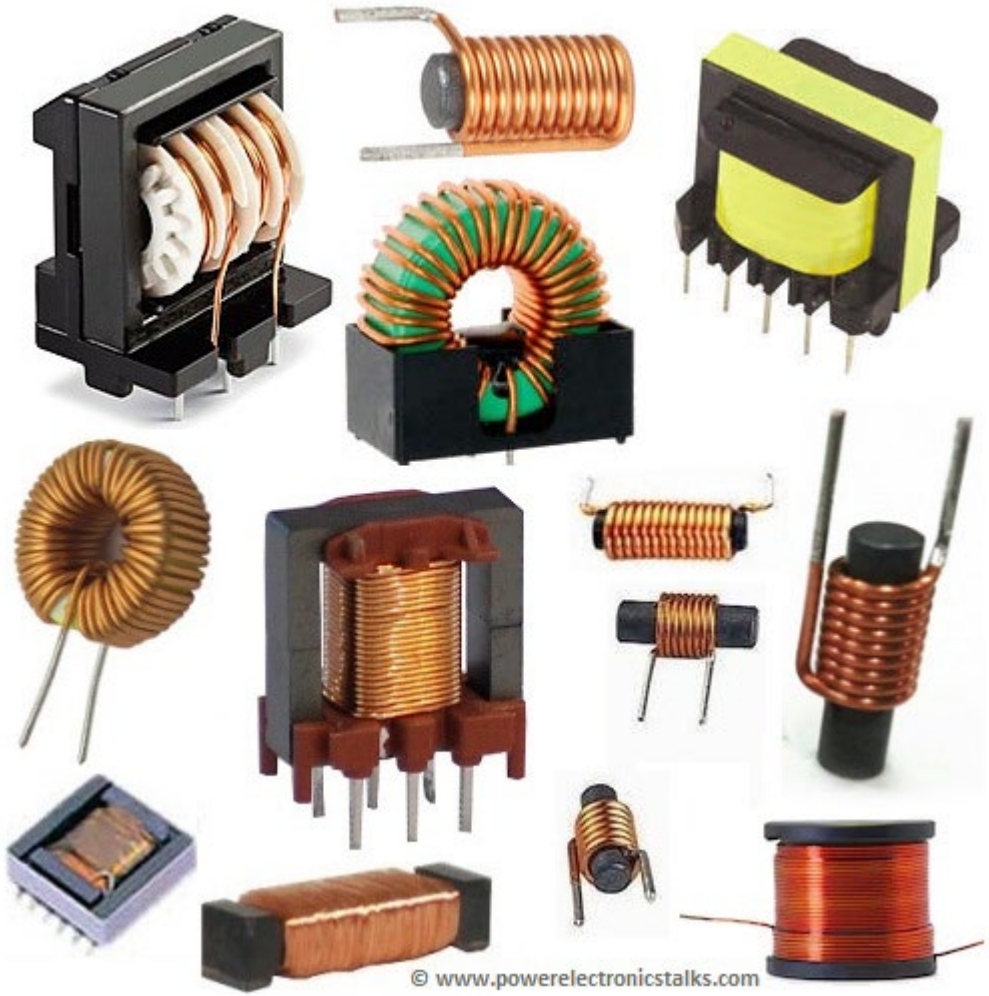
When designing with any part of an electronic circuit, it is very important to know which specifications from the data sheet are going to affect the circuit the most.

Knowing what losses result from different materials is incredibly important to designing and building an efficient circuit.

Introduction: What are the different materials commonly use in cores?

- The main 3 types of materials used in the industry are:
  - Ferrite
  - Amorphous
  - Powder
- Powder and Ferrite are used for both power materials as well as suppression materials. These are good materials because of the ease of manufacturability (they can be machined). Both are significantly cheaper than amorphous cores.
- Amorphous cores are most often used just for power applications, because of their high permeability. Amorphous is very good at reducing losses because of it being a wound core. It is also better at holding mechanical and electrical tolerances, because it does not require heat treatment.





Common Specifications

When buying any type of core, many specifications can be found online, usually including physical dimensions, A_L, and on the material page, resistance of the material and the permeability.

