
"Deep Dive into Inductors" Webinar

The following questions were asked in the chat or question box during the webinar.

Question / Comment	**Response**
What happens to the inductance of the lossless cable with the increase of frequency?	In a typical cable, there are typically no significant magnetic materials. Hence the inductance derives from energy storage in free space around the geometry of the wire(s). This is for the most part independent of frequency, although there might be a small effect due to redistribution of magnetic fields in skin effects.
Do you know who makes Metglas core inductors?	A company called Metglas - http://www.metglas.com/products/magnetic_materials/2714a.asp
Permittivity seems harder to control to a desired value, than capacitance	Inductance is a bit harder to control than capacitance because permeability varies more with magnet field strength than typical dielectric constants vary with electric field strength. However, there are some very good magnetic materials, especially when used under the controlled conditions for which they were designed.
If the load needs high-frequency "drinks" of current, would you need a load-side capacitor?	Yes. The ability to quickly source or sink some current without the voltage deviating significantly is precisely why the capacitors are there and needed. That is synonymous with maintaining low AC impedance at the filter point.
What is the impact of temperature rise on Inductor value?	In an air core transformer, there is no appreciable change in inductance with temperature rise. However, in an inductor with a magnetic material core the primary change over temperature would be a shift in the permeability of the core material, especially as it approaches the Curie temperature. This shift is usually toward less permeability and hence lower inductance.
Can you explain how multiple strand wire can be used in a transformer to help reduce skin affect?	If you use multiple small insulated wires, the skin effect cannot push the current from the inside wires to the outside wires. Hence the current would be more evenly spread over the entire cross sectional area of the wire bundle, decreasing skin effect and the net resistance. If you use a bundle of bare colinear wires, the skin effects can still push predominantly into the outside strands. But it is not quite as strong, especially if the number of bare strands is huge. Other methods have also been devised such as Litz wire and various winding techniques where strands on the outside plunge to the inside regularly and vice versa. This helps a lot. Some machines can also wind multiple strands of enameled wire at the same time.

How charge is passed through a parasitic cap at high frequency?	Charge is said to “flow through” a capacitor as it is charging because typically the same current flows in and out if you put it in a circuit. So at a macroscopic level this seems true. However, internally there is an insulator and essentially no charge can cross the insulating barrier. The current still seems to “flow through”. The answer lies in the shifting of net position of electrons with respect to the nuclei under the influence of an electric field. This is called “displacement current” and is covered in our webinar on capacitors. There is a huge amount of balanced charge in matter. If the electron “cloud” of bulk material shifts only a tiny fraction of the atoms size, it is equivalent to a large number of electrons passing one point. The evidence is that when you pass a current through a capacitor a Voltage builds up. This is evidence of the residual offset of the electron clouds from their nuclei in the dielectric material. A parasitic capacitor is not really any different than a manufactured one, except that it was incidental instead of deliberate.
If inductors and capacitors are equivalent, should you be able to store energy in an inductor in the same volume as a capacitor? We tend to use caps as you can charge them up and then store that energy (in the form of voltage) for a fairly long time without too much loss or heat.	A superconductor can exhibit zero resistance. An inductor made in such a way can store energy without decaying. That said, maybe “analogous” would be a better choice of word. Energy in “typical” capacitors has a half-life that typically exceeds that of energy stored in “typical” inductors, and the energy storage density in “typical” capacitors is higher than that in “typical” inductors.
In a toroidal transformer, is the cross-sectional area the only factor in determining the VA capacity of the core? (meaning the loop diameter does not really matter)?	No, there are a number of factors. The four most important are the frequency, the window or winding area which gets filled with copper wire, the cross-sectional area of the magnetic material, and the type of magnetic material.
You showed a scope trace of the hysteresis and it looked like the curve was folding back on itself (reversed direction a little). Why is that?	The horizontal axis (H) is driven by the current. If you drive a core with less current it will make smaller loops. While I don’t know for sure where this image was recorded, I would guess that the design of the circuit was such that it allowed the current to diminish somewhat at that point in the cycle, and did it symmetrically. I have never seen that effect in the circuits I have personally engineered, built or evaluated.

Is there a rule of thumb for the distance between traces in order to prevent inductive coupling?	There are no general purpose rules which work in all cases (although if you look hard you'll find some which disagree. And there is always coupling in real cases. One reason for lack of good equations is that is that all wires bend or end, and where they do all the effects change radically, especially in the presence of other traces, ground planes, magnetic materials, etc. In infinitely long wires in free space fields tend to fall off like 1/R, and the same is roughly true if you are much closer to it than its' length. But if you go far away compared to one with finite length it will tend to fall off like $1/R^2$. This is tied up in the difference between near fields and far fields. So go online and find some PCB trace calculators and use them to calculate characteristic impedances for differential pairs. As you move them apart you'll see the characteristic impedance change. You can the effects on each other by Even vs Odd impedances, or by how much the characteristic impedance changes as you move them apart. Granted, this is a combination of capacitive and inductive coupling, but that's probably closer to a real case. If bringing a trace from very far away to a certain point affects the characteristic impedance by 1%, you can get a pretty good approximate feel for how much that signal is affecting the other.
Designing chokes or picking beads for RF isolation, I find I am grasping at straws (relative to my other background) to pick adequate filtering. Any guidelines?	First, define the bounds and parameters of the problem. How much are you trying to filter out within what frequency ranges? What're the highest voltages? What're the maximum currents? How much impedance will you need at what frequencies? How much power loss can you tolerate? Second, go to a website which has some tables and calculators. Coilcraft comes to mind. Study various series and choices. Enter your parameters into the design calculators and see what they recommend. Do some basic computations to check it. Third, take the time to read and understand what all the parameters are. Figure you how they pertain to your application. For example, if you're trying to block EMI in a particular frequency range, you'll need a choke which exhibits a sufficiently high impedance in that range to block it, or a capacitance of sufficiently low impedance to short it out, or more likely a combination of the two. The other half of the problem is to choose them such that they do not block or short out the frequencies you want to keep. But they always will to some degree, so determine how much is acceptable. And don't forget the power ratings on components. If you model each component with a circuit of Rs, Ls, and Cs, you can put them

	together in SPICE and simulate it. But remember: the results will only be as good as your models.
Can you discuss the effects of creating a transformer by winding a secondary over a primary on a ferrtie rod - no gap!	First, a rod already has a huge magnetic gap from end-to-end, so the resulting permeability will be low and it will likely hold relatively little residual flux at zero current. Because the permeability is low, a lot of field lines will escape it resulting in a low inductance and marginal energy storage. If the secondary is wound over the primary, there will be fair magnetic coupling between the two coils. An example of a core with no gap is and uncut toroid, or a tape-wound rectangular core. Such a core could have extremely high permeability, contain nearly all the flux, exhibit high inductance, and very tightly couple the primary to a secondary would over it.