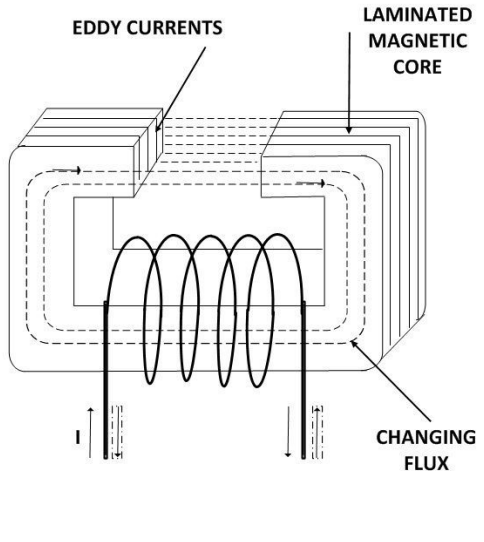
There may be some indications of loss in the datasheet, but that is at a specific test setup that could be at the wrong frequency for your application.

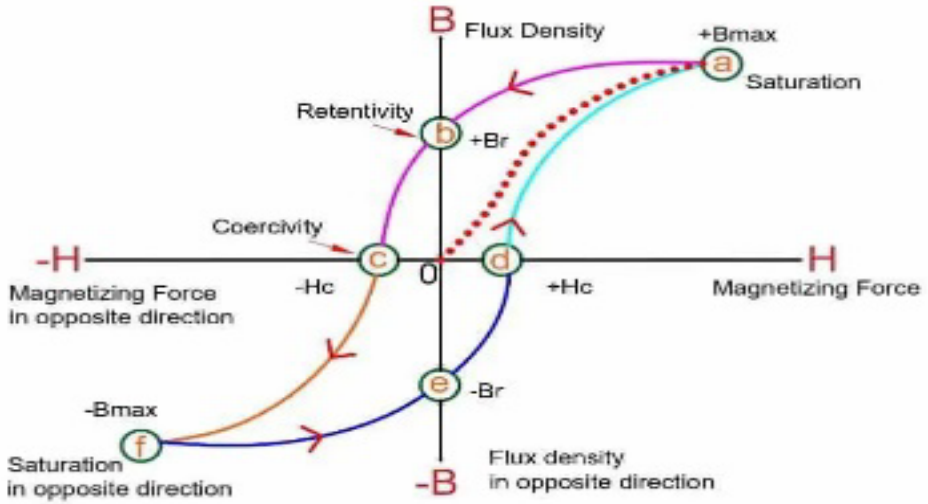
There are tools for Electrical Design Engineers to use to measure core losses on their own!

Approach to Measuring Core Losses

To find out what instruments are needed, the types of core losses must be considered:

- Hysteresis Losses – Correlated to magnetic fields
- Eddy Current Losses – Correlated to frequency
- Residual Losses – Correlated to frequency



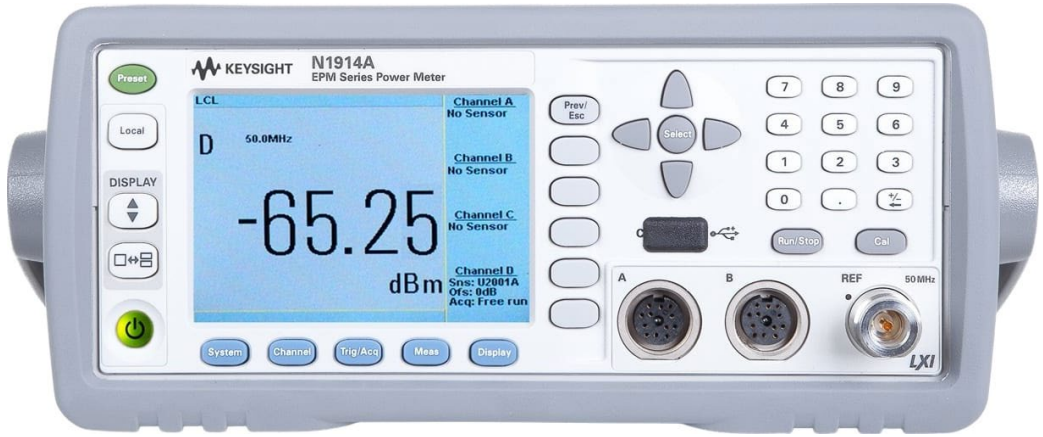


How to find Core Losses

There are three major ways to measure core loss:

- Q-Factor Measurement
- Impedance Analyzer
- Digital Oscilloscope
- Power Meter

Small Signal vs. Large Signal Analysis (linear vs. non-linear)

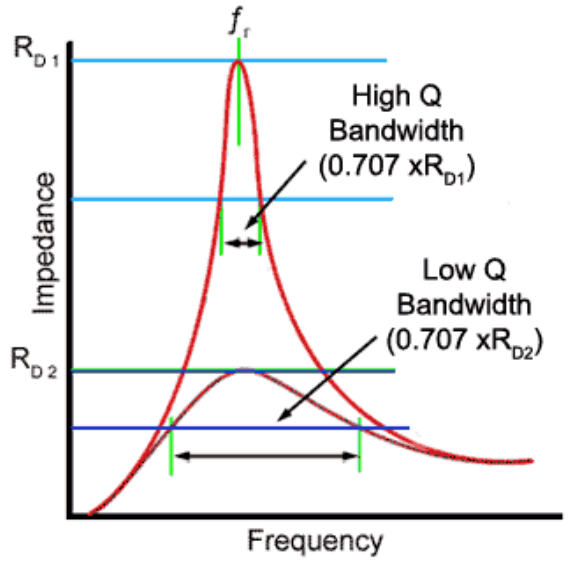


Q-Factor Testing

Q-Factor is an indicator of how efficient the core is, because it is the inverse of the total loss tangents (tan δ).

The total loss tangent is the sum of many different losses, including:

- Hysteresis
- Eddy Current
- DC Resistance
- Skin Effect
- Proximity Effect
- Self Capacitance



Q-Factor is important because it is a clear indicator how close the component is to its ‘ideal state’.

Q-Factor Testing: Loss Tangent Graph

δ_{tot} – Total Loss Tangent

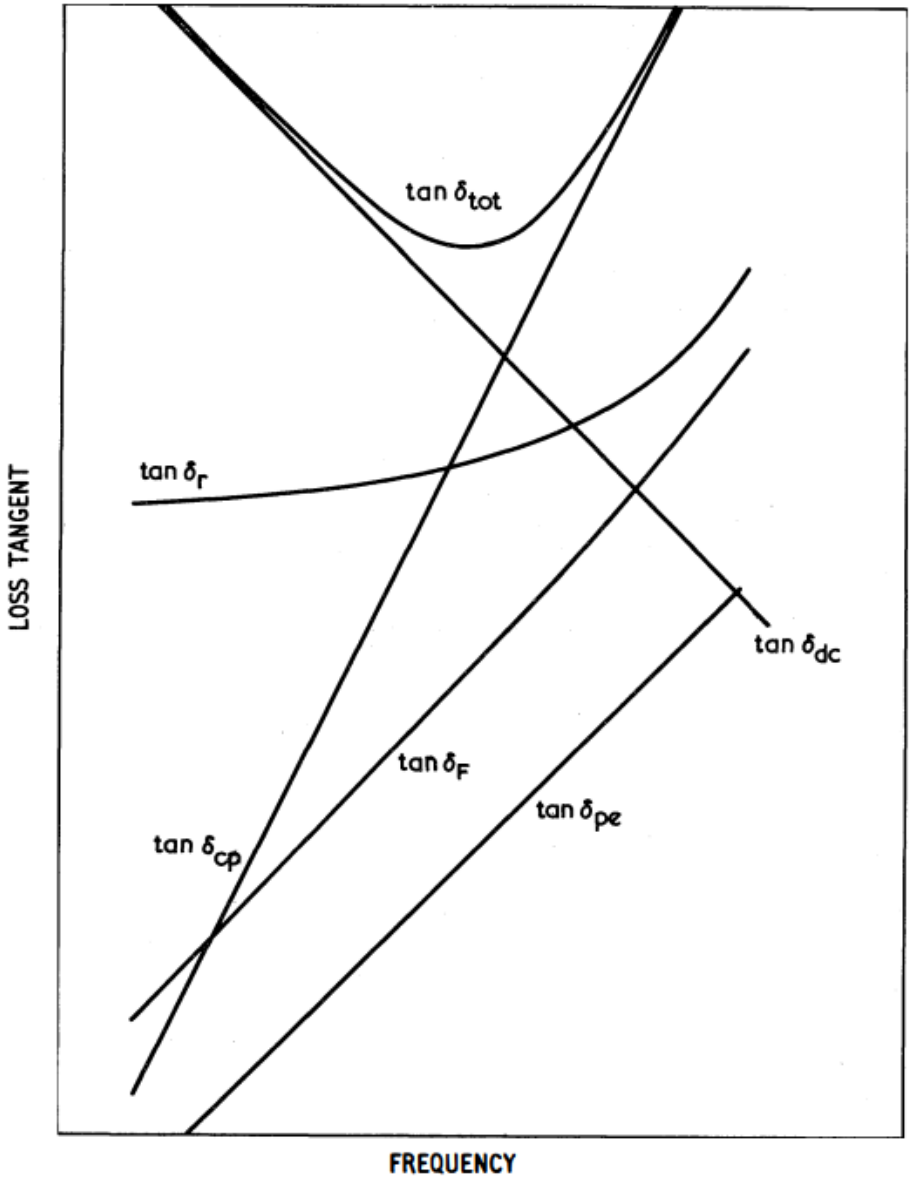
δ_r – Residual Loss

δ_{dc} – D.C. Resistance Loss

δ_{cp} – Self-Capacitive Loss

δ_F – Eddy Current Loss

δ_{pe} – Proximity Effect Loss



From Soft Ferrites Properties and Applications (p.215)
by E.C. Snelling

Q-Factor Testing

Q-Factor testing can be done on most LCR meters, and there are Q-meters as well.

When measuring the Q-factor, there are variables that can be controlled on the meter:

- Voltage
- Frequency
- Internal B-Field

Depending on the test, the magnetic flux can be kept within a smaller range to not oversaturate the core or can be brought up to see how the Q-factor changes with saturation.

The voltage should be kept constant (1-2V), and the frequency should change with the B value. The number of turns should be multiples of 10 (100, 1000, 10000).

Use the following equation to calculate what is needed in the test setup.

$$B = \frac{V * 10^4}{4.44 * A_e * N * F}$$

Impedance Analyzer Testing

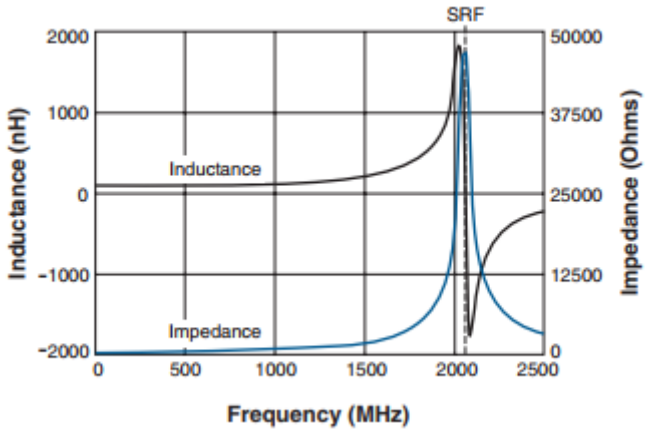
An impedance analyzer uses a range of frequencies to test the impedance of a core throughout the entire range.

This will give a graph of what frequencies have the highest and lowest impedance.

Impedance is important because it shows at which frequencies the core losses are most prevalent.

Eddy current and hysteresis losses are both dependent on the frequency, so seeing where the impedance is largest is very important to understanding the core.

The E4990A Impedance Analyzer From Keysight



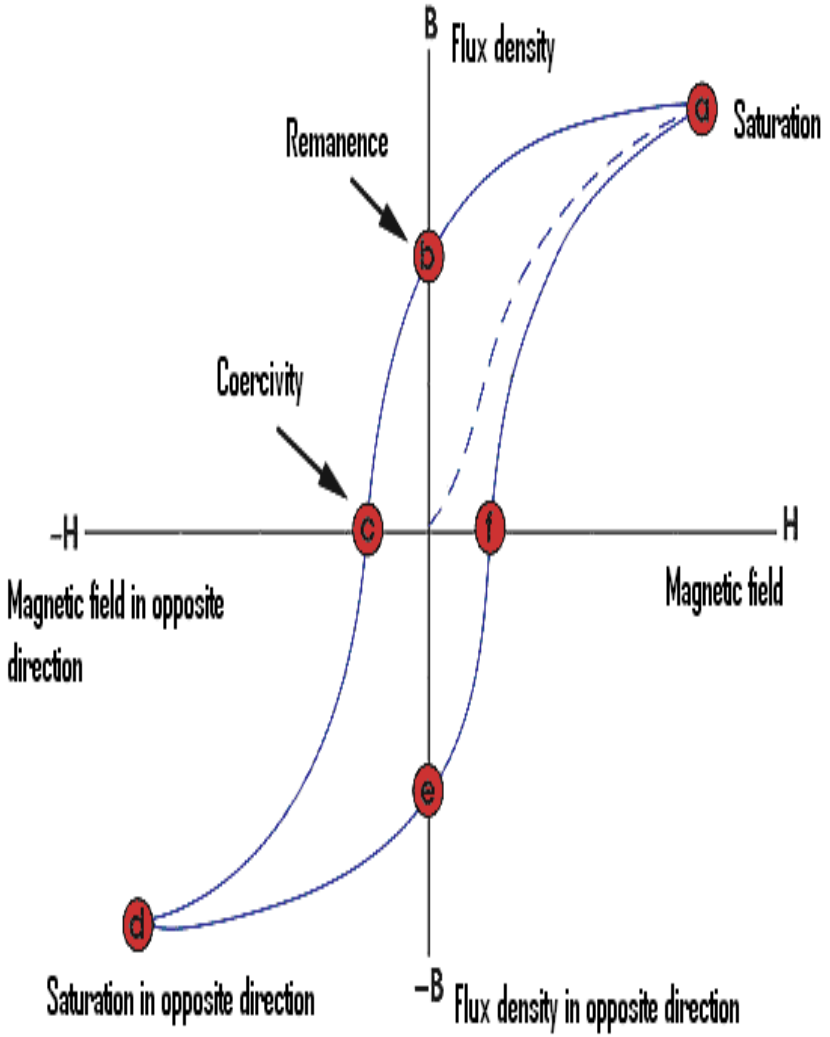
Example impedance curve

Impedance Testing

For suppression materials, high impedance at certain frequencies can be beneficial for design. When noise is being targeted for removal, having high impedance at those frequencies is needed.

The impedance can be easily correlated with heat as well; when power is lost in a soft magnetic material, it must be transferred into a different form. As eddy currents and hysteresis are causing unnecessary friction (either by changing the magnetic poles, or running current through the material), some of the magnetic power is transferred into heat energy.

The heat must be monitored, especially when pushing materials to their limits with transformer design.

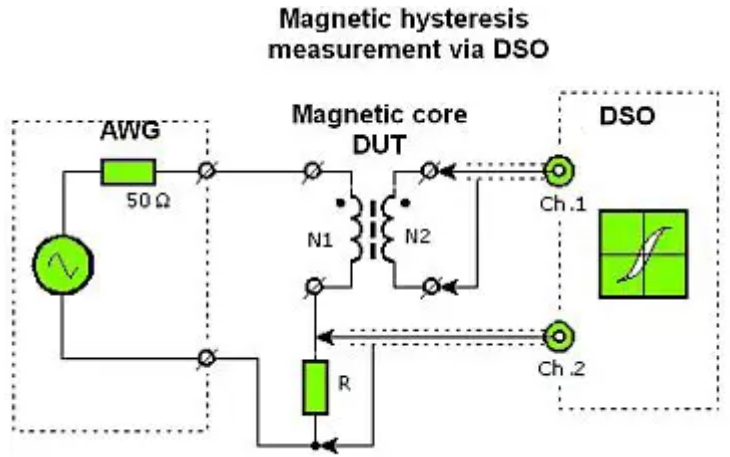


Hysteresis Measurement via Digital Storage Oscilloscope (DSO)

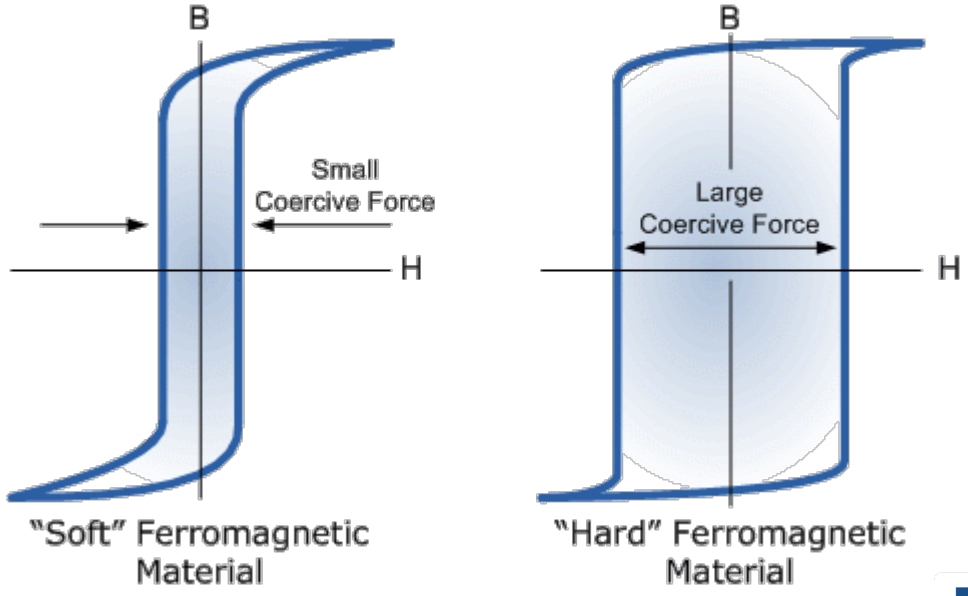
Hysteresis can be measured for transformers using a DSO.

Why?

- Hysteresis shows the lag between the magnetic field of a core, and the magnetic field generated from the windings.
- When a BH loop in a hysteresis graph is wide, the coercive force is high, meaning that the strength of the magnetic field must be higher to switch the field inside of the core.
- This is correlated to the inductance value as well.



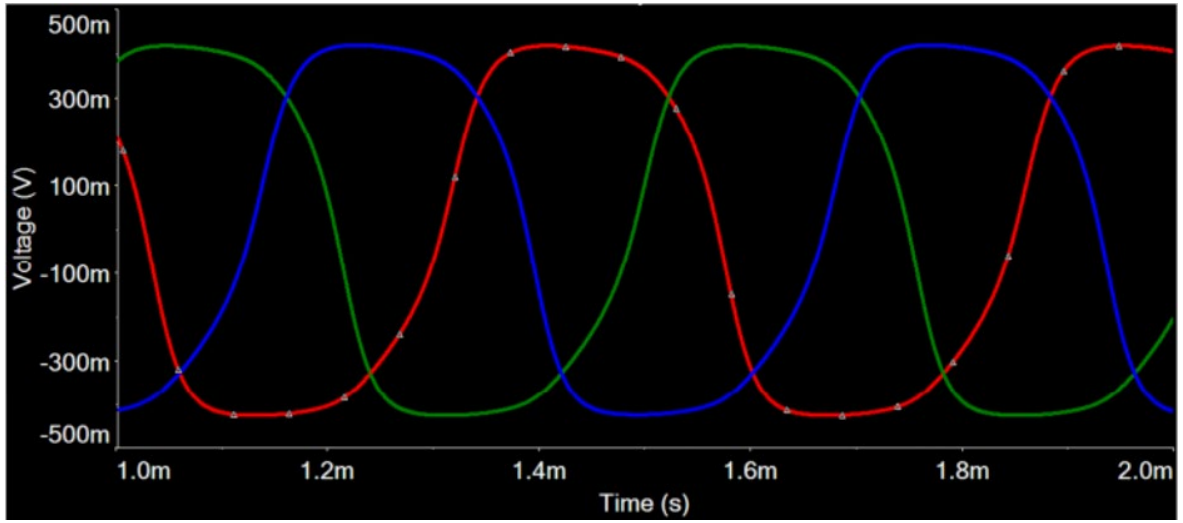
Test Setup for DSO measurement of hysteresis



Hysteresis Testing – DSO

What can be done with this information?

- This allows for designs to choose materials/cores that do not oversaturate the material with magnetic fields.
- This can also be useful for knowing if the core is good for suppression or power.
- It can be seen as well how it affects the circuit, as seen below in this 3-phase power simulation:



Summary

Looking at these methods of measurement, design engineers can fully understand where a core can be useful or detrimental in a system.

Specific core materials will continue to flourish in their respective strengths.

The main thing to consider is which test will be the most important to the design. Not every design needs the same core or material, so choose the most important tests, and standardize all of them for your organization.

Issues to Address

As cores continue to be more crucial to many circuits, teaching design engineers about core losses and what to look for in cores can significantly impact the electronics industry.

New engineers should read E.C. Snelling's Soft Ferrites Properties and Applications for a developed insight into core losses and magnetic components.

Questions?

Any Questions?

Conclusion

Thank you for your interest.

By Dominic Heye
Email: dheye@dextermag.com
Phone: +1 847-264-4043
PSMA Industry Session